College Student Changing Attitudes and Beliefs About the Nature of and Teaching of Mathematics and Science

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College Student Changing Attitudes and Beliefs About the
Nature of and Teaching of Mathematics and Science

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Abstract

With an estimated 17.3 million STEM jobs in the US, there exists a need for a STEM-ready workforce that is science literate with positive attitudes and beliefs toward the learning and teaching of mathematics and science (Graf, Fry, & Funk, 2018). However, the US has seen a steady decline in the number of high school students interested in STEM-related fields with only 16% of interested students with proven proficiency in mathematics and science and are ready to enroll in college STEM programs (ACT, 2017; Osborne & Dillon, 2008; Stake & Mares, 2001). With the decline in student interest, the US has fallen behind both China and India in the production of a STEM-ready workforce (Herman, 2018). To address the need for students to enroll in STEM-related fields, students need positive attitudes toward the learning and teaching of mathematics and science. Colleges and universities can increase positive attitudes and beliefs in students by immersing students in reformed science courses that utilize active learning practices such as experiential learning and modeling.

The study uses quantitative data analysis on a linear data set collected over twelve years, 2002 – 2013, through the use of a survey tool to collect pre- and post-survey data on students' attitudes and beliefs toward the nature of and the teaching of mathematics and science. The study focuses on two groups of students in two different reformed physics courses at a large mid-south research university; pre-service elementary education majors and physics and engineer majors. Pre-service education majors are students in training who have yet to undertake any teaching and are required to enroll in the Physics for Elementary Teachers course, an integrated lecture and lab course that meets three times a week for 110 minutes each time. The physics and engineer majors complete a calculus-based sequence of courses, University Physics I and II, that meets twice a week for a one-hour lecture and twice a week for a two-hour lab.

This study was guided by wanting to know to what extent are there significant differences in the change (pre- and post-test) in the attitudes and beliefs about the nature of and teaching of mathematics and science for students who have completed a one- or two-semester sequence of a reformed science course. The survey tool used in the study was *The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey*.

Study findings show that pre-service education students had very little change, remaining slightly higher than neutral, on attitudes and beliefs toward understanding the nature of science but, had significant changes toward teaching mathematics and science. Science students demonstrated significant positive changes in attitude toward understanding the nature of science but, had low attitudes towards learning to teach mathematics and science. The results of the study show that reformed science courses, as measured by a TROP observation, ties into Kolb's cycle on experiential learning with modeling as a reformed active learning practice in science labs, has an impact on student attitudes and beliefs.

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Dedication

I dedicate this dissertation to my parents, Dr. Robert Skinner and Raynell Skinner, to my wife, Mary Skinner, and to my two beautiful children, Matthew and Caroline.

To my mom, I thank you for always setting the example of perseverance and honesty. You taught me the meaning of love through all you did for your children. You taught me about grace and forgiveness through your battle with cancer.

To my dad, I thank you for showing me the wonder of science and to appreciate the dedication to hard work.

To my wife, thank you for sitting next to me in class, for saying yes when I asked you to marry me, and for joining me on this journey.

To my children, you are my future and my inspiration.

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Chapter I. Introduction

A. Context of the Problem

The United States has historically been a leader in the fields of STEM; science, technology, engineering and mathematics (Hom, 2014). However, Hom (2014) stressed a concern about the continual decline in the United Sates education system producing the necessary STEM ready workforce. According to the US Department of Education, (2009) 28% of high school freshmen declared an interest in a STEM-related field but 57% of these students lost interest by the time they finished high school. Of the 28% of high school students interested in STEM-related fields, only 16% had proven proficiency in mathematics and science (ACT, 2017). An assessment of US students in precollege mathematics and science by the National Science Board's (NSB) Commission on Precollege Education in Mathematics, Science and Technology and recently released data from the Pew Research Center on international math and science assessments, indicate that US high school students continue to rank slightly below the middle of the pack compared to international peers (National Science Board, 2006; National Science Board, 2016; Desilver, 2017). In recent tests, from 2015, 10 of the 48 countries that participated have statistically higher average math scores than the U.S. with seven having higher science scores (Desilver, 2017).

With students losing interest in science and math, sometime as early as primary school, a shortage of US born scientists and engineers is a major concern, and with this comes a loss in the competitive edge of the US in the international market for STEM related jobs (Osborne & Dillon, 2008; Stake & Mares, 2001). At the current rate of college age students enrolling in STEM programs, the United States will rank third in the world. As of 2016, China had at least 4.7 million recent STEM graduates, in 2017 India had 2.6 million and the US had 568,000

(National Science Foundation, 2018). This means that the US is third in STEM graduates per population at 0.18% with China first at 0.34% almost twice that of the US (Herman, 2018).

The decrease in students interested in and prepared to participate in STEM-related fields has created a major concern for the future of the United States' workforce. In 2014, Hom projected that by 2018 there would be a need for 8.65 million workers in STEM-related fields and that manufacturing sectors would face a shortage of nearly 600,000 employees with necessary skills to fill these jobs. The US Bureau of Labor Statistics reported that the majority of STEM careers would be in the areas of computing (71%), traditional engineering (16%), physical science (7%), life science (4%) and mathematics (2%) (Hom, 2014).

The decline of students interested in STEM-related careers and enrolling in STEM college degrees and programs has led to a growing interest over the last 40 years in research in the field of students' attitude toward science and mathematics. The results of these studies have led researchers to understand that there is a relationship between attitude toward science and science achievement (Arisoy, 2007). These studies have led to understanding that factors such as science and math achievement, gender differences, student-teacher interactions, and classroom learning environments as all having an effect on student attitude toward science (Ali, Yager, Hacieminoglu, & Caliskan, 2013). Simpson, Koballa, Oliver, and Crawley (1994) noted that gender is one of the most significant factors related to student attitude toward science.

Often a negative attitude toward science is influenced by a student's experience with mathematics and a level of anxiety toward math. Math anxiety can have multiple origins and can be perpetuated in the home, in society, and in the classroom (Shields, 2005). In the home, parents who suffer math anxiety can unintentionally transfer their anxiety to their children. Parental disappointment and reproach for errors are especially damaging due to the value placed on parents by children (Dossel, 1993). Stolpa (2004) also noted that parents often raise math anxiety in their children and provide them an excuse to stop trying when they are frustrated or upset due to difficult mathematical tasks. Society contributes to math anxiety through mathematical myths such as boys are better at math than girls or only some people have math minds, while others proudly display attitudes such as 'I'm no good at math' and view failure at mathematics and socially accepting (Latterell, 2005).

The classroom can also contribute to a student's math anxiety through traditional instructional practices and classroom culture. Classroom culture is defined as the norms and behaviors guiding classroom interactions (Latterell, 2005). Shields (2005) noted that the experience of learning mathematics in a structured, rigid classroom includes little opportunity for debate or discussion and focuses on searching for one right answer. These limited interactions discourage reflection on thinking and expects quick answers emphasized by timed worksheets.

Math anxiety is a major contributing factor to a student's self-efficacy, whether or not the student is motivated to higher achievement in math and science (Chen & Usher, 2012). A student's perceived self-efficacy has been shown to influence performance in academic subjects as well as their interest in subsequent academics and career choices (Pajares & Urdan, 2006). Students who suffer from a sense of low self-efficacy in performing science related tasks often avoid science-related careers and fields of study (Chen & Usher, 2012). With the decline in student interest in STEM-related fields, an increase in math anxiety, and a decrease in self-efficacy in science, science educators should pay explicit attention to improving student interest in and attitude toward sciences, and this should start at the primary school level (Tobin, Kippins, & Gallard, 1994). In the 1990s, many education initiatives focused on increasing the scientific knowledge, inquiry skills, and attitude of elementary school students by allocating more time to science education. Some of these initiatives worked, particularly with student enjoyment of science projects (Duschl, Schweingruber, & Shouse, 2007).

The major concern that remained in increasing student interest and success is elementary school teachers are not adequately trained to teach science (Van Aalderen-Smeets, Van Der Molen, & Asma, 2011). In order to achieve sustainable improvements in elementary science education, it is critical for teachers to develop their own positive attitudes toward science. A study by Van Aalderen-Smeets et. al, (2011) found that teachers with less positive attitudes toward science have several characteristics in common, including lower confidence and self-efficacy beliefs about how to teach science, spending less time discussing and teaching science topics in the classroom, and rely more on standardized methods, such as lectures and top-down, teacher directed learning, methods (Skamp, 1991; Aplleton & Kindt, 1999). Osborne and Dillon (2008) found that when teachers gain greater confidence and self-efficacy through experimentation with reformed educational practices and teaching methods, they are able to improve the attitudes of their students toward science and mathematics.

B. Statement of the Purpose

The purpose for conducting the study was to investigate to what extent completing a one or two-semester sequence of reformed science education in the field of physics impacts a shift in students' attitude and beliefs about learning and teaching mathematics and science. In particular, the study compared pre- and post-attitudes and beliefs of science majors and pre-service education majors in two different physics courses. This is a quantitative study using a linear data set collected over eleven years (2003 – 2013). Data were collected using a survey tool, *The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey*, administered at the University of Arkansas, a tier-one research university.

C. Research Questions

1. What was the demographic profile of students who completed a one- or two-semester sequence of reformed science teaching during 2003-2013?
2. What were the entering and existing attitudes of students who completed one- or two-semester sequence of reformed science teaching during 2003-2013?
3. To what extent are there significant differences in the change (pre- and post-test) between entering and exiting students who completed one- or two-semester sequence of reformed science teaching?
4. To what extent are there significant differences between science majors and pre-service education majors for pre- and post-class data?
5. To what extent are there significant differences in pre- and post-class data based on student academic performance?
6. To what extent do students' attitudes and beliefs about learning and teaching mathematics and science change after completing a one or two-semester sequence of reformed science teaching?

D. Definition of Terms

The study explores the shift in attitudes and beliefs of students about learning and teaching mathematics and science pre- and post- enrollment in four different courses at the University of Arkansas. Ascertaining the attitudes of students toward mathematics and science and learning has always been a concern for educators (Roberts, 2007). The definition of attitude has developed over the years. Simpson, Koballa, Oliver, and Crawley (1994) defined an attitude as "a predisposition to respond positively or negatively to things, people, places, events or ideas (p. 212) while Thompson and Mintzes (2002) defined attitude as "a tendency or state internal to a person which biases or predisposes a person toward evaluative responses which are to some degree favorable or unfavorable" (p. 646). Attitude can also be simply defined as "whether a person likes or dislikes science" (Simpson et al., 1994, p. 213). The study will use a definition of attitude as "a positive or negative feeling towards a specific subject, whether the student has prior experience with that subject or not" (Schruba, 2006, p. 11).

In addition to attitude, a student's self-efficacy has an important role in understanding students and their experiences in learning science. Researchers have defined self-efficacy as an individual's perception about one's own abilities and skills (Bong & Skaalvik, 2003). Relative to the study of the attitudes of students toward learning science, self-efficacy has not been studied in great detail. However, Baldwin, Ebert-May, and Burns (1999) noted that self-efficacy and attitude affect a student's desire to become scientifically literate. For example, a college student may judge personal ability MacIssac and Falconer's (2002) to be lacking in science (belief). That lack in confidence may lead to a dislike for science (attitude). The dislike for science may lead them to avoidance of science education (behavior) (Baldwin, et. al. 1999). The study does not look at the direct connection between self-efficacy and the pre- and post-scores; however, it cannot be dismissed as not having some effect on the pre-scores of participants in the pre-service education courses. In the study, self-efficacy is defined as the students' perception of their own abilities based on prior experience with a specific topic or task.

The student participants in this study are enrolled in one of two courses that meet criteria for reformed science teaching by being taught via inquiry-based methods advocated by professional organizations and researchers. One of the most common pedagogical practices of reformed teaching is active learning in the place of the standard lecture format for large-enrollment courses (Berkeley Center for Teaching & Learning, 2019). Both PET and University

Physics utilize a flipped classroom approach with required readings, reading quizzes, and pre-lab activities. According to Bishop and Verleger (2013), a flipped classroom approach, events that traditionally take place in the classroom now take place outside the classroom and vice versa, appears to have the most impact on student learning when compared to traditional classrooms. The lab components, of the two courses in this study, are connected to the learning outcomes for both courses and utilize active learning strategies that are recognized by researchers as high impact such as facilitated group conversations, turn and talk, and inquiry-based experimentation (Berkeley Center for Teaching & Learning, 2019). The only difference between the two courses is PET integrates the lecture and lab into one learning environment with a faculty member and one graduate student while University Physics has a lecture component taught by a faculty member and the required lab sections ae instructed by graduate students.

In order for a classroom environment to be considered reformed, traditional methods must be compared to active learning to determine the degree of reform. Two such assessments that measure the degree of reform are The Reformed Teaching Observation Protocol (RTOP) developed by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) at Arizona State University (Sawada, Piburn, Judson, Turley, Falconer, Benford, & Bloom, 2002) and The Classroom Observation Protocol for Undergraduates STEM (COPUS) developed by Smith, Jones, Gilber, and Wieman in 2013. The researcher has been extensively trained in the RTOP assessment and has over 75 hours of observation. The RTOP assessment was used to score both courses with scores verifying both courses to be classified as reformed science teaching.

The students in this study were enrolled in one of two courses, University Physics (a two-semester sequence course) or Physics for Elementary Teachers (a one-semester course).

University Physics I & II (UPI & UPII) is a two-semester sequence of calculus-based physics that surveys the principles of physics including mechanics, wave motion, temperature, heat, electricity, magnetism, and light. The course is designed for science majors in the fields of physics and engineering. Each course meets for 16 weeks and is a four-hour credit with lecture meeting two times a week for one hour with a required lab that meets twice a week for two hours each for a total of sex hours a week. A significant portion of the learning in the course is designed to take place in the lab through laboratory exploration, small group assignments, and exam preparation activities, see Appendix A for a sample syllabus.

Physics for Elementary Teachers (PET) is a physical science course based on state frameworks explored in a mixed lecture/lab environment. The inquiry-based lab activities cover topics such as; scientific inquiry, motion and forces, conservation of energy, heat, light, electricity and simple circuits, and magnetism. The course is designed for students who intend to become an elementary education teacher. The course meets for 16 weeks and is a four-hour credit course meeting three times a week for two hours for a total of six hours a week. The inquiry lab component of the course is integrated into the informal lecture in a merged classroom and laboratory setting, see Appendix B for a sample syllabus.

E. Assumptions

The following assumptions are accepted for the completion of the study:

1. The survey instrument used for data collection could effectively identify the attitudes and beliefs of students at their time during the semester. The survey instrument selected for the collection of data used in this study was *The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey*. This tool was selected to gather reliable formative feedback on the attitudes and beliefs of the students taking reformed

physics classes. The survey was developed at the University of Maryland and used with permission by the National Science Foundation's Collaborative for Excellence in Teacher Preparation Program (CEPT); contract grant number: DUE-9255745 (McGinnis, Kramer, Roth-McDufie, & Watanabe, 1998). During the development of the survey, it underwent a rigorous testing and analysis using a Cronbach alpha test to increase the survey's reliability (McGinni, Kramer, Shama, Graeber, Parker, & Watanabe, 2002). The survey consists of 44 questions grouped into 5 constructs; beliefs about mathematics and science, attitudes toward mathematics and science, beliefs about teaching mathematics and science, attitudes toward using technology to teach mathematics and science, and attitudes toward teaching mathematics and science. A copy of the survey instrument can be found in Appendix C.

2. Participants will answer survey questions based solely only on their own attitudes and beliefs about learning and teaching mathematics and science.
3. Participants are given equal opportunity to participate in both the pre- and post-survey.
4. College student attitudes can be fixed or fluid, recognizing that they can change over time in both positive and negative ways. The current study takes only a one-point in time self-report of these attitudes.

F. Limitations and Delimitations

This study seeks to determine if students' attitudes about the nature of and teaching mathematics and science change after completing a one or two-semester sequence of reformed science teaching by answering questions on a survey. The target population for the study was undergraduate students at the University of Arkansas enrolled in a physics course with a required lab component. Participants in this study fit into either of two categories; (1) enrolled in a science course with a lab component to meet a program requirement for a pre-service education degree or (2) students who have self-selected a STEM degree that requires one or more semesters of a physics course with a lab component. Participants in category one, are more often seeking non-science degrees and may have negative attitudes and beliefs about learning and teaching mathematics based on their perception of the difficulty of the course. Participants in category two may already have positive attitudes and beliefs about learning and teaching mathematics and science based on their selection of a STEM degree.

The survey tool was distributed in both electronic and paper form. Depending on the course in which a participant is enrolled, participants were either asked to volunteer to complete the survey or asked to complete the survey as part of the course assignments. Participants, in category one, were allowed to volunteer to complete the survey and sometimes bonus points were awarded for completing both the pre- and post-assessment. This process for implementing the survey may have led some participants to not complete the survey, while it is possible other participants may not have answered the questions seriously. Participants in category two were given the survey as part of the lab experience at the start of the first semester in the sequence and again at the end of the second semester. This process produced a larger return in completion of the pre-survey and post survey.

Another limitation of the study is the timeline for data collection. Participants, most often in category two, enrolled in a two-semester sequence may not have completed the courses in a sequential manner by either not enrolling in back-to-back semesters or by not completing the second semester course therefore not completing the post-assessment. As the survey was implemented in the lab setting, it is possible that a participant may have missed attending lab and may not have completed the pre- or post-survey for reasons out of their own control. It is also possible that a student may have enrolled in the second semester of the sequence in a summer session where the survey was not offered.

The course instructor and the use of graduate students as instructors is another limitation on the study. The instructor for the PET course was the same faculty member for all nine semesters of data collection (2005 – 2013) with a different graduate assistant each semester. However, there has been a total of eight different faculty and graduate students teaching the University Physics sequence of courses over the eleven years of data collection (2002 – 2013). The structure of the course was kept the same with the same faculty member, for the duration of data collection, acting as the course administrator. Graduate students were given roles as instructors in the laboratory portion of University Physics with some limited training but, with much oversight by the course administer and laboratory curator. This study does not control for differences in individual teaching styles and assumes reformed educational practices are implemented as stated in the course syllabi, see Appendix A and B.

Another limitation to the study was the collection of grades for student participant in the University Physics sequences of courses. The process for survey collection captured only a portion of the student identification number making it difficult to match student academic performance to students who participated in the study.

The most significant limitation of the study, with concern to research question six, is the small number of participants who self-identified as wanting to teach mathematics and science as a career option. Keeping track of these participants was somewhat difficult because the process for the collection of the data was not clear in asking them to fill out the questions relating to teaching on the post-survey if they no longer self-identify as wanting to teach mathematics and science as a career option.

G. Significance of the Study

American students are losing interest in science and mathematics at an early age (Herman, 2018). This decrease in interest has led to a decrease in the number of American students majoring in STEM degrees at colleges and universities. However, the overall number of students in STEM programs at institutions of higher education and in master and doctoral programs has been increasing thanks to international students from countries such as China and India. As international students graduate and return to their countries, the US is left with a decreased work force in STEM related areas (Herman, 2018). This decrease has a direct effect on higher education institutions and future employers of STEM graduates. The significance of this study focuses on three stakeholders; the students, the institution and the future employers.

The first group of stakeholders are the students enrolled in physics classes and whether or not they are receiving an education experience that causes a measurable shift in attitudes and beliefs about learning and teaching mathematics and science. The study does not look directly at the factors influencing students to enroll in STEM programs, but will however, focus on the shift of pre- and post-attitudes and beliefs of students enrolled in a physic course. It is believed that students enrolled in courses with pedagogical reformed practices focusing on learning outcomes and performance expectations will have a more positive shift in student attitude and beliefs toward learning and teaching mathematics and science.

The second stakeholder is the University of Arkansas. Arkansas has more than 40 higher education institutions, which includes 10 four-year universities and 22 two-year community colleges, 12 private universities and one academic health center. The University of Arkansas at Fayetteville is considered the flagship public institution with 1,628 new students enrolled in STEM related fields between 2012 and 2016 (Arkansas Economic Development Council, 2019).

The question the institution wants to answer is how current educational reforms in course design and structure effects the attitudes and beliefs of STEM students enrolled in a physics course. This is an invested interest of faculty and staff who teach physics courses and work directly with students. The desired outcome is retaining students in STEM courses and programs while making successful progress with positive attitudes and believes that learning and teaching mathematics and science is important and pursue careers in teaching and STEM in the state of Arkansas.

The third stakeholder is the state of Arkansas. As more industries incorporate innovative technologies into their operations, the demand for a technology prepared workforce continues to rise (Carnevale, Smith, & Melton, M., 2014). In 2018, STEM jobs made up 3% percent of all jobs in the state, accounting for 47,860 jobs. This is an increase from 38,650 jobs in 2008 with 47% of new jobs in computer science. In 2018, 87% of all available STEM jobs required a post-secondary degree or training (Carnevale, Smith, & Melton, 2014). It is important to the state that it's universities and colleges produce STEM majors who believe that learning and teaching mathematics and science is important and want to find jobs in STEM related fields.

H. Conceptual Framework

Experiential Learning Theory

Large college physics courses are challenging settings for physics instructors to provide opportunities for student learning outside of the traditional lecture (Scherr & Hammer, 2007). So, it is common practice for reformed-minded physics instructors to support student learning by having students explore conceptual course materials through active learning in small group and/or laboratory experiences (Scherr & Hammer, 2007; Anderson, Boud, & Cohen, 1996). Active learning in small groups, focused around problem solving exercises or "tutorials", is effective and leads to improvement in students' conceptual understanding, as tested through pre- and post-assessments (Scherr & Hammer, 2007). However, Redish, Saul and Steinberg (1998) point out that, these same students in tutorials, tend to come away with less sophisticated views of knowledge and learning in physics course. The results of the surveys, at the end of courses in the Redish et al. (1998) study, indicated that students saw introductory physics as less connected to their experiences and more a set of problems to solve.

To counter the disconnect between content and experience, many introductory physics course place students in laboratory settings to explore physics concepts through experimentation as an active-learning concept that supports experiential learning. Kolb (1984) defines experiential learning as "the process whereby knowledge is created through the transformation of experience" (p. 38).

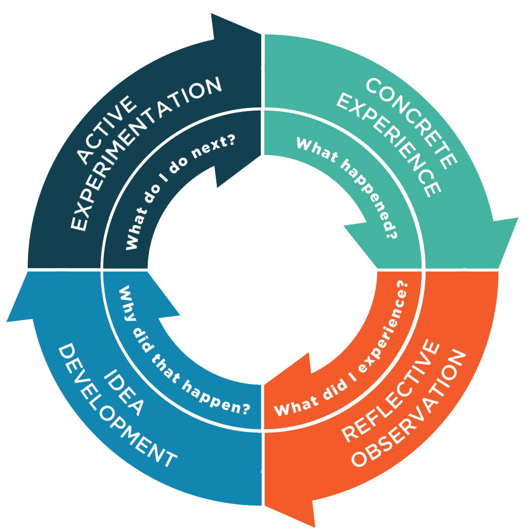

Figure 1. Kolb's Cycle of Experiential Learning

In Figure 1, Kolb's cycle of experiential learning begins with the student having a concrete experience followed by an opportunity to reflect on that observation made during the experience. Students then conceptualize and develop ideas about what they experienced and observed, leading students into active experimentation. Kolb's cycle of experiential learning is incorporated into an active-learning process used in physics laboratory practices called modeling.

Modeling

Modeling is a process of grounding teaching in a well-defined pedagogical framework (modeling theory, Hestenes, 1987) to organize course content around scientific models as structured knowledge to engage students collaboratively in making models to describe, explain, predict, design and control physical phenomena (Jackson, Dukerich, & Hestenes, 2008). Instruction is organized into modeling cycles that move students through all phases of model development; observation, evaluation, development and application (Jackson, 2018).

The modeling cycle typically begins with a demonstration and classroom discussion to establish a common understanding of a question to be asked of nature (Jackson et. al, 2008). After observing the demonstration, student collaborate in small groups in planning and conducting experiments to answer or clarify the question. Students then present and defend their conclusions, including the formation of a model for the phenomena. Students then evaluate the models presented by others through comparison and questioning. Students then apply their newly discovered model to a new situation to refine and deepen understanding.

Experiential learning and modeling are important to this study in determining if students who experienced reformed science teaching had a significant positive shift in attitude and beliefs about teaching and learning mathematics and science and had improved academic performances.

I. Chapter Summary

With the decline in student interest in STEM-related fields and the rising demand for STEM prepared employees, there is a need to improve the attitude toward and beliefs in teaching and learning mathematics and science. It has been shown that teachers who undergo reformed educational practices have improvements in attitude toward and beliefs in teaching science. These improvements carry over to the students in the classroom and laboratory with their own shift in positive attitudes and beliefs in science. The study will investigate to what extent completing a one or two-semester sequence of reformed science teaching in the field of physics causes a shift in students' attitude and beliefs about learning and teaching mathematics and science. In particular, this study is interested in comparing pre and post attitudes and beliefs of science majors and pre-service education majors in two different physics courses. This is a quantitative study using a survey tool, *The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey* to collect pre- and post-data.

Chapter II. Review of Related Literature

Creating a scientifically literate society has been a major goal of science education since the late 1950's (Evans, 2012). According to DeBoer (2000) a scientifically literate person is defined as a person who can understand science as a way of knowing, including the idea of the nature of science and understanding science in a societal context of how science, technology, and society effect one another as well as applying science knowledge and skills in everyday lives (National Research Council, 1996; Yager, 1996; Zeilder, Sadler, Simmons & Howes, 2004; AAAS, 2011)

The need for students to understand concepts and practices of science and the nature of science is a current trend in the American education system and has been advocated as a necessary outcome of an undergraduate science degree (AAAS, 2011; Next Generation Science Standards for States by States, 2013). During the late 19th century and early 20th century, based on writings from individuals such as Michael Faraday (1791-1867), Thomas Huxley (1825-1895), Herbert Spencer (1820-1903), Dewey (1859-1952), and the 1918 Commission on the Reorganization of Secondary Education (CRSE) of the National Education Association (NEA), a push for general science education was "justified on the basis of its relevance to daily life and the shared contributions to the understanding of the world by all member of society" (DeBoer, 2000, p.583; Evans, 2012).

In the second half of the 20th century, James B. Conant (1974) argued for a greater understanding of science by citizens. In 1957, with the launch of the earth orbiting satellite Sputnik by the Soviet Union, the National Society for the Study of Education focused more on science education, proposing that science educators should work to produce citizens who understand science and are sympathetic to the work of scientists (DeBoer, 2000). Following

World War II there was an explosion in the development of technology and an increasing concern about national security, enough to push the US educational system to look at how to become more effective in preparing people to live and work in a rapidly changing world. The goals of science education within this new environment came to be known as scientific literacy (DeBoer, 2000).

To create a scientifically literate population ready for STEM related job, requires students to want to know and understand scientific concepts, know and understand the nature of science, overcome mathematics and science anxiety, develop positive attitudes and beliefs toward mathematics and science, and have been exposed to reformed-education classrooms in K-12 and in college and university courses and laboratories.

A. Search Strategy

The search strategy for the study started by identifying keywords and phrases from the research questions. Keywords and phrases included: science literacy, 20th century education reforms, attitude and beliefs, attitudes of students toward mathematics and science, beliefs of students about mathematics and science, nature of science, reformed science education, and reformed science classroom and laboratories. A QuickSearch tool, provided by the University of Arkansas through the library system was used for preliminary searches as well as general topic searches on search engines like Google and Google Scholar. The QuickSearch tool has access to all the institution's library catalogs, including full text of most of the e-books and e-journals subscribed to in addition to thousands of open access journals. The search was initially limited to journals and book with publication dates in the last ten years, 2009-2019, and then refined to scholarly and peer reviewed. Subject terms such as mathematics, education, and science were used to refine searches resulting in 1,000 or more results.

Some older sources were included in order to provide a wider historical perspective on the topic. The reference section includes a subset of the sources, retrieved from subsequent searches, identified as relevant to this study to provide a foundation for the literature review.

This chapter will focus on five main themes: (1) current US student rankings in mathematics and science and an urgent need for student enrollment and persistence in STEM related fields of study, (2) nature of science (NOS) and importance in science education, (3) mathematics and science anxiety in students, (4) teachers and student's attitudes and beliefs toward mathematics and science, and (5) reformed-based science education.

B. Current US Ranking in Mathematics and Science

Recently released data from international math and science assessments indicates that US students continue to score around the middle of participant countries. The Programme for International Student Assessment (PISA) is an international cross-sectional test given every three years to 15-year-olds (primarily taken by 10th graders in the US) in 72 developed and developing countries, approximately 540,000 students, measuring reading ability, math and science literacy, and other key skills (Barshaw, 2016; Jackson & Kiersz, 2016; Desilver, 2017; Tures, 2018). In the most recent release of data from the 2015 implementation of the PISA, US students placed 38th out of 71 countries in mathematics and 24th in science (Desilver, 2017).

The National Assessment of Educational Progress (NAEP) is another long-running testing effort assessing the mathematics and science proficiency of third, eight and 12th-graders. In 2015 the NAEP rated 40% of fourth-graders, 33% of eight-graders and 25% of 12th-graders as proficient or advanced in mathematics with an average score of 152 on a 0-to-300 scale, one point lower than in 2013 and 2009 (Desilver, 2017).

The NAEP also rated the same students in science proficiency and found that 38% of fourth-graders, 34% of eight-graders and 22% of 12th-graders were rated proficient or better in science while 24% of fourth-graders, 32% of eight-graders and 40% of 12th-graders were rated below basic (Desilver, 2017). The 2015 science average for fourth and eighth graders improved from 150 in 2009 to 154 in 2015 while the 12th-graders average remained at 150.

John Tures (2018), a professor of political science at LaGrange College in LaGrange, Georgia, points out that just looking at the percentages and rankings can be misleading. While US student scores on the PISA test and the NAEP have remained flat or had very little improvement from 2000 to 2015, data from the latest Trends in International Mathematics and Science Assessment (TIMSS) test in 2015 show American's scored their highest marks in the 20-year history of the US participation in the test (Tures, 2018). Tures (2018) wrote that another way to look at the PISA results is, the US, in reading, ranked ahead of 42 countries and statistically tied with another 13 and scored only behind 14 countries. For math, the US is ahead of 28, tied with five and behind 36. In science, the US is a little better, ahead of 39, tied with 12, and behind 18 countries.

Placement rankings based on international assessments are simple to understand but they can be misleading (Serino, 2017; Tures, 2018). The results of the PISA, the NAEP, and the TIMSS give the impression that the US education system is moving down on the list based in both rakings and percentages. But in fact, the US scores have been relatively flat, with no statistically significant change between the scores from 2000 to 2015. These standings mean that the US has remained somewhat flat and possibly complacent while other countries are making changes in their education reform necessary to improving their rankings and have exceeded the current status of the US (Serino, 2017).

C. Need for Students in STEM Related Fields

Over the last decade, many reports from, US government agencies and US businesses have examined the status of STEM education and the demand for STEM graduates to fill the growing job market. The reported outcome is a warning that the US' competitive edge in the global economy is eroding (Kennedy & Odell, 2014). The reaction to the reports was a call for an extensive effort to reform K-12 STEM education, to cultivate the next generation of scientist, engineers, technicians, and science and mathematics educators (Miller, 2016; BHEF, 2007; NAS, 2007).

Jobs in STEM related fields are expected to grow 13% between 2017 and 2027, compared to 9% for non-STEM related jobs fields (Miller, 2016). Since 1990, employment in STEM related fields has grown from 9.7 million to 17.3 million jobs, an increase of 79%. Along with the increase in STEM related jobs, so has the need for a STEM educated workforce. In 2016, the average median hourly wage in a STEM related fields were $38.85 compared to other types of jobs in the U.S. with hourly wages of $19.30 (Miller, 2016).

Despite the increased demand in STEM related fields for qualified employees and the increase in hourly pay, the US Department of Education reported that the school system was only producing high school graduates ready to take college-level science courses at 36% in 2009. In 2009, 28% of high school freshman declared an interest in a STEM-related field but 57% of these students lost interest by the time they finished high school (U.S. Department of Education, 2009). Of the 28% of high school students interested in STEM-related fields, only 16% had proven proficiency in mathematics and science (Hom, 2014). This fits the current trend predicted by the President's Council of Advisors on Science and Technology (PCAST) (2012), that the US workforce will suffer a deficit of one million college graduates in STEM related fields over the next decade.

At the current rate of college students enrolling in STEM programs, the United States will rank third in the world for STEM graduates per population at only 0.18%, well behind China at 0.34% (Herman, 2018). The decrease in students interested in and prepared to participate in STEM-related fields creates a major concern for the future of the United States' workforce.

D. Science Literacy and the Nature of Science (NOS)

The justification most often used for studying science subjects in school is for the achievement of science literacy (Holbrook & Rannikmae, 2009). In 1996, The National Academies of Science, Engineering and Medicine published the National Science Education Standards (NSES), a guideline for K-12 science education in the US, defined scientific literacy as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participating in civic and cultural affairs, and economic productivity" (p. 22). The idea behind science literacy has long been promoted as important to science education and can be found in what is now referred to as the nature of science (NOS).

The understanding of NOS is central to reformed science education practices that produces scientific literate students who can make informed decisions and act responsibly as adults when dealing with complex issues related to science (Allchin, 2011; Holbrook & Rannikmae, 2007; Sadler, Sonnert, Hazari, & Tai, 2012). Although controversy exists among educators and philosophers of science regarding the details about NOS, it has become common practice to use Lederman's operational definition of NOS as 'science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development' in the field of education research (Akcay & Akcay, 2015; Kahana & Tal, 2014, p. 1; Lederman, 1992).

In 2011 the National Research Council (NRC) recognized the importance of the NOS in understanding the similarities and differences, and relationships between science and engineering. The NRC outlined in the 2013 Next Generation Science Standards (NGSS) Appendix H, the basic understandings of the nature of science to be:

- Scientific investigations use a variety of methods
- Scientific knowledge is based on empirical evidence
- Scientific knowledge is open to revision in light of new evidence
- Scientific models, laws, mechanisms, and theories explain natural phenomena
- Science is a way of knowing
- Scientific knowledge assumes an order and consistency in natural systems
- Science is a human endeavor
- Science address questions about the nature and material world

Putting the elements of NOS into practice in the classroom is no simple task. An active learning approach such as modeling or experiential learning are often used to introduce students to the basic understanding of the nature of science. For example, a modeling activity would start with students observing a physical phenomenon such as a ball rolling down an incline and back up an incline. Students can observe patterns, behaviors and actions and propose explanations of the cause-effect. Then, students can develop a model of the system based on proposed explanation and then design an investigation to test the model. In testing the model, students will gather and analyze data. Next, students use evidence to construct and explanation of the phenomenon. This process is an example of reformed science education.

Incorporating NOS in science classrooms has continued to be advocated in all major reforms of science education despite continued research showing that some high school students and adults do not possess adequate knowledge of or views of NOS (Kahana & Tal, 2014). McComas, Clough, & Almazora (1998) surveyed 2,000 adults on the understanding of science and NOS. Only 2% had an understanding that science concerns the "development and testing of a scientific theory." 21% of participants had a minimal understanding that experiments require control groups and 64% of the participants lacked any comprehension of the nature of science.

A study by Akcay, Yager, Iskander and Turget (2010) looked at the effects of teachers who participated in an in-service professional development program and used the STS instruction on the knowledge of NOS and the attitudes of students toward science. The in-service program selected was the Iowa Chautauqua Professional Development (ICPD) program. Eight teachers participated in the study, each teaching a traditional classroom and a science-technology-society (STS) instruction classroom. The goal of the professional development was to improve teachers' instructional strategies using STS approaches leading to the improvement of students' understanding of NOS concepts as related to student understanding of scientists and scientific theories as well as to develop positive attitude toward science, science teacher and science career. The results of the study show that ICPD program with STS instruction helps students to understand nature of science concepts and provide positive attitudes towards science, science class and science teacher than traditional textbook-oriented classrooms.

E. Math and Science Anxiety

Essential in today's society are adequate mathematical skills to make well-informed decisions related to one's financial decisions and other life choices, and learning mathematics is a complex endeavor that is both cognitive and emotionally challenging (Skaggerlund, Östergren, Västfjäll, & Träff, 2019). In a national wide survey in the US, it was found that roughly half the adult population lacked the minimal numerical skills required to use numbers in printed materials, such as calculating the sales price of an item (Wadlington & Wadlington, 2008). One important emotional factor that negatively affects individuals' from attaining adequate math skills is mathematics anxiety (MA), which can be defined as "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life"(p. 552) (Richardson & Suinn, 1972; Suarez-Pellicioni & Colome, 2016). More broadly, MA can be defined as the stress of learning and participating in the mathematics classroom and is often the result of a previous negative experience with math or a math teacher (Wadlington & Wadlington, 2008).

MA is not considered a learning disability but interferes with learning mathematics and often inhibits a student's understanding and stops them from participating in mathematics (Isiksal, Currran, koc, and Askun, 2009). Fear or apprehension about math is prevalent in the US and across the globe (Foley, Herts, Borgonovi, Guerriero, Levine, & Beilock, 2017). Beilock and Willingham (2014) reported that in the US, 25% of 4-year college students reported a moderate to high degree of math anxiety as well as up to 80% of community college students.

Math anxiety can have multiple origins and can be perpetuated in the home, in the classroom, and society (Niepel, Burrus, Freiff, Lipnevich, Brenneman, & Roberts, 2018; Shields, 2005; Whyte & Anthony, 2012). In the home, parents who suffer math anxiety can unintentionally transfer anxiety to their children. In a recent study it was found that the well-meaning homework help provided by math-anxious parents lead first- and second-graders to learn less math over the course of a school year than peers with math-anxious parents who did not help (Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015). Parental disappointment and reproach for errors are especially demoralizing due to the value placed on parents by children (Dossel, 1993).

The classroom can also contribute to student math anxiety through traditional instructional practices and classroom culture. Classroom culture is defined as the norms and behaviors guiding classroom interactions. In a study by Vinson (2001), it was reported that math anxiety in students, in connection with parental and societal factors, may be a result of math anxious teachers and their traditional instructional methods. Traditional methods, such as drills, flash cards, insistence on only one correct way to complete a problem, and concentration on basic skills rather than on concepts, may lead to overt and convert teacher behaviors increasing students' math anxiety (Breen, 2003; Gurganus, 2007). Shields (2005) noted that the experience of learning mathematics in a structured, rigid classroom includes little opportunity for debate or discussion and focuses on searching for one right answer. These limited interactions discourage reflection on thinking and expects quick answers emphasized by timed worksheets.

Society also often contributes to math anxiety through mathematical myths such as boys are better at math than girls or only some people have math minds, while others proudly display attitudes such as 'I'm no good at math' and view failure at mathematics as socially accepting (Latterell, 2005).

College can be anxiety-inducing for many students due to the increase in academic workload combined with new responsibilities (Mirsa & McKean, 2000). College STEM classes are known to be generally competitive and can foster environments that can cause students to have higher than normal levels of anxiety (Brainard & Carlin, 1998). In particular, science classrooms have been reported to be particularly stressful for some students because of the rigor and difficulty of the subject materials including the complexity of the mathematics involved (Hanson, 2009; Koul & Lerdpornkulrat, 2012).

According to Mallow (2006), the causes of science anxiety are varied and include negative messages received about science, little to no training for analytical thinking, teachers' attitudes and lack of preparation, lack of proper role models, and gender bias. Students begin to receive negative messages about science as early on as elementary school when teachers will often portray science as hard and not easily understood. Students also receive little to no training in analytical thinking. Memorization is stressed along with an emphasis on the recall as a way of assessment for learning. Often anxiety occurs when students are confronted by teachers who are under qualified to teach science courses. Another source of anxiety for some students is the lack of role models to look up to and the prevalent stereotype that boys are better at science than girls (Mallow, 2006).

Math and science anxiety are often combated in classrooms through the implementation of reformed education practices such as active learning and flipped classrooms. Cooper, Downing, and Brownell (2018) investigated how three active learning practices, clicker questions, group work, and cold call/random call, increased or decreased student anxiety by interviewing 52 students in a large-enrollment active learning college science class. The study concluded that active learning can both decrease and increase student anxiety depending on the way the active learning is implemented. It was found that over 50% of the students in the study indicated that clicker questions increased their anxiety because they felt that timed questions and questions for points caused them to stress and often miss points. However, the clicker questions aided the students in understanding what science topics they do and do not understand, reducing a broader level of achievement anxiety related to the student's achievement in science (Cooper et al., 2018).

Students also reported that working with other students during class could induce achievement anxiety if the students in their group would view them as low achieving or unknowledgeable of the subject materials. However, students also reported that being allowed to choose who to work with could reduce anxiety levels and that group work helps them to realize that other students also find science challenging (Cooper et al., 2018). It was found that cold call/random call only increased anxiety levels and in no way did students find these practices to decrease of have a positive effect on their anxiety solely based on a fear of negative evaluation (Cooper et al.,2018).

F. Attitudes and Beliefs Toward Mathematics and Science

Osborne, Simon, and Collins (2003) make a distinction between attitudes toward science and scientific attitudes. Scientific attitude is a complex mixture of wanting to know and understand, a questioning approach to all statements, and a search for data and their meaning with a demand for verification (Gardner, 1975). Attitudes toward science are the feelings, beliefs and values held about an object that may by the enterprise of science, school science, the impact of science on society or scientist themselves. Richardson (1996) identifies attitudes and beliefs as a subset of a group of constructs that are thought to drive a person's actions. Other constructs in this set include conceptions, perspectives, perceptions, orientations, theories, and stances (Richardson, 1996).

Osborne et al. (2003) gathered a range of components, from a review of literature from 1975-1994 used in the measurement of attitudes toward science including: the perception of the science teacher, anxiety toward science, the value of science, self-esteem at science, motivation towards science, enjoyment of science, attitudes of peers and friends toward science, attitudes of parent toward science, the nature of the classroom environment, achievement in science, and fear of failure of course. The perception of the science teacher and the nature of the classroom are two key components of attitude identified by Osborn et al. (2003) that are often researched when dealing with preservice teachers and programs designed to influence and impact preservice teachers. Teachers attitudes and beliefs drive classroom actions and influence the change process (McGinnis et al., 1998). These attitudes and beliefs strongly affect what and how students learn.

McGinnis et al. (1998) reported on the validity and reliability of an instrument to measure teacher candidates' attitudes and beliefs about the nature of and the teaching of mathematics and science. The study used a repeated-measures t-test design to determine if a reformed-based mathematics and science preservice candidate teacher course had the desired effect on the attitudes and beliefs of the participants. The results indicated that the participants, on all five different subscales (sets of questions with Likert scale questions), moved in the desired direction with a shift toward the positive with statistically significant shifts.

The reformed-practices identified by McGinnis et al. (1998) and put into practice by the Maryland Collaborative for Teacher Preparation (MCTP) (1996), an undergraduate teacher preparation program for specialist in mathematics and science elementary/middle school level teachers, believe undergraduate classes are best when taught by faculty in mathematics, science, and education who make efforts to focus on "developing understanding of a few central concepts and to make connections between the sciences and between mathematics and science" (MCTP, 1996, p. 2). Faculty also strive to infuse technology into their teaching practices, and to employ instructional and assessment strategies recommended by the literature to be compatible with the constructivist perspective (i.e., address conceptual change, promote reflection on changes in thinking, and stress logic and fundamental principles as opposed to memorization of unrelated facts) (Cobb, 1988; Driver, 1989; Tobin, Tippins, & Gallard, 1994; von Glasersfeld, 1987). Faculty lecture is diminished and student-based problem-solving is emphasized in cross-disciplinary mathematical and scientific applications.

In order for students to persist in STEM careers and related programs of study, literature suggests that only aptitude is not sufficient to explain STEM career persistence and that attitude can indirectly influence persistence (Spelke, 2005; Else-Quest, Hyde, & Linn, 2010; Frost, Hyde, & Fennema, 1994). A more positive attitude toward mathematics and science can influence student interest in STEM careers (Osborne et al., 2013) and other academic-related choices such as which courses to enroll in (Ing & Nylund-Gibson, 2017).

G. Reformed-Based Science Education

The decline of students interested in STEM-related careers and enrolling in STEM college degrees and programs has led to a growing interest in research in the field of students' attitude toward science and mathematics. The results of these studies have led researchers to understand that there is a strong relationship between attitude toward science and science achievement (Arisoy, 2007). These studies have led educators to understand that factors such as science and math achievement, gender differences, student-teacher interactions, and classroom learning environments as all having an effect on student attitude toward science (Ali, Yager, Hacieminoglu, & Caliskan, 2013). Of the four factors identified by Ali et. al, (2013), only two factors can be accounted for by colleges and universities, student-teacher interactions and classroom learning environments. Both of these factors are important in effectively teaching STEM courses.

The importance of effectively teaching STEM courses has been stressed in several recent reports including the Presidents' Council of Advisors on Science and Technology, *Engage to*

Excel (2012) and the American Association for the Advancement of Science, *Vision and Change* report (AAAS), the National Research Council, *Discipline-Based Education Research* report. Even with the increase in evidence-based recommendations for an increased use of active-engagement in the classroom, there is a recognized need for measures of teaching effectiveness and to measure the level of reformed classroom practices (Association of American Universities, 2011).

A study by the National Research Council in 1996 and in 2012 both recommended reforms in science education, indicating that teachers need to employ more reformed strategies in their classrooms. Reformed teaching methods have been shown to increase retention of students in STEM courses and to reduce the achievement gap for students historically underrepresented in STEM (Haak, HilleRisLambers, Freeman, & Pitre, 2011). Reformed methods have also been shown to encourage participation of students in STEM-related careers. Teachers who can implement reformed teaching strategies in the classroom are critical to increased retention and are the key in encouraging students to enter and remain in the STEM pipeline. Osborne, Simon, and Collins (2003) found that when teachers gain greater confidence and self-efficacy through experimentation with reformed educational practices and teaching methods, they are able to improve the attitudes of their students toward science and mathematics.

In response to the call for reform in science education practices, President Obama's Council of Advisors on Science and Technology (PCAST) prepared a report with a two-tiered strategy for improving K-12 STEM: Prepare and Inspire. The report contained five overarching recommendations; (1) improve Federal coordination and leadership on STEM Education, (2) support state-led movement for a common baseline for what students learn in STEM, (3) cultivate, recruit, and reward STEM teachers, (4) create STEM-related experiences, and (5) support states and schools in their effort to transform schools into STEM learning environment (President's Council of Advisors on Science and Technology, 2010). Most of the Federal initiatives and reform measures look to improve student involvement in STEM in K-12, colleges and universities are often left to determine their own best practices for the persistence of students in STEM related degree programs.

Most colleges and universities provide resources and training to its faculty to help them develop reformed pedagogical practices. One of the most common reformed pedagogical practices is active learning in the place of the standard lecture format for large-enrollment courses. Some active learning strategies are think-pair-share, facilitated group conversations, turn and talk, clickers, fishbowl, and idea line up to name a few (Berkeley Center for Teaching & Learning, 2019). According to Bishop and Verleger (2013), a flipped classroom approach, events that traditionally take place in the classroom now take place outside the classroom and vice versa, appears to have the most impact on student learning when compared to traditional classrooms.

In order for a classroom environment to be considered reformed, traditional methods must be compared to active learning to determine the degree of reform. Two such assessments that measure the degree of reform are The Reformed Teaching Observation Protocol (RTOP) developed by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) at Arizona State University (Sawada, et al., 2002) and The Classroom Observation Protocol for Undergraduates STEM (COPUS) developed by Smith, Jones, Gilber, and Wieman in 2013.

The RTOP is a 25-item classroom observation protocol that is standards based, inquiry oriented, and student centered (Sawada, et al., 2002). The RTOP is broken into three observation sections, Lesson Design and Implementation, Content, and Classroom Culture. A score of greater than 50 on the RTOP is considered to be proof of evidence of reformed instructional methods and implementation in one, two or all three observation sections on the protocol. The protocol looks for evidence through the use of observation and a 5-point Likert scale to rank the level of observation, 0 – Never Occurred to 4 – Very Descriptive. The RTOP requires extensive training and practice to properly use in a classroom setting and is often only used by researchers.

In comparison, Smith, et al. (2013) developed the COPUS in an attempt to answer the questions, “What the students are doing?” and “What the instructor is doing?” in connection to classroom learning environments. A faculty member can be taught to use the instrument in one day according to the developers. The instrument breaks the learning up into two-minute actions that can be associate with either the instructor or the students. The results of implementing COPUS has resulted in a collection of active learning actions for students that include students listening, individual thinking and problem solving, discussion of clicker questions, group activity, answering questions posed by the instructor, asking questions, engagement in whole-class discussion, making predictions, presenting, taking a test or quiz, or waiting. The results also identified actions by the instructor as lecturing, real-time writing, follow-up on clicker questions, posing non-clicker questions, asking a clicker question, answering student questions, moving through the class, one-on-one discussion with students, conducting a demo, experiment, etc. The results are used to characterize university STEM classroom environments and faculty as reformed or non-reformed based on the distribution of the two-minute intervals as who they are contributed to and what types of action is taking place.

As more and more faculty are starting to use active learning practice in the classroom, researchers began to study faculty members to asses what they believe they are doing in the classroom and to what extent. A study of faculty members in two national PD programs, Faculty Institutes for Reforming Science Teaching (FIRST II) and the National Academies Summer Institute on Undergraduate Education in Biology (SI) at the University of Wisconsin found that faculty often described their own instruction in surveys as including more active learning behaviors than that actually (Ebert-May, Derting, Hodder, Momsen, Long, & Jardeleza, 2011).

Research findings by Bainlower, Smith, Weiss, Malzahn, Campbell, & Weis (2013) reported that some reformed beliefs in science and math teaching are widely accepted and routine while others are far from common practice in the classroom. The types of reform with a high acceptance among teachers is providing lesson objectives, reviewing prior material, and student sharing of ideas. Formative assessment activities were reported as the number one type of reformed activities used in classrooms. The survey results also revealed that in most science classrooms, up to 70% of class time was spent in non-reformed activities. The survey also revealed that teachers were resistant to reform practices with high potential for discussions where teachers are more likely to feel a loss of control in the classroom with messy and unpredictable outcomes (Banilower et al., 2013).

Killough and Stuessy (2019) studied the beliefs about reformed practices of biology teachers before and after attending professional development on the understanding of and use of reformed practices in a science classroom. The results of the study showed that participants held more reformed beliefs in science teaching at the end of the workshop and the group of teachers with more experience, five or more years teaching, had the greatest change in beliefs about reform practices (Killough & Stuessy, 2019). However, the study did not indicate how many of the teachers adopted reformed practices despite the increased beliefs that reformed practices are important in science education.

The struggle to adopt and implement reformed practices by trained teachers and faculty is often due to barriers such as lack of time, incentives, or feedback and support of peers (Dancy & Hendeson, 2010; Brownell & Tanner, 2012). To address these barriers, Withers (2016) introduced an example of an instructional model, a learning cycle, based on the Biological Sciences Curriculum Study (BSCS) 5E model and can be used with any evidence-based or active-learning approach. It is best used with a backward design, an approach to course development that emphasizes learning over teaching (Wiggins & McTighe, 1998). This approach helps the instructor determine what and if something should be included in the classroom or is best learned by the student outside the classroom.

H. Chapter Summary

Developing a scientifically literate population ready for STEM related jobs requires more than students who want to know and understand scientific concepts, it requires teachers who are trained to use and implement reformed education practices in the classroom and an understanding of what causes math and science anxiety and ways to combat these issues at an early age to help student develop a better understanding of the nature of science. All of these positive experiences will help develop positive attitudes and beliefs toward mathematics and science creating a better prepared and functioning science and mathematics literate society.

Chapter III. Research Methodology

The purpose for conducting the study was to investigate to what extent completing a one or two-semester sequence of reformed science teaching in the field of physics impacts a shift in students' attitude and beliefs about learning and teaching of mathematics and science. In particular, the study will compare pre- and post-attitudes and beliefs of science majors and pre-service education majors in two different physics courses.

A. Research Design

This study was an instrumental case study that utilized a survey to investigate the impact of experienced-based learning, as described by Kolb's cycle of experiential learning, in reformed science courses on students' attitudes and beliefs about learning and teaching of mathematics and science. A case study is an in-depth exploration of a bounded system such as an activity, event, process, or individuals based on extensive data collection (Stake, 1994; Stake, 1995; Creswell, 2008). For a study to be considered a case study it must have boundaries (Merriam, 1998). The boundaries for this include; length of course term, the course instructor, number of times the course meets per week, course requirements, and laboratory experience including the teaching assistant and types of active learning strategies implemented in the laboratory.

The two courses selected for this study are *University Physics I & II (University Physics)* and *Physics for Elementary Teachers (PET)*. University Physics is a two-semester sequence of calculus-based physics that surveys the principles of physics including mechanics, wave motion, temperature, heat, electricity, magnetism, and light. The course is designed for science majors in the fields of physics and engineering who meet a mathematics requirement of completing Calculus I or an equivalent course. Each of the University Physics courses is a four-hours credit course that meets for 16 weeks with lecture meeting two times a week for one hour with a required lab that meets twice a week for two hours each for a total of six hours a week. A significant portion of the learning in the course is designed to take place in the lab through laboratory exploration, small group assignments, and exam preparation activities.

Physics for Elementary Teachers (PET) is a physical science course based on state frameworks explored in a mixed lecture/lab environment. The inquiry-based lab activities cover topics such as; scientific inquiry, motion and forces, conservation of energy, heat, light, electricity and simple circuits, and magnetism. The course is designed for students who intend to become an elementary education teacher. PET is a four-hour credit course that meets for 16 weeks meeting three times a week for two hours for a total of six hours a week. The inquiry lab component of the course is integrated into the informal lecture in a merged classroom and laboratory setting. A sample of individual course requirements for PET and University Physics can be seen in the sample syllabus for each of the two courses in Appendix A and B.

Data were collected using a survey instrument as a pre- and post-assessment. *The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey* was the survey tool selected to gather reliable formative feedback on the attitudes and beliefs of the students taking reformed physics classes. The survey was developed at the University of Maryland and used with permission by the National Science Foundation's Collaborative for Excellence in Teacher Preparation Program (CEPT); contract grant number: DUE-9255745 (McGinnis et al., 1998). During the development of the survey, it underwent a rigorous testing and analysis using a Cronbach alpha test to increase the survey's reliability (McGinnis et al, 2002). Sections of the instrument verified by factor analysis are beliefs about mathematics and science ($\propto = .76$); attitudes toward mathematics and science ($\propto = .81$); beliefs about teaching mathematics and science ($\propto = .69$); attitudes toward using technology to teach mathematics and science ($\propto$ = .80); and attitudes toward teaching mathematics and science ($\propto$ = .60) (McGinnis et al., 2002).

The survey consists of 44 questions grouped into 5 constructs. The survey uses a five-point nominal Likert Scale: 5-Strongly Agree, 4-Agree, 3-Neither Agree nor Disagree, 2-Disagree, 1-Strongly Disagree. The Likert Scale is a bipolar scaling method for measuring a student's positive or negative response to a statement. The first 4 questions are not included in a construct category and deal with gender, ethnicity, college credits and major. The remaining 40 questions are broken into 5 distinct constructs dealing with attitudes and beliefs. The first construct, X1, looks at *Beliefs about the nature of mathematics and science,* (Numbers: 9, 10, 11, 12, 14, 17, 21, 22, 24, 25, 26, 29, 31, 33). Subjects with a low score on X_1 tend to believe that mathematics and science can be understood only by people with special abilities and that the discipline consists of discrete sets of unrelated topics and skills to be memorized (McGinnis et al, 2002). Construct X_2 deals with *Attitudes towards mathematics and science,* (Question Numbers: 5, 6, 7, 19, 27, 28). Subjects with a high score on X_2 describe themselves as liking mathematics and science, enjoy learning how to use technology in the classroom and look forward to taking more math and science courses (McGinnis et al, 2002). Construct X_3 looks at *Beliefs about the teaching of mathematics and science,* (Question Numbers: 8, 13, 15, 16, 18, 20, 23, 30, 32, 34). People with a high score on construct X_3 believe that technology and manipulative should be used as aids in teaching mathematics and science, believe in the regular use of small group activities to emphasize learning, and giving students time to reflect on what they have learned in the classroom (McGinnis et al, 2002). The fourth construct, X_4, looks at *Attitudes towards learning to teach mathematics and science,* (Question Numbers 35, 36, 38, 41). Subjects with a high X_4 tend to expect college level mathematics and sciences course will be helpful to them in teaching mathematics and science. Subjects also express a desire to learn how to use technology in the classroom as a teaching tool (McGinnis et al, 2002). Construct X_5 looks at *Attitudes towards teaching mathematics and science* (Question Numbers: 37, 39, 40, 42). Subjects with a high X_5 score tend to feel confident in their ability to teach mathematics and science and feel prepared to integrate the two disciplines when teaching (McGinnis et al, 2002).

Questions 43 and 44 ask students who are considering teaching K-12 as a career to indicate the grade level and area they are interested in teaching. See Appendix C for a copy of the survey tool.

For this study, the outcome of a student's academic performance is indicated by a student's final grade in the course. The final grade for each student participants was collected as part of the study. The grades for each of the PET participants was provided by the course instructor. Grades for University Physics participants were collected through matching grades to final grade rosters provided by the different faculty who have taught the course and by using online resources. However, many of the University Participants were unable to be matched successfully due to incomplete data collection at the time of survey completion.

B. Participant Sample

The target population for this study was undergraduate students at the University of Arkansas at Fayetteville enrolled in a physics course with a required lab component. Data were only collected on an accessible sample of students who completed the University Physics I & II (University Physics) sequence or the Physics for Elementary Teachers (PET). Data were collected over the time period of Fall 2003 to Spring 2013. Students were asked to volunteer to complete a pre-survey at that start of the fall semester and then asked to complete a post-survey at the end of the spring semester for the two-semester university physics. Students enrolled in

PET, a one-semester course, were asked to complete the pre-survey at the start of the fall semester and the post-survey at the end of the fall semester. All enrolled students had an equal opportunity to complete the survey. The modified sample data set used for analysis includes only students who completed both the pre-survey and post survey. An ID number assigned to each student by the online survey tool was used to filter the data so that only matched pre and post data was included in the final report.

Table 1
Student Enrollment at the University of Arkansas

Year	Female	Male	ACT (25^{th} / 75^{th})*	GPA (% reported)**
2002	7,814 (48.7%)	8,221 (51.3%)	21.3 / 28	3.57 (98.5%)
2003	8,052 (49.0%)	8,397 (51.0%)	21.3 / 28.3	3.60 (98.6%)
2004	8,565 (49.6%)	8,704 (50.4%)	21.7 / 28	3.57 (99.0%)
2005	8,752 (49.1%)	9,069 (50.1%)	21.7 / 27	3.57 (99.3%)
2006	8,880 (49.5%)	9,046 (50.5%)	21.7 / 28	3.58 (99.3%)
2007	9,189 (49.3%)	9,459 (50.7%)	22.3 / 29	3.59 (99.3%)
2008	9,414 (49.0%)	9,780 (51.0%)	22.3 / 28.7	3.59 (99.5%)
2009	9,640 (48.6%)	10,209 (51.4%)	22.3 / 29	3.55 (99.3%)
2010	10,397 (48.6%))	11,008 (51.4%)	22.3 / 28.7	3.65 (99.2%)
2011	11,294 (44.8%)	11,905 (55.2%)	22.3 / 28	3.56 (99.5%)
2012	12,196 (50.1%)	11,905 (49.9%)	22.7 / 28.3	3.60 (99.7%)
2013	12,740 (50.3%)	12,601(49.7%)	22.7 / 28	3.62 (99.4%)

*Average ACT Score Based on students scoring in the 25^{th} or in 75^{th} percentile.
**GPA average based on percentage reported.

For the period of the study, 2002-2011, student enrollment by percentage of female and male remained steady with males making up slightly more than 50% of the total enrollment with the exception of Fall 2011, when the percentage of males increased from 51% to over 55%, and 2012 and 2013 when the percentages dropped just below 50%, see Table 1. Average ACT scores for entering students in the 25th percentile increased slightly from 21.3 to 22.7, while students in the 75th percentile remained steady with an average around 28 with an exception for 2006 and 2009 when the average score was 29. Overall the average reported GPA remained steady with a narrow range between 3.55 to 3.65.

C. Data Collection

The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey was administrated in a science lab setting. Students were asked to log onto a computer in the lab room and directed to a secure website. Each student entered his/her name and was assigned a 5-digit ID number. The students were then asked to answer 44 questions using a Likert scale. The students were given the following directions at the start of the survey, "Below are a series of statements about mathematics and science. Indicate the extent to which you agree or disagree with each statement. There are no right or wrong answers. The correct responses are those that reflect your attitude and beliefs. *Do not spend too much time with any statement."* Data were collected and stored on a secure server for later analysis.

D. Data Analysis

Descriptive analysis was used to answer research questions one providing a demographic profile of the students who completed both pre and post-survey which including; gender, ethnicity, number of completed college credits, and major area of concentration. Central tendencies, mean, median, and mode, was reported to answer research question two describing the entering and existing attitudes of students who completed one- or two-semester sequence of reformed science teaching.

For research questions three, four, five and six, a t-test is not appropriate because the researcher is comparing groups of students who experienced reformed education in different courses and participated in the same survey on two different occasions. To preserve statistical accuracy, each course will be used as the unit-of-analysis. Therefore, we are treating the Likert scores as ratio allowing calculated means for the pre-survey and post-survey to be used to determine the shift in the attitudes and beliefs of the students. This allows us to use a dependent t-test to compare the means of two related groups to determine whether there is a statically significant difference between these means (Laerd Statistics, 2018). However, using a repeated measures dependent t-test on multiple subscales increases the chance of making a Type I error of rejecting the null hypothesis. To correct for this, a Bonferroni correction is made to the significance level (McGinnis, Kramer, Graeber, & Parker, 2001). To maintain an overall-experiment Type I error rate of 5%, a new significance level is calculated, based on the five constructs compared between the student groups, to be .01, where significance is determined at $p \leq .01$ (Statistical Solutions, 2019).

Each group of questions, making up the five constructs, was written so that they all have a desired attitude and beliefs response in the same direction (McGinnis et al, 2002). However, not all five constructs were written to have a desired shift to be in the same direction, so some recoding of data was done so all five contracts show a desired shift in attitude and beliefs to be positive. The computed effect size for each group of participants and the percent shift in standard deviation from the pre-survey mean to the post-survey mean was calculated for each of the five constructs.

E. Chapter Summary

This study was a case study that utilized a survey instrument to investigate the impact of experienced-based learning in reformed science courses on students' attitudes and beliefs about learning and teaching of mathematics and science. The instrument used to collect pre- and post-assessment data was the *The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey* developed at the University of Maryland. The tool was selected to gather reliable formative feedback on the attitudes and beliefs of the students taking reformed physics classes.

A dependent t-test analysis was selected as the best method for analyzing data. In order to account for repeated measures a Bonferroni correction was made to the significance level, from $P \leq .05 \; to \; P \leq .01,$ to maintain a 5% chance of an overall-experiment Type I error, rejecting the null hypothesis. The shift in pre and post-mean for each of the five constructs for each course will be evaluated to identify significant changes in attitude and beliefs in learning and teaching mathematics and science. The constraints on the cases will be examined to determine effect on the significance of the shift.

Chapter IV. Findings

With the decline in student interest in STEM-related fields and the rising demand for STEM prepared employees, there is a need to improve the attitude toward and beliefs in teaching and learning mathematics and science. It has been shown that teachers who undergo reformed educational practices have improvements in attitude toward and beliefs in teaching science. These improvements carry over to the students in the classroom and laboratory with their own shift in positive attitudes and beliefs in science. In this study we are investigating to what extent completing a one or two-semester sequence of reformed science teaching in the field of physics impacts a shift in students' attitude and beliefs about learning and teaching of mathematics and science.

The current chapter starts with a summary of the study, then discusses the research method, then identifies the target population, and finally presents the results from the study by answering the research questions. The summary of the study includes the purpose and rationale for the study. The research method includes the research methodology and a discussion of the survey tool. The target population is identified with a short description of the participants in the study. The last section, data analysis, presents the findings by answering the five research questions.

A. Summary of Study

This study was an instrumental case study that utilized a survey to investigate the impact of experienced-based learning, as described by Kolb's cycle of experiential learning, in reformed science courses on students' attitudes and beliefs about learning and teaching of mathematics and science. Data were collected using a survey instrument as a pre- and post-assessment. *The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey* was the survey tool selected to gather reliable formative feedback on the attitudes and beliefs of the students taking reformed physics classes. The survey was developed at the University of Maryland and used with permission by the National Science Foundation's Collaborative for Excellence in Teacher Preparation Program (CEPT)

The purpose for conducting the study was to investigate to what extent completing a one or two-semester sequence of reformed science teaching in the field of physics impacted a shift in students' attitude and beliefs about learning and teaching of mathematics and science. In particular, the study compared pre- and post-attitudes and beliefs of science majors and pre-service education majors in two different physics courses.

B. Summary of Research Method

This study was an instrumental case study that utilized a survey instrument. The instrument used to collect pre- and post- assessment data was *The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey* developed at the University of Maryland. The tool was selected to gather reliable formative feedback on the attitudes and beliefs of the students taking reformed physics classes.

The survey consisted of 44 questions grouped into 5 constructs, X_1, X_2, X_3, X_4, and X_5. The survey used a five-point nominal Likert Scale ranging from 5-Strongly Agree to 1-Strongly Disagree. The Likert Scale was set up as a bipolar scaling method for measuring a student's positive or negative response to a statement. Data were collected and stored on a secure server for analysis.

The first 4 questions on the survey tool are not included in a construct category and deal with gender, ethnicity, college credits and major. Responses to these four questions were used to develop statistical characteristics of the students enrolled in both courses.

The remaining 40 questions were broken into 5 distinct constructs dealing with specific areas of attitudes and beliefs. The first construct, X_1, looks at students' *Beliefs about the nature of mathematics and science*. Construct X_2 deals with students' *Attitudes towards mathematics and science.* Construct X_3 measures students' *Beliefs about the teaching of mathematics and science.* Construct X_4 evaluates students' *Attitudes towards learning to teach mathematics and science*. The last construct, X_5, measures students' *Attitudes towards teaching mathematics and science*. The last two questions on the survey, 43 and 44, ask students who are considering teaching K-12 as a career to indicate the grade level and subject area they are interested in teaching.

A dependent t-test analysis was selected as the best method for analyzing data. In order to account for repeated measures a Bonferroni correction was made to the significance level, from $p \leq .05 \ to \ p \leq .01$, to maintain a 5% chance of an overall-experiment Type I error, rejecting the null hypothesis. The shift in pre and post-mean for each of the five constructs for each course will be evaluated to identify significant changes in attitude and beliefs in learning and teaching mathematics and science.

C. Participants in the Study

The target population for this study were participants enrolled in one of two courses, Physics for Elementary Teachers (PET), a pre-service education science course, or University Physics I and II, (University Physics), a two-semester sequence of calculus-based physics for engineers and science majors. Data were collected over the time period of fall 2003 to spring 2013. Data were collected on an accessible sample of students who volunteered to complete *The Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Survey* as a pre and post-survey. Students were asked to log onto a computer in the lab room and directed to a secure website to complete the survey. Data collected for PET yielded a matched sample size of 234 participants out of a possible 419 enrolled students from spring 2005 to spring 2013. The modified data set for University Physics yielded a matched sample size of 1,509 participants out of 5091 in semester one and 3291 in semester two from fall 2003 to spring fall 2013.

D. Data Analysis

Descriptive analysis of data collected will answer research questions one providing a demographic profile of the students who completed both pre and post-survey and currently enrolled in a course participating in the study including; gender, ethnicity, number of completed college credits, and major area of concentration.

Central tendencies, mean, median, and mode, will be reported to answer research question two describing the entering and exiting attitudes of students who completed one- or two-semester sequence of reformed science teaching.

For research questions three, four, five and six, a t-test is not appropriate because the researcher is comparing groups of students who experienced reformed education in different courses and participated in the same survey on two different occasions. To preserve statistical accuracy, each course will be used as the unit-of-analysis. Therefore, the Likert scores are treated as ratio allowing calculated means for the pre-survey and post-survey to be used to determine the shift in the attitudes and beliefs of the students. This method allows for a dependent t-test to compare the means of two related groups to determine whether there is a statically significant difference between the means (Laerd Statistics, 2018). However, using a repeated measures dependent t-test on multiple subscales increases the chance of making a Type I error of rejecting the null hypothesis. To correct for this, a Bonferroni correction is made to the significance level (McGinnis et al, 2002). A new significance level is calculated to maintain an overall-experiment Type I error rate of 5% based on the five constructs compared between the student groups. The new significance level is calculated at .01; where significance is determined at $p \leq .01$ (Statistical Solutions, 2019).

Each group of questions, making up the five constructs, was written so that they all have a desired attitude and beliefs response in the same direction (McGinnis et al, 2002). However, not all five constructs were written to have a desired shift to be in the same direction, so some recoding of data was done so all five contracts show a desired shift in attitude and beliefs to be positive. The computed affect size for each group of participants and the percent shift in standard deviation from the pre-survey mean to the post-survey mean was calculated for each of the five constructs.

*Research Question 1: What was the demographic profile of students who completed a one- or two-semester sequence of reformed science teaching during 2003-2013*I

The first four questions on the survey asked students to self-select gender (male or female), ethnicity (African American, Asian/Pacific Island, Caucasian, Hispanic, or Other), range of completed college credits (0-31, 31-60, 61-90, 90+, or Post-Baccalaureate), and current declared major (Education/Math, Education/Science, Education/Math 7 Science, Education/Other, or Non-Education).

PET Participant Demographics

Data collected for PET yielded a matched sample size of 234 participants out of a possible 419 enrolled students from spring 2005 to spring 2013. The matched sample represents a 55.8% participation rate. Students enrolled in PET were asked to complete an electronic version of the pre-survey at the start of the spring semester and again as a post-survey at the end of the semester. All enrolled students had an equal opportunity to complete the survey. The modified sample data set used for analysis included only students who completed both the pre-survey and post survey, see Table 2.

The number of participants ranged from eight in 2005 and 2008 to 48 in 2012, see Appendix C for breakdown of participation characteristics by semester. The largest increase in participation occurred from 2008 to 2009 when the course increased from one section to two sections with a maximum enrollment of 32 students per section. The increase in number of sections offered was to meet the demand for an increase in enrollment in pre-service education courses.

The PET sample was comprised of 97.0% female students and 3.0% male students. For duration of data collection, females made up 90% or more of the participants with an exception in 2005 when the percentage of female participants was at its lowest, 83%. The overall ethnic profile of the participants was 94.4% Caucasian with the exception of 2006 and 2010 when it dropped to 80% and 86.4% respectively. Participants in 2010 were the most diverse with 6.8% African American, 2.3% Asian/Pacific Island, 86.4% Caucasian, and 2.6% Hispanic.

At the time of enrollment, 47.0% of all participants had earned between 30 to 59 hours of credit and 38.5% between 60 - 90 hours of credit placing the majority of the participants in the categories of sophomores and juniors. Between 2005 and 2011, over 90% of the participants selected their major as education with an emphasis other than math or science, see Table 2.

From 2011 to 2012 significant shifts in declared majors occurred with an increase in Education/Math from 4.2% to 14.3%, an increase in Education/Math & Science from 4.2% to 21.4%, a decrease in Education/Other Science from 83.3% to 28.6% and an increase in non-Education majors from 5.1% to 6.2%.

Table 2
PET and UP Participant Characteristics

	PET (N=234)		University Physics (N=1509)	
Gender, n (%)				
Male	7 (3.0%)		1070 (70.9%)	
Female	227 (97.0%)		239 (29.1%)	
Ethnicity, n (%)				
African American	5 (2.1%)		53 (3.5%)	
Asian/Pacific Island	2 (0.9%)		89 (5.9%)	
Caucasian	221 (94.4%)		1264 (83.8%)	
Hispanic	2 (0.9%)		48 (3.2%)	
Other	4 (1.7%)		55 (3.6%)	
Credits Earned, n (%)			Pre	Post
0-30	21 (0.9%)		976 (64.7%)	442 (29.3%)
31 – 60	110 (47.0%)		362 (24.0%)	692 (45.9%)
61-90	90 (38.5%)		117 (7.8%)	241 (16.0%
91+	13 (5.6%)		41 (2.7%)	121 (8.0%)
Post-Baccalaureate	0 (0.0%)		13 (0.9%)	13 (0.9%)
Major, n (%)			Pre	Post
Education/Math	4 (1.7%)		19 (1.3%)	20 (1.3%)
Education/Science	2 (0.9%)		49 (3.2%)	39 (2.6%)
Education/Math & Science	5 (2.1%)		121 (8.0%)	94 (6.2%)
Education/Other Science	212 (90.6%)		22 (1.5%)	16 (1.1%)
Non-Education	11 (4.7%)		1298 (86.0%)	1340 (88.8%)
Areas of Teaching Certificate	Pre	Post	Pre	Post
Elementary (grades 1-8)	217 (92.7%)	219 (93.6%)	6 (0.4%)	10 (0.7%)
Secondary Mathematics (grades 8-12)	1 (0.4%)	0 (0.0%)	18 (1.2%)	24 (1.6%)
Secondary Science (grades 8-12)	1 (0.4%)	1 (0.4%)	29 (1.9%)	27 (1.8%)
Other	14 (6.0%)	11 (4.7%)	185 (12.3%)	161 (10.7%)
No Response	1 (0.4%)	3 (1.3%)	1271 (84.2%)	1287 (85.3%)
Intended Teaching Grades	Pre	Post	Pre	Post
K-3	201 (85.9%)	201 (85.9%)	3 (0.2%)	4 (0.3%)
4-8	23 (9.8%)	24 (10.3%)	6 (0.4%)	8 (0.5%)
9-12	3 (1.3%)	1 (0.4%)	37 (2.5%)	40 (2.7%)
Post-secondary	0 (0.0%)	0 (0.0%)	23 (1.5%)	13 (0.9%)
Undecided	6 (2.6%)	5 (2.1%)	169 (11.2%)	157 (10.4%)
No Response	1 (0.4%)	3 (1.3%)	1271 (84.2%)	1287 (85.3%)

The majority of PET students, 217 (92.7%), intended to earn a teaching certificate in elementary education, one (0.4%) student selected secondary math, one (0.4%) student selected secondary science, and the 15 (6.4%) remaining students selected category other or no response, see Table 2. Of those PET students who intend to teach for a career, 201 (85.9%) selected grades k-3, 23 (9.8%) chose grades 4-8, 3 (1.3%) chose grades 9-12, and 7 (3.03%) chose either undecided or no response. Overall the student demographic in PET did not change much over the period of nine years.

University Physics Participant Demographics

For the University Physics sequence, data were collected from fall 2003 to spring 2013. Both courses were offered in the spring and fall semesters as well in the summer sessions. Students enrolled in University Physics were asked to complete the pre-survey at the start of UPI and the post-survey at the end of UPII. Sample sets were arranged to match student participants based on a two-semester sequence of enrollment. For example, students enrolled in UPI in fall 2006 would most likely have completed the post-survey in spring 2007 in UPII while UPI students enrolled in spring 2007 would have completed the post-survey in fall 2007 in UPII. However, some participants might have a semester or summer session between UPI and UPI and would match in non-sequence semesters, for example, a student completed the pre-survey in UPI fall 2005 and the post-survey in UPII fall 2006. Students in summer courses were not given the survey as the course structure was different leading to some students not being matched and not included in the study. The University Physics modified data set includes only students who were identified as having completed both the pre-survey and post-survey.

The modified data set for University Physics yielded a sample size of 1,509 participants from fall 2003 to spring fall 2013, see Table 1. The only gap in data is spring 2008 when data could not be recovered from the server, see Appendix E for breakdown of participant characteristics by University Physics semester sequence. For the period of the study, a total of 5091 students were enrolled in the first course in the sequence and 3291 in the second course in the sequence. In order to be included in the study, students must have completed both the pre- and post-survey, a participation rate of 45.9%.

The semester sample sizes range from 30 matching participants in the spring 2009/fall 2009 sequence, to 138 matching participants in the fall 2011/spring 2012 sequence, see Appendix E. There was a noticeable shift in sample size from the fall/spring sequence to the spring/fall sequence. This was mostly due to smaller enrollments in the spring UPI and fall UPII courses and was affected by students completing the course sequence in the summer when the survey was not offered, or some students were not required to enroll in UPII for degree completion. There was significant shift in the number of participants starting in fall 2007, 50 to 126, due to an increase in the enrollment of freshman in the engineering school.

The University Physics sample was comprised of 70.9% males and 29.1% females, see Table 1. The majority of the participants, 83.8%, self-selected as Caucasian with the remaining participants selecting African American, 3.5%, Asian/Pacific Island, 5.9%, Hispanic, 3.2% and Other, 3.6%. In pre-survey data, 64.7% of participants enrolled have earned 30 or less course credits classifying the majority of pre-survey participants freshmen. In post-survey data, 45.9% of participants enrolled have earned 31- 60 credits and 24.9% have earned 61 or more credits classifying the majority of the students as sophomores or higher.

1,298 (86.0%) of pre-survey participants self-declared their major as Non-Education and 238 (14.0%) as either Education/Math and Science, Education/Science, Education/Math, or Education/Other. Of the declared Education Majors, six selected elementary, 18 selected secondary math, 29 selected secondary science, and 185 selected other as an emphasis. Overall there was a shift down in the post-survey responses from 14.0% (238) to 11.2% (222) of participants declaring an Education Major.

In summary, 55.8% (234) of PET students and 45.9% (1,509) of University Physics students participated in the study from fall 2003 to spring 2013. The PET sample was comprised of 97.0% (227) female students and 3.0% (7) male students compared to the University Physics sample comprised of 70.9% (1070) males and 29.1% (239) females, see Appendix J. 85.5% (200) of the PET students are sophomores or juniors while 64.7% (976) of the University Physics students were freshman at the time of pre-survey. All but 11 (4.7%) of PET students indicated a major in education with and emphasis in either mathematics or science while 14.0% (211) University Physics students declared a major in education at the time of pre-survey and dropped to 11.2% (169) at the time of post-survey.

Research Question 2: What were the entering and existing attitudes of students who completed one- or two-semester sequence of reformed science teaching during 2003-2013?

The survey includes 38 questions (7 – 44) broken into 5 distinct constructs dealing with attitudes and beliefs, see Appendix C for a copy of the survey tool. Constructs X_1, X_2, and X_3 measure the participants general attitudes and beliefs about the nature of mathematics and science while constructs X_4 and X_5 measure attitudes and beliefs about the learning and teaching of mathematics and science.

Construct X_1 - *Beliefs about the nature of mathematics and science* ($\propto = .76$)

Students entering the PET course demonstrated slightly positive beliefs about the nature of mathematics and science ($M = 3.39, SD = .49$), see Table 3, indicating they tend to believe that science can be understood by everyone and topics in different science courses are connected. Pre-survey attitudes and beliefs of students in University Physics ($M = 3.69, SD = .59$) indicated a slightly higher belief than PET students about the nature of mathematics and science.

Construct X_2 - *Attitudes towards mathematics and science* *($\propto = .81$)*

Pre-survey participants in PET indicated a neutral attitude toward mathematics and science in general ($M = 3.07, SD = .78$), neither liking or disliking mathematics and science and have no noticeable attitude toward taking more math and science courses, see Table 3. In comparison, students entering University Physics displayed a very high attitude (*M = 4.37, SD = .52*) toward the importance of mathematics and science displaying the importance of taking more math and science courses.

Table 3

PET and University Physics Pre-Survey Construct Means and Standard Deviations, M (*SD*)

		PET (N=235)	University Physics (N=)1509
X1 - *Beliefs about the nature of mathematics and science* M (SD)	Overall	3.42 (0.56)	
	Pre-survey	3.39 (0.49)	3.69 (0.48)
	Post-survey	3.46 (0.62)	3.56 (0.59)
X2 - *Attitudes towards mathematics and science* M (SD)	Overall	3.11 (0.83)	
	Pre-survey	3.07 (0.78)	4.37 (0.52)
	Post-survey	3.16 (0.87)	4.18 (0.62)
X3 - *Beliefs about the teaching of mathematics and science* M (SD)	Overall	3.47 (0.31)	
	Pre-survey	3.44 (0.29)	3.29 (0.33)
	Post-survey	3.49 (0.33)	3.34 (0.36)
X4 - *Attitudes towards learning to teach mathematics and science* M (SD)	Overall	4.30 (0.78)	
	Pre-survey	4.39 (0.71)	3.23 (0.52)*
	Post-survey	4.22 (0.84)	3.28 (0.49)**
X5 - *Attitudes towards teaching mathematics and science* M (SD)	Overall	3.14 (0.87)	
	Pre-survey	3.02 (0.85)	3.14 (0.51)*
	Post-survey	3.26 (0.88)	3.23 (0.46)**

* (n=244) pre-survey participants who answered questions 35-44
**(n= 222) post-survey participants who answered questions 35-44

Construct X_3 - *Beliefs about the teaching of mathematics and science* (∝ = .69)

PET participants on the pre-survey had a slightly positive belief about the importance of teaching math and science (*M = 3.44, SD = .29*) through the use of technology and group activities while University Physics pre-survey students displayed a slight lower belief (*M = 3.29, SD = .33*) toward the importance of teaching math and science, see Table 3.

Construct X_4, - *Attitudes towards learning to teach mathematics and science* (∝ = .80)

PET students indicated a high positive attitude toward learning to teach mathematics and science (*M = 4.39, SD = .71*) on the pre-survey and expressed a desire to learn how to use technology in the classroom as a teaching tool. Out of 1,509 matched survey participants in University Physics, 238 self-declared as interested in teaching as a career on the pre-survey and answered questions 35-44. These students had a mostly neutral attitude (*M = 3.23, SD = .52*) toward viewing college level mathematics and science course as helpful to them in teaching mathematics and science or in learning to use technology in the classroom as a teaching tool, see Table 3.

Construct X_5 - *Attitudes towards teaching mathematics and science* ($\propto = .60$)

PET students on the pre-survey displayed a very neutral (*M = 3.02, SD = .85*) attitude toward confidence in their own ability to teach mathematics and science and in preparedness to integrate the two disciplines when teaching. Pre-Survey University Physics students showed only a slightly higher positive attitude (*M = 31.4, SD = .51*) toward their confidence and ability to teach mathematics and science as integrated disciplines, see Table 3.

In summary, pre-survey PET participants displayed a slightly positive attitude and belief for constructs X_1, X_2, X_3, and X_5, while having a positive attitude and belief for construct X_4. Students entering PET tend to demonstrate that learning about and teaching about mathematics and science is important to them while also demonstrating a positive attitudes and beliefs toward their ability to teach and integrate the two subjects. See Appendix K for a graphical display of pre-survey attitudes and beliefs for PET.

Overall University Physics participants displayed slightly positive attitudes and beliefs towards constructs X_3, X_4, and X_5 demonstrating an importance in learning to teach Mathematics and Science as well as a slightly positive belief in the ability to teach and combine both subjects. University Physics students had a high attitude and belief (M = 4.37) toward construct X_2, describing themselves as liking mathematics and science and looking forward to taking more math and science courses. The students also displayed a medium high attitude and belief toward construct X_1, believing that mathematics and science can be understood by people most students and that the discipline consists of discrete sets of related topics and skills. See Appendix K for a graphical display of pre-survey attitudes and beliefs for University Physics.

Research Question 3: To what extent are there significant differences in the change (pre- and post-test) between entering and exiting students who completed one- or two-semester sequence of reformed science teaching?

A dependent t-test analysis was selected as the best method for evaluation of shift in the pre- and post-survey means to identify significant changes in attitude and beliefs in learning and teaching mathematics and science for each of the five constructs. In order to account for repeated measures a Bonferroni correction was made to the significance level, from $P \leq .05\ to\ P \leq .01$, to maintain a 5% chance of an overall-experiment Type I error, rejecting the null hypothesis. Cohen's effect size for each case was examined to determine the significance of the shift, where d = .02 is a small effect, d = 0.5 is a medium effect, and d = 0.8 is a large effect. Table 4 presents the change in means for each construct for both PET and University Physics, SD for pre-survey in order to computer Cohen's d effect size, t-score for critical two-tail test, and significance value, P (Cohen, 1977).

Construct X_1 - *Beliefs about the nature of mathematics and science ($\propto = .76$)*

There was no significant change for all PET students from the pre-survey (*M = 3.39, SD =.49*) to the post-survey (*M = 3.46*) for construct X_1, $t(233) = 1.97$, $P = .058$, see Table 4. There was a significant decrease in the attitudes and beliefs of all University Physics students for construct X_1 from the start of the sequence (*M = 3.69, SD = .48*) to end of the sequence of course (*M = 3.56, SD = ?*), $t(1508) = 2.58$, $P < .001$ with a small effect size of $d = .27$.

Table 4

PET and University Physics Change in Means

Construct	Statistic	PET (N = 234) df = 233	University Physics (N=1509) df = 1508	
X_1 – ***Beliefs about the nature of mathematics and science***	Pre-Mean	3.39	3.69	
	Post-Mean	3.46	3.56	
	SD-pre	0.49	0.48	
	Effect Size, d	0.14	0.27*	
	T Critical two-tail	1.97	2.58	
	$P(T \leq t)$ two-tail	.058	P<.001**	
X_2 - ***Attitudes towards mathematics and science***	Pre-Mean	3.07	4.18	
	Post-Mean	3.16	4.36	
	SD-pre	0.78	0.62	
	Effect Size, d	0.12	0.29*	
	T Critical two-tail	2.60	2.58	
	$P(T \leq t)$ two-tail	.020	P<.001**	
X_3 – ***Beliefs about the teaching of mathematics and science***	Pre-Mean	3.44	3.29	
	Post-Mean	3.49	3.34	
	SD-pre	0.29	0.33	
	Effect Size, d	0.17	0.15	
	T Critical two-tail	2.60	2.58	
	$P(T \leq t)$ two-tail	.028	P<.001**	
X_4 – ***Attitudes towards learning to teach mathematics and science***			(N=1509)	(N=375)***
	Pre-Mean	4.39	0.51	2.05
	Post-Mean	4.22	0.48	1.95
	SD-pre	0.71	1.20	1.61
	Effect Size, d	0.24*	0.03	0.06
	T Critical two-tail	2.60	2.58	2.59
	$P(T \leq t)$ two-tail	P<.001**	.468	.496
X_5 - ***Attitudes towards teaching mathematics and science***			(N=1509)	(N=375)***
	Pre-Mean	3.02	0.49	1.99
	Post-Mean	3.26	0.48	1.89
	SD-pre	0.85	1.16	1.57
	Effect Size, d	0.28*	0.01	0.06
	T Critical two-tail	2.60	2.58	2.59
	$P(T \leq t)$ two-tail	P<.001**	.606	.507

*Cohen's d Effect Size is based on standard deviation of the pre-survey results for matched participants, d=0.2 is a small effect, d=0.4 is a medium effect, and d=0.8 is a large effect.
** $P \leq .01$,
***Matched group of participants in University Physics who answered Constructs X_4 and X_5.

Construct X_2 - *Attitudes towards mathematics and science* *(∝ = .81)*

There was no significant change for all PET students from the pre-survey (*M = 3.07, SD =.78*) to the post-survey (*M = 3.16*) for construct X_2, $t(233) = 2.60$, $P = .020$. There was a significant increase in the attitudes and beliefs of all University Physics students for construct X_2

from the start of the sequence (*M = 4.18, SD = .62*) to end of the sequence of courses (*M = 4.36*), $t(1508) = 2.58$, $P < .001$ with a small effect size of $d = .29$.

Construct X_3 - *Beliefs about the teaching of mathematics and science* (∝ = .69)

There was no significant change for all PET students from the pre-survey (*M = 3.44, SD =.29*) to the post-survey (*M = 3.49*) for construct X_3, $t(233) = 2.60$, $P = .028$. There was a significant increase in the attitudes and beliefs of all University Physics students for construct X_3 from the start of the sequence (*M = 3.29, SD = .33*) to end of the sequence of courses (*M = 3.34*), $t(1508) = 2.58$, $P < .001$ with an effect size of $d = .15$.

Construct X_4, - *Attitudes towards learning to teach mathematics and science* *(∝ = .80)*

There was a significant decrease for all PET students from the pre-survey (*M = 4.39, SD = .71*) to the post-survey (*M = 4.22*) for construct X_4, $t(233) = 2.60$, $P < .001$ with an effect size of $d = .24$. There was no significant change in the attitudes and beliefs of all University Physics students for construct X_4 from the start of the sequence (*M = .51, SD = 1.20*) to end of the sequence of courses (*M = .48*), $t(1508) = 2.58$, $P = .468$. There was also no significant change for only pre/post matched University Physics participants who answered questions pertaining to construct X_4, $t(1508) = 2.59$, $P = .496$.

Construct X_5 - *Attitudes towards teaching mathematics and science* (∝ = .60)

There was a significant increase for all PET students from the pre-survey (*M = 3.02, SD = .85*) to the post-survey (*M = 3.26*) for construct X_5, $t(233) = 2.60$, $P < .001$ with a small effect size of $d = .28$. PET students in spring 2011 had a significant increase in attitudes and beliefs for construct X_5, $t(37) = 2.70$, $P = .001$. There was no significant change in the attitudes and beliefs of all University Physics students for construct X_5 from the start of the sequence (*M = .49, SD = 1.16*) to end of the sequence of courses (*M = .48*), $t(1508) = 2.58$, $P = .606$. There was also no significant change for only pre/post matched University Physics participants who answered questions pertaining to construct X_4, $t(1508) = 2.59$, P = .507.

In summary, PET student entered into the course with a slightly positive attitude and belief toward all five constructs, means greater than three, with the highest pre-survey attitude and belief for construct X_4, *Attitudes towards learning to teach mathematics and science*, with a mean of 4.39.

After completing the semester course, PET participants in the study had non-significant positive gains in means for constructs X_1 ($\Delta M = +.07$), X_2 ($\Delta M = +.08$), X_3 ($\Delta M = +.05$), and X_5 ($\Delta M = +.24$). The post-survey means for construct X_5 had a significant decrease in mean from 4.39 to 4.22 at P < .001. See Appendix L for a graphical chart of the changes in means for PET participants.

University Physics student entered into the course with a slightly positive attitude and belief toward the first three constructs, X_1, X_2, and X_3, with X_2 having a high positive attitude and belief mean of 4.18. Participants had negative pre-survey attitudes and beliefs toward constructs X_4 and X_5 with means $M = 1.05$ and $M = 1.99$ respectively.

After completing the two-semester sequence for University Physics, participants in the study had significant \positive gains in means for constructs X_2 ($\Delta M = +.18$) and X_3 ($\Delta M = +.05$) at P < .001. Post-survey results for constructs X_4 ($\Delta M = -.10$), and X_5 ($\Delta M = -.10$) had non-significant decreases in means along with a significant drop in mean for X_1, -.13 at $P < .001$. See Appendix M for a graphical chart of the changes in means for University Physics participants.

Research Question 4: To what extent are there significant differences between science majors and pre-service education majors for pre- and post-class data?

PET is a physical science course designed for pre-service education students who intend to become an elementary education teacher. Over 90% of the study participants indicated their major to be education with an emphasis in a subject other than mathematics or science with 85% indicating an intent to work in grades K-3rd. University Physics is a two-semester sequence of calculus-based physics that is designed for science majors in the fields of physics and engineering with 86% of the pre-survey study participants indicating a degree program other than education.

Both PET and University Physics participants had slight positive means of $M = 3.39$ and $M = 3.69$ respectively for construct X_1 *- Beliefs about the nature of mathematics and science.* After completing the semester, PET students had a slight positive gain in mean up to $M = 3.46$ while UP students, after completing the course sequence, had a significant decrease in means down to $M = 3.56$ at $P < .001$.

University Physics students had high pre-survey mean on construct X_2 **-** *Attitudes towards mathematics and science* of $M = 4.18$ while PET students had an almost neutral mean of $M = 3.07$. At the completion of the semester, PET students had a slight gain in mean up to $M = 3.16$. University Physics students had a significant gain in mean up to $M = 4.36$ at $P < .001$.

PET and University Physics participants had slight positive means of 3.44 and 3.29 for X_3 – *Beliefs about the teaching of mathematics and science*. PET students' attitudes and beliefs for construct X_3 remained about the same with only a slight gain up to 3.49. University Physics students had a significant positive gain in mean up to $M = 3.34$ at $P < .001$.

PET Students had a high positive mean for construct X_4 – *Attitudes towards learning to teach mathematics and science* at the start of the course with a mean of $M = 4.39$. As a pre-survey group, University Physics students had a low mean of $M = 0.51$ indicating a very low attitude toward learning to teach. Removing University Physics participants who did not indicate a career choice to teach, reduced the sample from 1509 to 375 participants with a mean of $M = 2.05$, a negative attitude toward learning to teach.

PET students had a significant decrease in means from $M = 4.39$ to $M = 4.22$, P < .001, while University Physics students had only a slight drop in mean to $M = 1.95$ with no significance.

PET Students had a positive mean for construct X_5 **-** *Attitudes towards teaching mathematics and science* at the start of the course with a mean of 3.02. University Physics students had a low mean of 0.49 indicating a very low attitude toward teaching mathematics and science. University Physics participants, who indicated a career choice to teach, had a mean of 1.99, a negative attitude toward teaching.

PET students had a significant increase in means from $M = 3.02$ to $M = 3.26$, P < .001, while University Physics students had only a slight drop in mean to 1.89 with no significance.

In summary PET students had no significant changes in means for constructs X_1, X_2, and X_3. However, PET students showed a significant negative change in means for construct X_4, $M = 4.39$ to $M = 4.22$, P < .001 with a small affect size of .24. They also showed a significant positive shift in construct X5, with means shifting from $M = 3.02$ to $M = 3.26$, P < .001 with a small affect size of .28.

University Physics students displayed negative change in means for construct X_1 (M = 3.69 down to $M = 3.56$, P > .001), and significant positive changes in means for constructs X_2 ($M = 4.18$ up to $M = 4,36$, P < .001) and X_3 ($M = 3.29$ up to $M = 3.34$, P > .001). University Physics students showed no significant changes to constructs X_4 and X_5.

Research Question 5: To what extent are there significant differences in pre- and post-class data based on student academic performance?

PET participants completed the course with an average grade $M = 3.46$ with $SD = .78$ on the standard 4-point scale, see Table 5. PET students entering the course, no matter their final success in the course, had a neutral pre-survey attitude toward construct X_2 ($M = 2.94$ to $M = 3.14$), had a slightly positive attitude toward construct X_3 ($M= 3.44$ to $M = 3.46$), and had a high positive attitude toward construct X_4 ($M = 4.00$ to 4.47).

Table 5
*PET Participants Change in Means by Grade, N = 233**

Grade (df)		**A (137)**	**B (72)**	**C, D, & F (24)****
X_1 – ***Beliefs about the nature of mathematics and science***	Pre-Mean	3.53	3.25	2.93
	Post-Mean	3.60	3.32	2.99
	T Critical two-tail	2.61	2.65	2.81
	P(T ≤ t) two-tail	.133	.292	.630
X_2 - ***Attitudes towards mathematics and science***	Pre-Mean	3.14	2.93	3.01
	Post-Mean	3.31	2.97	2.79
	T Critical two-tail	2.61	2.65	2.83
	P(T ≤ t) two-tail	P<.001	.562	.095
X_3 – ***Beliefs about the teaching of mathematics and science***	Pre-Mean	3.44	3.44	3.46
	Post-Mean	3.53	3.48	3.34
	T Critical two-tail	2.61	2.65	2.83
	P(T ≤ t) two-tail	.006	.381	.143
X_4 – ***Attitudes towards learning to teach mathematics and science***	Pre-Mean	4.47	4.34	4.00
	Post-Mean	4.28	4.17	3.91
	T Critical two-tail	2.61	2.65	2.83
	P(T ≤ t) two-tail	.010	.029	.509
X_5 - ***Attitudes towards teaching mathematics and science***	Pre-Mean	3.20	2.94	2.23
	Post-Mean	3.41	3.21	2.52
	T Critical two-tail	2.61	2.65	2.83
	P(T ≤ t) two-tail	.001	.002	.147

*n = 233, one student was a course observer and did not earn a grade
**Category represents 10.3% of sample
***Significance determined at $P \leq .01$

PET students, who were successful in completing the course with an A, had a slightly positive pre-survey attitude toward construct X_1, beliefs about nature of mathematics and science, ($M = 3.53$) in comparison to those who earned a B ($M = 3.25$) and those who earned a C, D, or F

($M = 2.93$). Students who earned an A ($M = 3.20$) or B ($M = 2.94$) also had much higher positive pre-survey attitude toward teaching mathematics and science, construct X_5, than those who earned a C, D, or F ($M = 2.23$).

Participants in the PET course who earned a grade of A (138, 58.7%) showed significant change in means in constructs X_2, X_3, and X_5, see Table 5. PET Participants had a significant increase from the pre-survey, $M = 3.14$, to the post-survey, $M = 3.31$, for construct X_2, $t(137) = 2.61$, $P < .001$, indicating that they have a medium positive attitude toward mathematics and science in general. Participants displayed a positive shift in beliefs about the importance of teaching mathematics and science with a significant increase in means for construct X_3 from $M = 3.14$ to $M = 3.53$, t(137), $P = .006$. Participants also had a significant positive increase in means for construct X_5, $M = 3.20$ to $M = 3.41$, t(137), $P = .001$, indicating a positive shift in attitudes toward teaching mathematics and science.

Participants with a course grade of B (73, 31.3%) had a significant positive shift in means on construct X_5 with an positive attitude toward teaching mathematics and science, $M = 2.94$ to $M = 3.21$, t(72) = 2.65, $P = .002$. Participants with course grades C, D, or F (21, 9.0%) showed no significant shift in means for all five constructs.

Research Questions 6: To what extent do students' attitudes and beliefs about learning and teaching mathematics and science change after completing a one or two-semester sequence of reformed science teaching?

The PET course was developed by Dr. Robert Karplus at the University of California in Berkeley to improve the elementary school science education. The PET course addresses the needs of elementary teachers by emulating the instructional methods expected of them in the classroom. According to Goldberg, Robinson, and Otero (2006) the development of the PET curriculum was guided by current research on how students learn most effectively. The course uses a learner-oriented, guided inquiry-based pedagogy that helps pre-service teachers develop a deep understanding of physical science ideas (Robinson, Goldberg, Otero, 2005).

For each learning goal, the course provides a sequence of activities designed to build on students' prior knowledge. The activities provide opportunities for students to test their initial ideas and to guide them towards the development of ideas that are closely aligned with the ideas of scientists (Robinson, Goldberg, Otero, 2005). A unique aspect of the course is that it also contains embedded components that allow students to examine important aspects of the effective learning of science in three contexts; that of their own learning, the learning of elementary students, and the processes by which scientists develop knowledge (Robinson, Goldberg, Otero, 2005). The PET course is a four-hour credit that meets three times a week for 110 minutes each time.

The University Physics sequence is a two-semester sequence of calculus-based physics that surveys the principles of physics including mechanics, wave motion, temperature, heat, electricity, magnetism, and light. These courses are designed for science majors in the fields of physics and engineering. Each course in the sequence is a four-hour credit course with lecture meeting two times a week for one hour with a required lab that meets twice a week for two hours. Lecture components include reading assignments with a pre-lecture quiz, lecture notes, and in-lecture clicker questions with small group discussion. A significant portion of the learning in the course is designed to take place in the lab through laboratory exploration, small group assignments, and exam preparation activities.

The claim that both PET and University Physics courses' instructional methods are reformed can be supported by observation through the use of the Reformed Teaching

Observation Protocol (RTOP) for determining the validity of reformed instructional methods. The RTOP was developed by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) at Arizona State University (Sawada, et al., 2002). The RTOP is a 25-item classroom observation protocol that is standards based, inquiry oriented, and student centered (Sawada, et al., 2002). The RTOP is broken into three observation sections, Lesson Design and Implementation, Content, and Classroom Culture. A score of greater than 50 on the RTOP is considered to be proof of evidence of reformed instructional methods and implementation in one, two or all three observation sections on the protocol. The protocol looks for evidence, through observation, of types of student and instructor actions then uses a 5-point Likert scale to rank the level of observation, 0 – Never Occurred to 4 – Very Descriptive.

The PET course was observed two times using the RTOP protocol, in spring of 2017, score of 72, and in spring of 2019, score of 75. In both cases the instructor and the syllabus were the same. The scores on the RTOP ins a strong indicator the PET course is a reformed science course. The high scores were associated with how the students interacted with each other, the course materials and goals, and with the instructor. This supports the courses intention of PET students spending most of their time working in small groups, performing experiments, manipulating computer simulations, making sense of their observations, and sharing ideas in whole class discussions (Goldberg, Robinson, Otero, 2005). The instructor's role was as a guide to class discussions, a help to support the development of ideas based on evidence by students, and to promote participation by all students (Goldberg, Robinson, Otero, 2005F).

The University Physics I (UPI) courses was observed in fall of 2016 and University Physics II (UPII) in spring of 2017. Both courses were taught by different instructors and the labs were taught by graduate assistants with 1-4 semesters of teaching experience. Observations were made with permission by the instructor of the course and a lab section for each course was chosen at random. In fall 2016, the lecture component of UPI scored 45 and the lab component scored 72 for a mean of 58.5. In spring of 2017, the lecture component of UPII scored 47 and the lab component scored 76 for a mean of 61.5. In both cases, the lab portion of the courses scored much higher than the lecture portion of the course. Accounting for the time spent in the lab versus lecture and using a weighted average, UPI scored 63.1 and UPI scored 66.4. Both courses scored above 50 indicating that they are reformed in science education practices.

In summary, Both PET and University Physics students participated in courses with reformed science teaching practices. PET students had no significant changes in means for constructs X_1, X_2, and X_3. However, PET students showed a significant negative change in means for construct X_4, $M = 4.39$ to $M = 4.22$, $P < .001$ with a small affect size of .24. They also showed a significant positive shift in construct X5, with means shifting from $M = 3.02$ to $M = 3.26$, $P < .001$ with a small affect size of .28.

University Physics students displayed negative change in means for construct X_1 (M = 3.69 down to $M = 3.56$, $P > .001$) with a small effect size of .27, and significant positive changes in means for constructs X_2 ($M = 4.18$ up to $M = 4,36$, $P < .001$) with small effect size .29, and X_3 ($M = 3.29$ up to $M = 3.34$, $P > .001$). University Physics students showed no significant changes to constructs X_4 and X_5.

In comparison, PET students had significant changes in their attitudes and beliefs toward learning to teach and teaching mathematics and science while University Physics students had significant changes in the beliefs about the nature of science, attitudes toward mathematics and science, and beliefs about the teaching of mathematics and science.

Chapter V. Conclusions, Recommendations, and Discussion

This chapter includes the summary of the study, focusing on the answers to the six research questions, conclusions drawn from the findings, recommendations for future research and a discussion on the impact of reformed education on students' attitudes and beliefs about learning and teaching mathematics and science including implications of the limitations on the outcomes.

A. Summary of the Study

The summary of the study discusses the results of the research questions this study sought to answer. The results were arrived at through data analysis of the results of a pre- and post-survey. The significance of these results is discussed in this chapter.

Research Question 1: What was the demographic profile of students who completed a one- or two-semester sequence of reformed science teaching during 2003-2013?

In summary, 55.8% (234) of PET students and 45.9% (1,509) of University Physics students participated in the study from fall 2003 to spring 2013. The PET sample was comprised of 97.0% (227) female students and 3.0% (7) male students compared to the University Physics sample comprised of 70.9% (1070) males and 29.1% (239) females. 85.5% (200) of the PET students self-selected as sophomores or juniors while 64.7% (976) of the University Physics students self-selected as freshman at the time of pre-survey. All but 11 (4.7%) of PET students indicated a major in education with and emphasis in either mathematics or science while 14.0% (211) of University Physics students declared a major in education at the time of pre-survey but dropped to 11.2% (169) at the time of the post-survey.

Research Question 2: What were the entering and existing attitudes of students who completed one- or two-semester sequence of reformed science teaching during 2003-2013?

Overall pre-survey PET participants displayed a slightly positive attitude and belief for constructs X_1, X_2, X_3, and X_4, while having a slightly negative attitude and belief for construct X_5. Students entering PET tend to demonstrate that learning about and teaching about mathematics and science is important to them while also demonstrating a slight negative attitude and belief toward their ability to teach and integrate the two subjects.

Overall University Physics participants displayed slightly positive attitudes and beliefs towards constructs X_3, X_4, and X_5 demonstrating an importance in learning to teach Mathematics and Science as well as a slightly positive belief in the ability to teach and combine both subjects. University Physics students had a high attitude and belief ($M = 4.37$) toward construct X_2, describing themselves as liking mathematics and science and looking forward to taking more math and science courses. The students also displayed a medium high attitude and belief toward construct X_1 ($M = 3.69$), believing that mathematics and science can be understood by most people and that the disciplines consist of discret sets of related topics and skills.

Research Question 3: To what extent are there significant differences in the change (pre- and post-test) between entering and exiting students who completed one- or two-semester sequence of reformed science teaching?

After completing the semester course, PET participants, pre-service education majors, in the study had non-significant positive gains in means for constructs X_1 ($\Delta M = +.07$), X_2 ($\Delta M = +.08$), and X_3 ($\Delta M = +.05$). The means for construct X_4 had a significant decrease from pre-survey of 4.39 to post-survey of 4.22 at $P < .001$ with a small affect size of .24. The means for construct X_5 had a significant increase from pre-survey of 3.02 to post-survey of 3.26 at $P < .001$ with a small affect size of .28.

Overall, pre-service education majors had slightly higher than neutral attitudes toward construct X_1, *Beliefs about the nature of mathematics and science*, and construct X_3, *Beliefs about the teaching of mathematics and science.* While having a high positive attitude toward X_4, *Attitudes towards learning to teach mathematics and science*, $M = 4.39$.

University Physics students, science majors, entered into the course with a slightly positive attitude and belief toward the first three constructs, X_1, X_2, and X_3, with X_2 having a high positive attitude and belief mean of 4.18. Participants had negative pre-survey attitudes and beliefs toward constructs X_4 and X_5 with means $M = 1.05$ and $M = 1.99$ respectively.

After completing the two-semester sequence for University Physics, participants in the study had significant positive gains in means for constructs X_2 ($\Delta M = +.18$) and X_3 ($\Delta M = +.05$) at $P < .001$. Post-survey results for constructs X_4 (ΔM = -.10), and X_5 (ΔM = -.10) had non-significant decreases in means along with a significant drop in mean for X_1, from pre-survey mean of 3.69 to post-survey 3.56 at $P < .001$ with a small affect size of .27.

Overall, science majors, had slightly higher than neutral attitudes toward construct X_1, *Beliefs about the nature of mathematics and science*, and construct X_3, *Beliefs about the teaching of mathematics and science.* While keeping a high positive attitude toward X_4, *Attitudes towards learning to teach mathematics and science,* despite a small drop in means.

Research Question 4: To what extent are there significant differences between science majors and pre-service education majors for pre- and post-class data?

Overall, pre-service education majors had slightly higher than neutral attitudes and beliefs toward constructs X_1, *Beliefs about the nature of mathematics and science*, X_3, *Beliefs about the teaching of mathematics and science* and X_5 - *Attitudes towards teaching mathematics and science*. PET students had a high positive attitude toward X_4 – *Attitudes towards learning to* *teach mathematics and science*, while, having neutral attitudes and beliefs toward X_2 - *Attitudes towards mathematics and science.*

In comparison, science majors had high attitudes and beliefs toward constructs X_1, *Beliefs about the nature of mathematics and science,* and X_2 - *Attitudes towards mathematics and science*, and slightly higher than neutral attitudes and belief toward construct X_3, *Beliefs about the teaching of mathematics and science*. In comparison to pre-service education majors, science majors had low attitudes and beliefs toward constructs X_4 – *Attitudes towards learning to teach mathematics and science,* and X_5 - *Attitudes towards teaching mathematics and science*.

PET students had no significant changes in means for constructs X_1, X_2, and X_3. However, PET students showed a significant negative change in means for construct X_4, from pre-survey of $M = 4.39$ to post-survey of $M = 4.22$ at $P < .001$ with a small affect size of .24. They also showed a significant positive shift in construct X_5, with means shifting from pre-survey of $M = 3.02$ to post-survey of $M = 3.26$ at P < .001 with a small affect size of .28.

University Physics students displayed negative change in means for construct X_1 (M = 3.69 down to $M = 3.56$, P > .001), and significant positive changes in means for constructs X_2 ($M = 4.18$ up to $M = 4,36$, P < .001) and X_3 ($M = 3.29$ up to $M = 3.34$, P > .001). University Physics students showed no significant changes to constructs X_4 and X_5.

Research Question 5: To what extent are there significant differences in pre- and post-class data based on student academic performance?

Overall PET participants completed the course with an average grade of $M = 3.46$ with $SD = .78$ on the standard 4-point scale. Participants in the PET course who earned a grade of A showed significant change in means in constructs X_2, X_3, and X_5, see Table 4. Participants with a course grade of B, had significant positive shift on construct X_5 with a positive attitude toward teaching mathematics and science, while, participants with course grades C, D, or F showed no significant shift in means for all five constructs.

University Physics participants completed a sequence of two courses with an overall average grade of M = 3.28 and SD = .86 on the standard 4-point scale.

Research Questions 6: To what extent do students' attitudes and beliefs about learning and teaching mathematics and science change after completing a one or two-semester sequence of reformed science teaching?

Both PET and University Physics courses were all determined to be reformed science courses based on scores from using the Reformed Teaching Observation Protocol (RTOP). PET students had significant changes in their attitudes and beliefs toward learning to teach and teaching mathematics and science while University Physics students had significant changes in the beliefs about the nature of science, attitudes toward mathematics and science, and beliefs about the teaching of mathematics and science.

B. Conclusions

1. Pre-service education majors tend to demonstrate pre-survey positive attitudes toward the nature of and beliefs about the teaching of mathematics and science, see Appendix K. They have a neutral attitude toward mathematics and science in general along with attitudes toward teaching mathematics and science. However, they exhibit high positive attitudes toward learning to teach mathematics and science.
2. Pre-survey science majors displayed slightly positive beliefs about the nature of mathematics and science and in their beliefs about teaching mathematics and science such as using active learning strategies in the classroom, see Appendix K. They also exhibit high positive attitudes towards mathematics and science indicating that they

enjoy math and science courses and look forward to taking more courses. As a group they have very low attitudes toward learning to teach and teaching about science and mathematics as important and a possible career choice. The smaller sample of science majors who indicated they consider teaching as career, had slightly higher attitudes toward learning to teach and teaching about science and mathematics but is still negative.

3. Post-survey pre-service education majors had non-significant changes in means in the positive directions in beliefs toward nature of mathematics and science and in their beliefs toward using active learning strategies in teaching, see Appendix L. They also had a non-significant positive shift in attitudes toward the importance of taking more math and science courses. They had a significant positive shift in means for Attitudes toward teaching indicating they are more confident in their ability to teach both mathematics and science in elementary classrooms. The most significant change is a slight negative decline in their attitudes toward learning to teach mathematics and science indicating they believe that future college courses in mathematics and science may not be useful to them in their career, see Appendix N.
4. Science majors had medium positive attitude shifts in means for attitudes toward mathematics and science wanting to take more college courses and in their beliefs about teaching mathematics and science such as using lab equipment and or manipulatives in combination with active learning strategies, see Appendix M. Overall, science majors had low negative attitudes toward learning to and teaching about mathematics and science with non-significant negative shifts in means for both. The most significant change in means was a slight negative shift in beliefs about the

nature of mathematics and science with a post-survey mean still in the positive range, see Appendix N.

5. Participants in the PET course (pre-service science majors) who earned a grade of A showed significant change in means displaying higher post-survey attitudes and beliefs about liking mathematics and science, enjoying learning how to use technology in the classroom and looking forward to taking more math and science courses. PET participants with a course grade of B, had significant positive shift on construct X_5 believing that technology and manipulative should be used as aids in teaching mathematics and science, believing in the regular use of small group activities to emphasize learning, and giving students time to reflect on what they have learned in the classroom. Participants with course grades C, D, or F showed no significant shift in means for all five constructs. For University Physics (science majors), matched grades were not obtainable for all participants due to constraints on data collection.
6. Both the PET and University Physics courses are considered to be reformed science courses as supported by the results of an RTOP survey, each scoring over 50 points with scores of 73.5 for PET, 63.1 for UP first semester, and 66.4 for UP second semester. The PET course scored higher based on all the educational experience taking place in one setting and the goals of the course are followed so that students do the majority of the talking which is favored on the RTOP survey.

C. Recommendations

Recommendations for Future Research

1. Future research using data sets such as these can determine if gender plays a role in the attitudes and beliefs of students about the nature of and teaching of mathematics and science.
2. Future research using data sets such as these can compare the results of non-science pre-service teachers with those of pre-service teachers with science majors.
3. Future research could survey students to determine their understanding of reformed science education and their personal experience with it.
4. Future research using data sets such as these could look at students' attitudes and beliefs about nature of and teaching of mathematics and science at several points across their education.

Recommendations for Practices

1. The physics department should consider adopting a course for pre-service science education majors, similar to PET for pre-service elementary education majors, with an emphasis on instructing how to implement the modeling practices in middle and high school science classrooms.
2. Science courses should consider surveying students about attitudes and beliefs as a regular part of the course evaluation and assessment to determine student satisfaction toward the courses' impact.
3. Science and education instructors should be taught how to use an observation protocol like RTOP or COUPUS in order to evaluate peer instruction for reformed practices in lecture and lab settings and to reflect on their own practices.

4. Education program aimed at improving and teaching pedagogical practices could use similar surveys to determine shift in students' attitudes and beliefs about learning and teaching to improve programs and determine impact of specific courses.

D. Discussion

Both courses selected for this study were selected based on the types of students enrolled and their connection to mathematics and science. The PET course is designed specifically for pre-service elementary education majors who have competed college algebra while the University Physics sequences of courses is designed for physics and engineering majors with a minimum of completion of one semester of calculus. Student in University Physics are mostly freshmen with 70.9% males and 29.1% females with 83% self-selecting as Caucasian. However, the students in PET are mostly sophomores with 97.0% female and 3.0% males with over 94.4% self-selecting as Caucasian. The percentage of females and females in PET compared to University Physics is significantly different and may be a contributing factor in the differences between attitudes and beliefs for the two courses. The results of the University Physics courses may translate well to similar physics courses with an emphasis in laboratory experimentation. However, the results of the participants in the PET course are not as translatable to similar courses due to the very nondiverse demographics of the students being mostly female and Caucasian.

The rate of participation in the two-course differed from 55.8% in PET to 45.9% in University Physics. One factor for this difference is how the survey was implemented and when the students took the pre- and post-survey. PET students voluntarily took the pre- and post-survey in the same semester while University Physics students were instructed to take the pre- and post-survey as part of the lab experience in two different semesters leading to some limitations in the collection of matched data. Some students did not complete the University Physics courses in sequential semesters or may have taken one of the courses in a summer session when the survey was not given. As well, some University Physics students did not complete the second semester of the course or may not have been present in lab on the day the survey was given. The findings of the study only apply to those students who completed both the pre- and post-survey and therefor are not transferable to similar courses for all students.

Another limitation to consider, when discussing the findings of this study, is the consistency in which the courses are taught over the duration of data collection. The PET class offered students the opportunity to participate in the survey from 2005 to 2013. During this time the course was taught by the same instructor and followed a very uniform course structure with the inclusion of lecture and lab in the same learning environment. The results of the survey in the PET course is consistent over the length of the data collection, see Appendix F. The structure for the PET course makes the transferability of the data to another course difficult because of the uniqueness of the course's structure.

University Physics offered the survey from 2003 to 2013 and during this time had five different faculty instructors as well as ten or more graduate students instructing up to 24 lab sections per semester, see Appendix I. The department used a course supervisor to maintain the integrity of the course's structure and required assignments as well as number of lab activities. Appendix I displays some differences between semesters that could be contributed to the differences in the course instructor and to differences between graduate students teaching lab sections. These varied differences and their influence on the attitudes and beliefs of the students makes the transferability of the results of this study to other large physics difficult.

Overall PET students entered the course with just slightly higher than neutral attitude and beliefs that mathematics and science can be understood by all, that learning mathematics and science is important, and that teaching mathematics and science is important. However, PET students had a neutral attitude and belief toward the idea that college math and science courses are helpful in learning to teach mathematics and science as well as a neutral confidence in their ability to teach the two subjects.

PET students left the course with only small positive gains in attitude and beliefs that mathematics and science can be understood by all, that learning mathematics and science is important, and that teaching mathematics and science is important. PET students had a significant negative shift in attitudes and belief toward the idea that taking more college courses in mathematics and science is important to learning to teach the two subjects. The shift down may be contributed to the difficulty of the course concepts overall and the amount of work required for the PET course. However, PET students had a significant positive shift in attitude and beliefs toward feeling confident in their ability to teach mathematics and science in an elementary classroom. The shift may be contributed to the instructor for demystifying how to teach science to elementary students through students' own role in the experiential learning process.

In comparison to PET students, the University Physics students had an almost opposite outcome. University Physics students has a significant negative shift in attitudes and beliefs that mathematics and science can be understood by all. This may be contributed to the high difficulty of the course and to the number of students who struggle with the calculus requirement and often switch out of the engineering program all together. University Physics students had significant positive shifts in attitudes and beliefs in both liking mathematics and science and expect to take more courses in the future as well as believing that active-learning strategies are important and should be included in math and science courses. This can be contributed to University Physics students as self-selected STEM majors who plan on employment in a STEM related field after graduation as well as students who learn well in student-engaged learning environments where teamwork is recognized as important.

Post-survey results for University Physics students showed no significant changes in the negative attitude and beliefs that college math and science courses are important to learning to teach and confidence in their ability to teach the two subjects. The slight shift down can be contributed to the very small number of students who indicated that they intended to pursue teaching as a career choice on the pre-survey and the even lower number on the post-survey leading to a very small sample. Another supporting cause is the low importance placed on discussing teaching as a career while a high emphasis is placed on practical application of course content.

Both the PET course and the University Physics sequence of courses are considered to be reformed science courses. The claim that both courses are reformed in their practices is supported by the results of the RTOP survey were both PET and the University Physics courses scored over 50 points, 73.5, 63.1 (first semester) and 66.4 (second semester) respectively; where greater than 50 points is considered reformed. The high scores are an indication of a heavy emphasis on experiential learning, as outlined in Kolb's cycle of experiential learning (see Figure 1), through the integrated laboratory experience in the PET course and the increases required hands-on lab meetings in the University Physics courses. Kolb's cycle of experiential learning encourages students to answer four questions, delving deeper into learning; (1) "What happened?", (2) "What did I experience?", (3) "Why did that happen?", and (4) "What do I do next?" (Kolb, 1984). Kolb's cycle of experiential learning is incorporated into an active-learning process used in the PET and University Physics laboratory practices called modeling.

The process of modeling is teaching within a well-defined pedagogical framework (Hestenes, 1987) to organize course content around scientific models as structured knowledge to engage students collaboratively in making models to describe, explain, predict, design and control physical phenomena (Jackson, Dukerich, & Hestenes, 2008).

Engaging students in the modeling process within Kolb's cycle is a vital part of the PET course and the lab portion of the University Physics courses. Both courses reserve a large number of course hours to the experiential process of leaning through engagement and therefore it has the largest impact on students' attitudes and beliefs about the nature of and teaching of mathematics and science. Of the active learning actions identified by Smith, et al. (2013) related to students; students listening, individual thinking and problem solving, group activity, answering questions posed by the instructor, asking questions, engagement in group discussion, making predictions, and presenting, are actions of students completing a lab assignments and participating in the PET and University Physics courses. By becoming involved in the modeling process and making their way through Kolb's cycle, the student's relationship with mathematics and science is challenged and shifts in their attitudes and beliefs about learning and teaching mathematics and science occur. Osborne and Dillon (2008), determined that when teachers gain greater confidence and self-efficacy through experimentation with reformed educational practices and teaching methods, they are able to improve the attitudes of their students toward science and mathematics. This determination by Osborne and Dillon (2008) supports that the efforts made in the labs by the instructors are just as important as the student-to-student interactions. This conclusion of the study has the most transferability to similar courses because the learning environment can be duplicated.

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Appendices

Appendix A

University Physics I & II (UPI & UPII) Syllabi

UPI PHYSICS 2054/0L, 2054H/0M Spring 2013 Syllabus

Instructor: James Cooper	Office: SCEN 119	Phone: 575-2506	e-mail:jfc04@uark.edu (best contact)
For info on TAs, graders, & UGTAs, as well as office hours please see the class Blackboard website.			

Required:

Textbook: Eric Mazur, *Principles*. (The first four readings are on line, so if you haven't got the textbook yet, there is NO EXCUSE for not doing the reading.) To keep costs down, there are three different versions! Most common is the 2005 edition, so it is for that that the syllabus is written. For other editions, use the titles of the sections in the study guide available on the website or the Blackboard site to identify the assigned sections.

Lab: *University Physics I Activity Guide* Labs are held in SCEN 111. Make sure you know your section number and are in the correct one. All your grades get entered depending on your lab section number!

Other: Always bring paper and something with which to write to lecture and lab.

An **optional** text recommended for those who want some math help: Calculus for Physics, available at the University Bookstore.

Last semester, we had complaints about the speed of Blackboard. It is better since the upgrade, but we wanted to play it safe and have a backup. You will still find class information and weekly outlines on Blackboard. The study guide, practice tests, homework assignments, homework solutions, online homework, and online homework solutions are located at: http://physinfo.uark.edu/upis13

Your user name is your uark email address, and your initial password is your student id. The reading assignments on this syllabus also are included in the on-line homework assignments.

Makeup Policy: Lecture Quizzes and Homework may not be made up. Activities and Experiments may be made up by attending a different lab section with permission of the lab instructor. Going to a lab section different than the one in which you are enrolled should be a rare occurrence, especially since almost every lab is *completely* full!

Drop the class now if you intend to miss many labs! Miss more than four and you fail, end of discussion.

Study Tips: Since activities are relevant to the exams, they provide an excellent opportunity to prepare for exams. Students should come to lab prepared to ask questions. ***Best strategy***: study incrementally for exams. Each time you study, make a list of any questions you have. The next time you study, try to answer the previous questions. Any questions remaining, ask in class (lecture or lab)! Readings are **required before** you come to lecture. Read the study guide to get an outline of what you are expected to understand. Read the textbook to fill it in. Come to class ready to ask (and answer) questions.

Assignment Descriptions

Lab –this is where you really learn the material. The course is designed for lecture to set you up for learning in the lab. There is a penalty (5 points) for missing lab. The **Activities:** 5 pts each. "Activity" may not mean a lab. Participate in a positive fashion on test summary, review and catch up days. All of these activities will improve your overall performance in the class, and are worth your time. The **Experiment:** 50 points. If you do not get a passing score on the one written lab report required in the class, you will receive a penalty of 100 points. You only have to do one once, but it needs to be good.

Lecture Quizzes-Each lecture day, students will have a homework assignment. A question based on the on-line homework or a textbook checkpoint will be given at the beginning of lecture, and other questions on the general concept from the lecture will be given as there is time to make sure you are engaged, so stay awake and ask questions if you don't understand!

Homework: There is homework due EVERY lecture day. On-line homework (-2 to 2 points) is every lecture day. These are to make sure you did the reading for that day. Homework sets (available on the website as assignments you can print out, that you must work out on paper, -4 to 4 points each) get turned in at the beginning of the first lab each week. These problems are for you to see if you mastered what I expect you to be able to do with the material we covered the previous week. Your best strategy here is to print them out a week in advance and be thinking about them during class, as we cover the material. Regular homework problem solutions will usually show how the points would have broken down if we had graded them on a test. Actual homework grading will sample features from throughout the set. Solutions to both types of homework will be posted on the web. There is never an excuse to miss points, you should always read and try the problems before they are due so you will have a chance to ask questions in class. The lowest 2 online homework and 1 regular homework assignment grades are dropped. A more detailed discussion is posted as Homework 0. Days with a regular homework due are marked in the schedule below with (h#) where # represents the number of the homework.

Office hours are posted on the course web site.

Inclement Weather Policy: Unless classes have been officially canceled by the UA, students are expected to attend all class meetings and examinations. If you live someplace from which you feel it would be dangerous to travel to the University, you should call and inform your instructor, TA, or leave a message for your instructor with the physics department. You will then be expected to make up the day's work on your own time, at a time arranged with your TA. Students missing a test for this reason will be required to take an alternate test that I will attempt to make of the same difficulty as the missed one. Since problems often differ more in difficulty than the instructor may expect, this cannot be guaranteed. **You are responsible for making the decision of whether it is safe for you to travel when there is bad weather in the area. I *never* want a student to put him- or herself at risk to attend class!**

Grading Policy

UPI is graded on a straight percentage scale >85% A, >70% B, >60% C, >50% D, otherwise F. ***(Note: An 84.99 is NOT > 85.)***

Failing the Class: You will fail the class if you score less than 50% in the class, or less than 50% on the tests or less than 50% on the final. You will also fail the class if you miss >4 labs. Hint: I want you in lab.

EXAMS DURING THE SEMESTER: Each exam is closed book and may contain multiple-choice as well as free-response questions. The tests will only cover material from the immediately preceding Wednesday lecture you are specifically told to expect.

While they will emphasize material since the previous test, they will expect understanding of everything covered in the class to that point! These tests are written so a prepared student can take them in 60 minutes. You will be allowed three hours. You get to drop one of the four semester exams, or the final, whichever helps your grade more. The **EQUATION SHEET** for the course is available on the website. Print it out and use it both when doing homework and for group problems in lab, so you are familiar with it. You must bring it to the tests, and only the information written on it is allowed, so **DON'T** write stuff on it!

FINAL EXAM: The final exam is two hours long, comprehensive, and closed-book. You may again use your equation sheet.

FINAL COURSE GRADES: Except in extraordinary circumstances, such as if you score less than 50% on the tests, you will receive at least the grade you mathematically earned in the class. Some of you may end up near the next higher grade. **I will consider giving you the next higher grade only if you have made that grade on the final exam; if not, DO NOT even ask!** Students with an A in the course with zero points for the final will automatically be excused from the final exam. Students who are happy with their final grades in the course with zero points for the final, as long those grades are C or higher, may be excused from the final exam. Students will receive information on what they must make on the final to maintain or raise their grades during the last lab period. Missing that lab is a VERY BAD IDEA.

Academic Dishonesty

Instances of Academic Dishonesty will be handled in accordance with the guidelines outlined on the UA website (links from the home page for this course). I take cheating very seriously. If you are caught cheating, I will ask that you immediately drop the class.

UPI Reading and Activity Schedule:

wk of	Lec: M	Lab: M, T	Lec: W	Lab: W, Th	Lec: F
1/14	Handouts, Quiz, 3.1,.2	Pretest, strt **A**1: Dist & Vel	**R**: 3.3-3.6	Fin **A1, A**2: Measurement	**R**: 3.7-3.10
1/21	MLK, Jr. Day	Office hrs in lab 8:30-5:20	**R**: 4.1-6(skip.5) (h3)	Finish **A2**, **A**3: Free fall	**Do your Homework!**
1/28	**R:** 4.7-5.2 (h4)	**A**4: Inclined planes	**R:** 5.3-5.6	**A**5: Collisions & Inertia	**Do your Homework!**
2/04	**R:** 6.1-6.7 (h6)	**A**6: Momentum & Energy	**R:** 6.8/Review	**A**7: group problems	**Thurs 2/9 Exam 1**
2/11	**R:** 6.9-7.4 (h8)	**A**8: ExpCol./Test 1 sum.	**R:** 7.5, Notes 7.6-10	**A**9: group problems	**Do your Homework!**
2/18	**R:** 8.1-8.3, 8.9 (h10)	**A**10: Cons of Energy	**R:** 8.4,7,8,10	**A**24: Catch up, HW check	**Do your Homework!**
2/25	**R:** 9.1-5 (h12)	**A**11: FB Diagrams	**R:** 9.6-9.10	**A**12: group problems	**Thurs 3/1 Exam 2**
3/04	**R:** 9.11-10.3 (h14)	**A**13: Imp&mom/Test 2 sum	**R:**10.4-.8	**A**14: Work/Energy	**Do your Homework!**
3/11	**R:** 11.1,2,3,6,7 (h16)	**EXP**1: Projectile Motion	**R:** 10.9,10;11.4,5	**A**15: Force review	**Do your Homework!**
3/18	**Spring Break-have a good time, but get caught up and healthy, too!**				
3/25	**R:** 11.8-12.2 (h18)	**A**16: Uniform Circ. Motn	**R:** 12.3-12.6	**A**17: Rotational Motion	Do your Homework!
4/01	**R:**13.1,2,3,5 (h20)	Finish **A**17, **A**25: HW rev	**R:** 13.6-.7	**A**18: Statics and torque	**Thurs 4/5 Exam 3**
4/08	**R:** 14.1-14.4 (hw22)	**A**26: Test 3 summary	**R:** 14.5-14.7	**A**19:Group problems	**Do your Homework!**
4/15	**R:** 16.1,2,4,5 (hw24)	**A**20: Simple Pendulum	**R:** 16.6-16.7	**A**21: Mass-spring sys	**Do your Homework!**
4/22	**R:** 17.1 –17.3 (hw26)	**A22:** Waves	**R:**17.4,review	**A**23: Group problems	**Do your Homework!**
4/29	Thermo notes (hw28)	**A**27: Test 4 return	**Final hints, come to lab or lose points->**	**A**28:Mat'ls return, points check, activity makeup	**Dead Day; Final next Wednesday 8-10 am**

Axx:**Activities**, write-ups will be completed in class and checked before you leave. Each student must answer all the questions in the activity for him- or herself. **R:Reading** to be done **before** class! **The formal Experiment** must be NEATLY written or typed, figures and equations may be handwritten. **Tests, except for the final, will be from 6-10pm, locations to be announced in lab.**

Assignment type	Points Per Assignment	Total w/drops	Non-Performance Penalty	Dropped Assignments
Semester Exams	4 @ 150	600 *		1
Final Exam	150	150 *		(600 test points total)*
Homework	14 long-answer @ 4	52	-4 for each not tried	1
Lecture Quizzes	29 @ 4	108		2
Activities	28@5	130	-5 for each missed	2
Formal Experiment	50 (no forgiveness for doing wrong one!)	50	-100 (if don't pass it)	0
On-Line HW	24@2	44	-2 for each not done	2
Totals		984		

Some of these numbers may change due to unforeseen circumstances, so all numbers above are approximate. A non-performance penalty means you receive a negative score for missing or inadequate (in the case of homework) work.

***Dropping a Test**, whichever is better for your grade. This will happen automatically.

****Honors** Students enrolled in the honors course will receive a separate syllabus in lab

The University is attempting to support the quality of instruction in its core classes. A set of basic learning goals has been identified, that will be evaluated. By the end of this course you should

1. be able to identify systems of interest and interactions to solve problems, and based on their properties choose the best method to solve the problem, conservation principles or transfer, and implement it.
2. be able to describe and calculate the behavior of simple objects acted upon by forces, including gravity.
3. be able to describe and calculate features of wave motion and other wave effects.
4. be able to define temperature and heat and qualitatively relate these problems to conservation of energy.
5. be able to accept or reject standard theories based on measurements in the lab.

PHYS 2074/2070L---UPII Fall 2012 Syllabus

Instructors

Dr. John Stewart
Office: Physics 242B
e-mail: johns@uark.edu

Mr. Tim Ransom
Office: Physics 236
e-mail: tcransom@uark.edu

Mr. Hamed pour Imani
Office: Physics 232
e-mail: hpourima@uark.edu

Mr. Atanu Dutta
Office: Physics 244
e-mail: adutta@uark.edu

Mr. Sean Nomoto
Office: Physics 233
e-mail: snomoto@uark.edu

Dr. Stewart will hold office hours in SCEN 110, the lab room. Some TAs may choose to hold office hours in the physics library. Office hours times and locations are available in the Information and Tools folder in Blackboard.

Physics Office Phone 575-2506

Course Materials: The course lab manual is available at the University Bookstore near the corner of Garland and Maple. The course readings are available for free online. There is an optional textbook for those who want additional reading or are planning to take UPIII. I will make no reference to the optional textbook. All homework and supplementary course materials are available through Blackboard. Online homework, lab quizzes, and some supplementary materials are provided through an additional site linked to Blackboard. There is homework and reading due Wednesday, so you must make sure you can access the site immediately.

- The main UPII website is the Blackboard site at http://learn.uark.edu
- Additional UPII Website: http://physinfo.uark.edu/upiif12
  User Name: Your university e-mail address – Example johns@uark.edu or just johns
  Password: Your university id – Example 010023450
  If you have trouble logging in, your lab TA will assist you during the first lab session.

Assignments: All assignments and readings are available through Blackboard. There is a homework assignment due EVERY lecture day and an Activity during every lab period.

Makeup Policy: Lecture quizzes, lab quizzes, and homework may not be made up. Activities and experiments may be made up by attending a different lab section with permission of the lab instructor. Going to a different lab section than the one in which you are enrolled should be a rare occurrence.

Academic Integrity: Instances of academic dishonesty will be handled in accordance with the guidelines outlined by the Provost for Academic Affairs available at http://provost.uark.edu/245.php and http://provost.uark.edu/246.php .

Illness Policy: If you are ill, please stay home. Dropped assignments are provided to cover normal sickness. If you have an extended illness, please contact me and I will make provisions.

Office Hours: Office hours for the course are posted under Information and Tools in Blackboard.

Inclement Weather Policy: Unless classes have been officially canceled by the U of A, students are expected to attend all class meetings and examinations. If the student lives somewhere from which he or she feels it would be dangerous to travel to the University, he or she should e-mail and inform his or her instructor or TA. The student will then be expected to make up the day's work on their own time, at a time arranged with their TA. Students missing a test for this reason will be required to take an alternate test that we will attempt to make of the same difficulty as the missed exam. Since problems often differ more in difficulty than the instructor may expect, this cannot be guaranteed. You are responsible for making the decision to travel in bad weather. I never want a student to put themselves at risk to attend class.

Schedule of Topics

Week 1 beginning 8/20: Electric Charge and Electric Force
Week 2 beginning 8/27: Electric Field.
Week 3 beginning 9/3: Gauss' Law
Week 4 beginning 9/10: More Gauss and Exam 1 Review: Exam 1 Thursday 9/13 at 6:30pm
Week 5 beginning 9/17: Conductors and Dielectrics
Week 6 beginning 9/24: Potential and Capacitance
Week 7 beginning 10/1: Circuits
Week 8 beginning 10/8: RC Circuits and Exam 2 Review: Exam 2 Thursday 10/11 at 6:30pm.
Week 9 beginning 10/15: Magnetic Field
Week 10 beginning 10/22: Magnetic Field and Force
Week 11 beginning 10/29: Faraday's Law and Inductance
Week 12 beginning 11/5: EM Waves + Radiation
Week 13 beginning 11/12: Exam 3 Review + Light: Exam 3 Tuesday 11/13 at 6:30pm.
Week 14 beginning 11/19: Optical Elements
Week 15 beginning 11/26: Optical Systems
Week 16 beginning 12/3: Test 4 and Final Exam Review: Exam 4 Tuesday 5/4 at 6:30pm.
Final Exam: Thursday December 13th at 6:00pm. Note: This is a special time for a 10:30 class. No alternate final is ever given, so be there.

Grading Policy

UPII is graded on a straight percentage scale >85% A, >70% B, >60% C, >50% D, otherwise F.

Assignment	Points Per Assignment	Total Points	Non-Performance Penalty	Dropped Assignments
Exams	200	1000		1
Homework	4	84	-4	4
Online Homework	4	92	-4	4
Lecture Quiz	2	50	-2	4
Activities	3	84	-3*	2
Lab Assignments	20	40	-100*	
Lab Quizzes	3	75		2
Totals		1425		

Some of these numbers may change due to unforeseen circumstances, so all numbers above are approximate. A non-performance penalty means you receive a negative score for missing work.

***Activities and Lab Assignments**

This is a lab-based course and your time in lab is the most important part of your course work. As such, you will fail the course if you miss more than 4 labs. Two lab reports are required (Lab Assignments). A very detailed grading rubric is provided for each in the Activity Guide and a student following the rubric should easily score at least 50% on each report. On the first lab report, for students scoring less than 50% on the report, the report may be reworked and turned back in to receive up to 50%. Lab reports are worth 20 points, students will lose 10 points for every point they score below 10; that is a score of 7 of 20 will result in a grade of -30. I expect good work on the lab reports.

Scaled Grading

Everything in the course is graded out of the number of points that correctly represent the work and then this number is SCALED to the number of points above. A homework set receiving 30 points out of a total of 60 would receive 30/60*4 points = 2 points toward the class. Grades are rounded to one decimal place.

Failing the Class

- You will fail the class if you score less than 50% in the class.
- You will fail the class if you miss more than 4 labs.
- You will fail the class if you do not score at least 50% on either the final exam or on the average of the four in-semester exams without drops. You can't pass the class without learning something.

Failing Test Average: If your average on the four in-semester exams (without drops) is less than 50%, you must score at least 50% on the final exam to pass the class.

Not Using Required Assignments Wisely – This is difficult material and you earn points for doing the various assignments in the class. You must do the assignments so that you master the material and can demonstrate that mastery on tests; it's not about getting points, it's about understanding. Your final grade in the class will not be more than one letter grade higher than your test average without drops.

In-Semester and Final Exam Format: Each in-semester exam will be closed book and contain ten multiple-choice questions and two free-response questions. The final exam will be six free-response questions. The exams are written so a prepared student can take them in one hour. You will be allowed two hours. If an exam turns out to be particularly long, I will allow more time. You are allowed one 3in-by-5in index card, front and back, as a formula sheet for an in-semester exam. Two cards will be allowed for the final.

Learning Outcomes – University Requires This is Here: Be able to describe and calculate the behavior of electrical & magnetic devices. Be able to describe and calculate the behavior of electromagnetic waves. Be able to describe and calculate the behavior of optical devices. Be able to accept or reject standard theories based on measurements in the lab.

Final Grades: At the end of the course, final grade decisions are mine. I reserve the right to give students near a grade boundary or with special circumstances a higher grade than they have mathematically earned. In extraordinary circumstances, I reserve the right to give a student a lower grade than he or she mathematically earned. (This has only happened twice, don't be the third.)

LAB LOCATION: The UPII Lab Meets in SCEN 110.

Appendix B

Physics for Elementary Education (PET)

Course Information: Physics for Elementary Teachers (PET)

Instructor: Tamara Snyder
Office: SCEN 105 (right next door!)
E-mail: tsnyder@uark.edu
Phone: 575-2981
Office Hours: MWF 11:30 - 12:30 in the classroom, and also by appointment
Class website: http://physics.uark.edu/pet/

Section 1: MWF 9:30 - 11:20
Section 2: MWF 12:30 - 2:20

Science for Future Teachers

This class is designed to meet your needs - to teach you many of the physical science ideas that you will be expected to teach your own students. The Arkansas Science Curriculum Framework lays out what science is expected for each of the grade levels (http://arkansased.org/educators/pdf/science_k-8_011006.pdf). This course was designed with these frameworks in mind.

This class has four main goals:
1. To help you learn physics concepts
2. To help you develop an understanding of how knowledge is developed in a scientific community
3. To help you become aware of how your own learning processes work
4. To help you analyze and appreciate the thinking of elementary students while they engage in scientific inquiry.

Research has shown that people learn physics best when they are *doing* physics. Research also shows that teachers tend to teach a subject the way they have been taught themselves. For these reasons, this class has been structured as an activity based class - one in which you will be doing activities every class period, and discussing your ideas with your lab partners and classmates. *I will not give you the right answers.* You will develop answers that make sense to you as the class goes along. I am here to guide you, but you will be the one mainly in charge of your own learning in this class. When you are teaching science to your elementary class, you will want to do it the same way. If you embrace the methods of this class, it will make teaching science in your own class much more fun. It will also give you the confidence you will need to teach a science class where at least 20% of the instructional time is hands-on learning (something stipulated by the state framework)

Required Materials:

The Physics and Everyday Thinking manual is available from the U of A bookstore on Garland, and also the Campus Bookstore on Dickson St. It includes a PET Student Resources CD. This CD includes electronic versions of all the homework assignments (in Microsoft Word), plus several Quicktime movies of elementary children performing science activities. These movies are part of a set of special Elementary Student Ideas (ESI) homeworks, to be assigned periodically during the semester. Other course materials will be distributed to you as needed during the course.

Everyone needs to have a copy of this book. You can't just make copies of a friend's, or try to keep all of the information on a slip of paper. Please be sure you have a copy of this book by Friday (January 20).

Attendance and Participation:

You will be primarily responsible for your own learning in this class. By engaging in meaningful discussions with your group members, by actively participating in whole class discussions, and by performing interesting experiments, you will develop with your classmates a set of ideas. Similar to the way in which scientists develop ideas, your ideas will be based on evidence gathered from the experiments you do. At appropriate times, you will be able to compare your ideas with those developed by scientists. It is expected that, except for some special jargon, the ideas you develop with the class should be quite similar to the scientists' ideas.

Because you will play such an important role in your own learning, and especially the learning of your classmates, **you are expected to come to class on time every class period and participate throughout the period**.

It is very easy to be distracted in this sort of environment, because so much is going on. There are a few rules to help minimize the distractions:

1. **No cell phones** at any time during class.
2. No visitors in class (children, friends, etc.) This class is *not* an appropriate substitute for your babysitter.
3. No visiting with people in another group, except during the "group sharing" part of an activity
4. No working on homework from other classes while in this class.
5. No food or open drink containers in class. If you need a drink, be sure it is in a bottle or cup with a closable lid (not, for instance, a can or an open-top cup)
6. Minimize bathroom breaks (go before or after class).

Because discussion with other students plays a large role in this class, it is important that students should not make fun of the ideas of other students. Students should listen carefully to all input and respond to presented ideas based solely on their merit. Students should feel free to present ideas they hold only tentatively, without fear of ridicule. (Sometimes these turn out to be the right ideas!) It is important that *evidence* be used as the ultimate arbiter when making a judgment about the relative merits of ideas.

You will be working in groups in this class, and I will be changing the composition of the groups several times during the semester. I do this because I am trying to maximize the learning for every student. Very often groups will develop a leader who does most of the work, while the rest of the group goes along for the ride. This is not good for the members of the group, or for the class. I want *everyone* to think, to develop ideas and explanations, and to look for ideas that explain the evidence you discover. Often rearranging the groups stimulates better discussions and learning. Don't expect to always be with your friends in a group. Sometimes you might be with people you don't know or don't like. Make the best of it - maybe they have good ideas that your group of friends wouldn't have thought of!

Missing Class and Make-Up Work

This really isn't one of those classes where you can just get the notes from your friends and be OK. You *can* get the notes, of course, but if you don't do the activities yourself, you may not be OK.

There is very little time to make up missed work in this class. We have classes going on from 9:30 to 2:30 on MWF, and the math department has the room the rest of the time. You may be able to make up part of a missed lab during office hours (11:30-12:30). But the learning experience is not the same when you are not working with your group. The bottom line is that you will do better in this course if you don't miss class.

If you have more than 2 unexcused absences from this class, your grade will drop by one letter. Excused absences include: being sick (you need a doctor's note for the absence to be excused), going to a funeral (you need some sort of evidence that you were there), representing the U of A at a sporting event (you are on a team, the band, etc., and you have a note from the head of your group asking for you to be excused). Unexcused absences include: going to a friend's wedding, staying home to take care of your kids, missing class because it is your birthday, etc. If you are not sure if your absence will be excused or not, ask me.

Homework:

Homework will be assigned almost every class period and, unless otherwise stated, will be due at the beginning of the following class period. (The ESI assignments, mentioned above, will generally be due two class periods later.) Most of the time the homework will be gone over and discussed during the class period when it is due. Do the homework yourself, it is good for you! I know it can be hard to find the time to do your homework. But simply copying down answers from someone is not a good idea. If you didn't think through the concepts yourself, then you not getting the full learning experience for this topic - which might come back to hurt you later on, or on the test. *As an incentive not to copy, I will give 0 points to people who turn in homeworks that are exactly the same.* If you work with someone on the homework, be sure you each write down the answers in your own words.

Late Homework:
Late homework is not accepted unless you miss the class period it is due. If you miss a class, the homework for that missed class is due the day you return. Any other missed homework should be turned in on the second day after you return. Example: You miss a Monday class, and return on Wednesday. Homework was due on both Monday and Wednesday. You need to turn in Monday's homework when you get class on Wednesday. The Wednesday homework can be turned in on Friday (that gives you time to find out what you missed on Monday).

Many of the assignments will require you to have access to a computer with an Internet connection. If you do not have one at home, there are several computer labs on campus, or you can use the computers in our classroom before or after class (but this might not be enough time to finish the homework)

The Elementary Students' Ideas (ESI) homeworks are more extensive. They will require you to view Quicktime movies of children from grades two through five discussing physics ideas. You will be asked to make claims about what the students are learning and will use direct quotes from what the children say or pictures they draw as evidence to support your claims. Electronic transcripts of the movies and the students' pictures are provided on the student resource CD, along with the movies themselves. We will spend class time discussing the children's learning during the periods when the ESI homeworks are due.

Grading Criteria and Test Info:

Tests are short answer type - usually 7 to 10 questions based on the chapters covered by the test. You will not be allowed to use a calculator, notes, or your book. Obviously, you should not copy your test answers from another student.

After the tests are graded, I will pass them back so you can see what your grade is. You will not be allowed to keep the tests, however. Any time you would like to see your test, let me know and I will show it to you. Tests must not leave the classroom.

Note that the second test is the week before Spring Break. If we get snow early in the semester, it may be the Friday before Spring Break. **Plan to be in class the Friday before Spring Break, you don't want to miss the test.**

Course component	Point value	Approximate Dates
Chapter 1 Test	40 points	Feb. 6 - 10
Chapters 2 and 3 Test	50 points	Mar. 12 - 16 (the week before spring break)
Chapters 4 and 5 Test	60 points	Around Apr. 18 or 20 or so
Final Exam (ch. 1- 6, with an emphasis on 6)	60 points	Final Exam Time
Regular homework (2.1 points each)	40 points	
ESI Homeworks (3 assignments, 10 pts ea.)	30 points	
Total points =	280 points	

Final Exam Times:
Morning Class: Monday, May 7, 10:15 - 12:15
Afternoon Class: Monday, May 7, 1:00 - 3:00

Grading Scale:

Usual range For a given Grade:	A 90% +
	B 80% - 90%
	C 70% - 80%
	D 60% - 70%
	F below 60%

Don't forget - if you miss more than 2 classes, your grade will drop by one letter!

Bonus Points - there will be only one chance for bonus points this semester: a survey that must be done both at the beginning and at the end of the semester. More details will be given in class.

Schedule

The book has 6 chapters, and each chapter has several activities. Generally speaking, we will do one activity at each class meeting. Some activities are shorter, and we may occasionally do two activities in one day. There are some activities that are longer, and we may not finish them in one meeting, but will finish them the next class period, and then continue with the next activity. We should be able to finish the book, unless the university closes for several snow days.

Bad Weather

We may get bad weather/snow/ice this semester. If the university cancels classes, then we won't have class. If the university delays opening, then we will start class when the university opens:

Morning class: If the university delays opening until 11am or later, we will not have class. If the opening time is before 11am (like 10am or 10:30) then we will start class at that time.

Afternoon class: If the university opens before 12:30, then we will have class.

If the university closes while we are in class, then we will end class and leave.

If you are not sure what is going on, check the web site. Assuming there hasn't been a power failure, I will update it with weather related starting info. If there is no message saying class is cancelled or delayed, then assume it is still taking place, and you should come to class at the regular time. That being said, if road conditions are too dangerous for you to come to class, then stay home.

Cheating

No course information sheet would be complete without mentioning cheating. Don't cheat. This is what I consider cheating in this class:

a) copying regular homework answers from someone else (all people involved will get a 0 for that homework assignment)
b) copying some or all of your answers for an ESI type homework. (all people involved will get 0 points for the answers that are the same or very similar)
c) copying answers on a test (if you do this, I will have to report you to the university and follow their guidelines)

The tables in this room are great for group work, but much too small for test taking. If I am very lucky, I can schedule a big room where we can spread out and we can go there for our tests - but this probably won't happen (big rooms tend to be in regular use). So I may have to reserve another small room, and split the class - sending some people to the other room for the test. I will randomly choose who goes to the other room, and I will try not to send the same people to the other room for each test.

Appendix C

Survey Instrument

Attitudes and Beliefs about the Nature of and Teaching Mathematics and Science

Background Information:

1. Gender	**A** **Male**	**B** **Female**			
2. Ethnicity	A African American	B Asian/Pacific Island	C Caucasian	D Hispanic	E Other
3. Number of completed college Credits	A 0-30	B 31-60	C 61-90	D 91+	E Post-baccalaureate
4. Major or area of concentration	A Education / Mathematics	B Education / Science	C Edcuation / Mathematics & Science	D Education / Other Subject(s)	E Not in a teacher certificate program

Below are a series of statements about mathematics and science. Indicate the extent to which you agree or disagree with each statement. There are no right answers. The correct responses are those that reflect your attitudes and beliefs. *Do not spend too much time with any statement*.

	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
5. I am looking forward to taking more mathematics courses.	A	B	C	D	E
6. I enjoy learning how to use technology (eg.., calculators, computers, etc.) in mathematics classrooms.	A	B	C	D	E
7. I like Mathematics	A	B	C	D	E
8. Calculators should always be available for students in mathematics classrooms.	A	B	C	D	E
9. In grades K-9, truly understanding mathematics in schools requires special abilities that only some people possess.	A	B	C	D	E
10. The use of technologies (e.g., calculators, computers, etc.) in mathematics is an aid primarily for slow learners.	A	B	C	D	E
11. Mathematics consists of unrelated topics (e.g., algebra, arithmetic, calculus, and geometry).	A	B	C	D	E
12. To understand mathematics, students must solve many problems following examples provided.	A	B	C	D	E
13. Students should have opportunities to experience manipulating materials in mathematics classroom before teachers introduce mathematics vocabulary.	A	B	C	D	E
14. Getting the correct answer to a problem in the mathematics classroom if more important than investigating the problem in a mathematical manner.	A	B	C	D	E

15. Students should be given regular opportunities to think about what they have learned in the mathematics classroom.	A	B	C	D	E
16. Using technologies (e.g., calculators, computers, etc.) in mathematics lesson will improve students' understanding of mathematics.	A	B	C	D	E
17. The primary reason for learning mathematics is to learn skills for doing science.	A	B	C	D	E
18. Small group activity should be a regular part of mathematics classroom	A	B	C	D	E
19. I am looking forward to taking more science courses.	A	B	C	D	E
20. Using technologies (e.g., calculators, computers, etc.) in science will improve students' understanding of science.	A	B	C	D	E
21. Getting the correct answer to a problem in the science classroom is more important than investigating the problem in a scientific manner.	A	B	C	D	E
22. In grades K-9, truly understanding science in the classroom requires special abilities that only some people possess.	A	B	C	D	E
23. Students should be given regular opportunities to think about what they have learned in the science classroom.	A	B	C	D	E
24. Science is a constantly expanding field.	A	B	C	D	E
25. Theories in science are rarely replaced by others.	A	B	C	D	E
26. To understand science, students must solve many problems following examples provided.	A	B	C	D	E
27. I like science	A	B	C	D	E
28. I enjoy learning how to use technologies (e.g., calculators, computers, etc.) in science.	A	B	C	D	E
29. The use of technologies (e.g., calculators, computers, etc.) in science is an aid primarily for slow learners.	A	B	C	D	E
30. Students should have opportunities to experience manipulating materials in the science classroom before teachers introduce scientific vocabulary.	A	B	C	D	E
31. Science consists of unrelated topics like biology, chemistry, geology, ad physics.	A	B	C	D	E
32. Calculators should always be available for students in science classes.	A	B	C	D	E
33. The primary reason for learning science is to provide real life examples for learning mathematics.	A	B	C	D	E
34. Small group activities should be a regular part of the science classroom.	A	B	C	D	E

Respond to ITEMS 35-44 only if you intend to teach.

	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
35. I expect that the colleges mathematics courses I take will be helpful to me in teaching mathematics in elementary or middle school.	A	B	C	D	E
36. I want to learn how to use technologies (e.g. calculators, computers, etc.) to teach mathematics.	A	B	C	D	E
37. The idea of teaching science scares me.	A	B	C	D	E
38. I expect that the college science courses I take will be helpful to me in teaching science in elementary or middle school.	A	B	C	D	E

39. I prefer to teach mathematics and sciences emphasizing connections between the two disciplines.	A	B	C	D	E
40. The idea of teaching mathematics scares me.	A	B	C	D	E
41. I want to learn how to use technologies (e.g., calculators, computers, etc.) to teach science.	A	B	C	D	E
42. I feel prepared to teach mathematics and science emphasizing connections between the two disciplines.	A	B	C	D	E
43. Areas of teaching certificate	A Elementary (grades 1-8)	B Secondary Mathematics (grades 5-12)	C Secondary Science (grades 5-12)	D Other	
44. I intend to teach grades	A K-3	B 4-8	C 9-12	D Post-Secondary	E Undecided

Appendix D

Table 6

PET Participant Characteristics, N=235

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sample (n)	8	10	12	8	38	44	38	48	29
Gender (%)									
Male	16.7	10	8.3	-	5.3	2.3	2.6	-	-
Female	83.3	90	91.7	100.0	94.7	97.7	97.4	100.0	100.0
Ethnicity (%)									
African American	-	10.0	-	-	2.6	6.8	-	-	-
Asian/Pacific Island	-	-	-	-	-	2.3	2.6	-	-
Caucasian	100.	80.0	100.0	100.0	94.7	86.4	94.9	100.0	96.6
Hispanic	0	10.0	-	-	-	-	2.6	-	-
Other	-	-	-	-	2.6	4.5	-	-	3.4
Credits Earned (%)									
0-30	-	-	8.3	12.5	23.7	4.5	7.7	4.2	10.3
31 – 60	33.3	20.0	41.7	62.5	39.5	54.5	43.6	52.1	51.7
61-90	50.0	60.0	41.7	25.0	34.2	38.6	41.0	37.5	34.6
91+	16.7	20.0	8.3	-	2.6	2.4	7.7	6.3	3.4
Post-Baccalaureate	-	-	-	-	-	-	-	-	-
Major (%)									
Education/Math	-	-	-	-	-	-	-	4.2	14.3
Education/Science	-	-	8.3	-	-	-	-	2.1	-
Education/Math & Science	-	-	-	-	-	2.3	-	4.2	21.4
Education/Other Science	83.3	90.0	91.7	100.0	97.4	95.5	94.9	83.3	28.6
Non-Education	16.7	10.0	-	-	2.6	2.2	5.1	6.2	35.7

Appendix E

Table 7

University Physics Participant Characteristics, N=1509

Year	F2003 - S2004	S2004 - F2004	F2004 - S2005	S2005 - F2005	F2005 - S2006	S2006 - F2006	F2006 - S2007	S2007 - F2007	F2007 - S2008	F2008 - S2009
Sample (N)	82	58	68	47	76	38	37	50	126	136
Gender (%)										
Male	73.2	84.5	58.8	78.7	77.6	81.6	67.6	82.0	65.1	66.9
Female	26.8	15.5	41.2	21.3	22.4	18.4	32.4	18.0	34.9	33.1
Ethnicity (%)										
African American	2.4	6.9	1.5	2.1	2.6	5.3	2.7	2.0	0.8	6.5
Asian/Pacific Island	7.3	5.2	10.3	8.5	8.0	5.3	2.7	6.0	7.1	7.4
Caucasian	87.8	84.5	83.8	83.0	82.9	78.8	82.2	82.0	86.5	82.4
Hispanic	-	3.4	2.9	4.3	2.6	5.3	5.4	4.0	2.4	1.5
Other	3.3%	-	1.5	2.1	23.9	5.3	-	6.0	3.2	2.2
Credits Earned (%)										
0-30	36.6	8.6	33.8	6.4	43.4	21.1	48.6	10.0	54.0	73.5
31 – 60	34.1	74.1	48.5	70.2	46.1	63.1	35.2	60.0	31.0	16.9
61-90	20.7	12.1	8.9	19.1	7.9	13.2	10.8	26.0	13.5	7.4
91+	7.3	5.2	5.9	4.3	1.3	2.6	5.4	4.0	1.5	1.5
Post-Baccalaureate	2.3	-	2.9	-	1.3	-	-	-	-	0.7
Major (%)										
Education/Math	2.4	1.7	-	-	3.9	2.6	2.7	2.0	4.0	-
Education/Science	4.9	-	4.4	2.1	3.9	-	-	2.0	1.5	1.5
Education/Math & Science	9.8	6.9	7.4	4.3	6.6	2.6	-	2.0	4.0	9.6
Education/Other Science	2.4	-	1.6	2.1	1.3	5.3	-	-	0.8	1.5
Non-Education	80.5	91.4	86.8	91.5	84.3	89.5	97.3	94.0	89.7	87.5

Table 7 (Continued)

University Physics Participant Characteristics, N=1509

Year	F2009 - S2010	S2010 - F2010	F2010 - S2011	S2011 - F2011	F2011 - S2012	S2012 - F2012	F2012 - S2013	S2013 - F2013
Sample (N)	111	26	115	35	138	29	112	22
Gender (%)								
Male	70.3	61.5	64.3	74.3	77.5	69.0	65.2	72.7
Female	29.7	38.5	35.7	25.7	22.5	31.0	34.8	27.3
Ethnicity (%)								
African American	1.8	-	1.7	8..6	2.9	10.3	3.5	4.5
Asian/Pacific Island	4.5	3.8	6.1	2.9	2.2	6.9	5.4	13.6
Caucasian	89.2	80.8	84.4	74.3	89.1	65.6	85.7	59.1
Hispanic	-	7.7	1.7	8.5	2.9	6.9	5.4	18.2
Other	4.5	7.7	6.1	5.7	2.9	10.3	-	4.5
Credits Earned (%)								
0-30	65.8	19.2	73.9	11.4	73.9	27.6	76.8	4.5
31 – 60	17.1	46.2	15.6	68.6	15.3	55.2	11.6	82.0
61-90	14.4	26.9	7.0	14.3	4.3	10.3	8.0	4.5
91+	2.7	7.7	0.9	5.7	4.3	6.9	2.7	4.5
Post-Baccalaureate	-	-	2.6	-	2.2	-	0.9	4.5
Major (%)								
Education/Math	0.9	-	1.7	2.9	-	3.5	-	-
Education/Science	6.3	-	6.1	2.9	4.3	-	4.5	4.5
Education/Math & Science	9.0	7.7	7.8	2.9	9.4	17.2	9.8	4.5
Education/Other Science	0.9	3.8	0.9	-	-	-	1.8	-
Non-Education	82.9	88.5	83.5	91.3	86.3	79.3	83.9	91.0

Appendix F

Table 8

PET Pre-Attitude and Beliefs

Year	N	2005	2006	2007	2008	2009	2010	2011	2012	2013
(n)	235	6	10	12	8	38	44	38	48	29
X_1										
Mean	3.39	3.80	3.38	3.45	3.45	3.33	3.23	3.45	3.42	3.45
Medium	3.43	3.93	3.21	3.46	3.50	3.32	3.29	3.50	3.46	3.43
Mode	3.29	4.36	3.93	-	-	3.71	3.29	3.71	3.71	3.29
X_2										
Mean	3.07	2.92	3.17	2.64	3.02	3.08	3.02	3.09	3.06	3.29
Medium	3.17	3.08	3.17	2.92	2.92	3.17	3.08	3.17	3.08	3.33
Mode	3.17	3.33	3.67	2.33	3.17	3.50	3.17	2.33	2.67	3.67
X_3										
Mean	3.44	3.32	3.49	3.27	3.46	3.47	3.43	3.43	3.44	3.51
Medium	3.50	3.25	3.45	3.25	3.40	3.50	3.50	3.50	3.40	3.50
Mode	3.50	-	3.40	3.00	3.40	3.50	3.50	3.50	3.30	3.60
X_4										
Mean	4.39	4.38	4.45	3.85	4.19	4.38	4.52	4.31	4.43	4.48
Medium	4.50	4.63	4.38	4.00	4.25	4.50	4.75	4.50	4.50	4.75
Mode	5.00	4.75	4.25	4.00	4.50	4.75	5.00	5.00	5.00	5.00
X_5										
Mean	3.02	2.38	2.93	3.13	2.94	3.32	3.07	2.95	3.09	2.84
Medium	3.00	2.50	3.00	3.38	2.75	3.25	3.25	3.00	3.00	2.75
Mode	3.50	2.75	3.00	1.50	2.75	3.50	3.75	3.50	3.00	2.50

X_1 - Beliefs about the nature of mathematics and science
X_2 - Attitudes towards mathematics and science
X_3 - Beliefs about the teaching of mathematics and science
X_4 - Attitudes towards learning to teach mathematics and science
X_5 - Attitudes towards teaching mathematics and science

Appendix G

Table 9

PET Post-Attitude and Beliefs

Year	N	2005	2006	2007	2008	2009	2010	2011	2012	2013
(n)	235	8	10	12	8	38	44	38	48	29
X_1										
Mean	3.46	3.56	3.44	3.43	3.74	3.42	340	3.60	3.41	3.41
Medium	3.50	3.43	3.29	3.46	3.93	3.61	3.43	3.57	3.46	3.36
Mode	3.36	-	-	3.50	-	3.93	3.14	3.57	3.36	3.36
X_2										
Mean	3.16	2.86	3.35	2.97	3.44	3.00	3.05	3.08	3.30	3.39
Medium	3.17	2.75	3.42	2.83	3.58	3.17	3.00	3.17	3.17	3.50
Mode	3.50	2.67	-	2.17	3.50	3.17	3.50	1.67	3.00	3.50
X_3										
Mean	3.49	3.57	3.66	3.29	3.55	3.55	3.41	3.48	3.51	3.53
Medium	3.50	3.55	3.70	3.30	3.55	3.60	3.40	3.50	3.50	3.60
Mode	3.60	-	3.70	3.40	3.70	3.60	3.60	3.60	3.50	3.70
X_4										
Mean	4.22	2.92	3.95	3.98	4.44	4.41	4.26	4.31	4.32	3.98
Medium	4.50	3.00	4.00	4.13	4.50	4.50	4.50	4.50	4.50	4.25
Mode	5.00	3.00	4.00	4.75	4.75	5.00	5.00	5.00	5.00	5.00
X_5										
Mean	3.26	2.21	3.30	3.13	3.59	3.31	3.33	3.33	3.29	3.11
Medium	3.25	2.75	3.38	3.25	3.63	3.25	3.50	3.25	3.50	3.25
Mode	5.00	2.75	3.50	3.25	3.00	3.25	3.00	3.00	3.50	3.00

X_1 - Beliefs about the nature of mathematics and science

X_2 - Attitudes towards mathematics and science

X_3 - Beliefs about the teaching of mathematics and science

X_4 - Attitudes towards learning to teach mathematics and science

X_5 - Attitudes towards teaching mathematics and science

Appendix H

Table 10

PET Participants Attitudes and Beliefs with Effect Size

Year	N	2005	2006	2007	2008	2009	2010	2011	2012	2013
(n)	**235**	**8**	**10**	**12**	**8**	**38**	**44**	**38**	**48**	**29**
X_1										
Pre-Mean	3.39	3.80	3.38	3.45	3.45	3.33	3.23	3.45	3.42	3.45
Post-Mean	3.46	3.56	3.44	3.43	3.74	3.42	3.40	3.60	3.41	3.41
SD-pre	0.49	0.75	0.43	0.45	0.73	0.50	0.50	0.45	0.46	0.46
Effect Size*	0.14	0.32	0.14	0.44	0.41	0.18	0.34	0.33	0.02	0.09
T Critical two-tail	1.97	4.03	3.25	3.11	3.50	2.72	2.70	2.71	2.68	2.76
$P(T \leq t)$ two-tail	.058	.286	.525	.838	.080	.396	.016	.117	.868	.740
X_2										
Pre-Mean	3.07	2.92	3.17	2.64	3.02	3.08	3.02	3.09	3.06	3.29
Post-Mean	3.16	2.86	3.35	2.97	3.44	3.00	3.05	3.08	3.30	3.39
SD-pre	0.78	0.67	0.65	0.91	0.87	0.62	0.69	0.99	0.80	0.72
Effect Size*	0.12	0.09	0.23	0.36	0.48	0.13	0.04	0.01	0.30	0.13
T Critical two-tail	2.60	4.03	3.25	3.11	3.50	2.72	2.70	2.71	2.58	2.76
$P(T \leq t)$ two-tail	.020	.858	.253	.069	.069	.394	.750	.959	.003	.417
X_3										
Pre-Mean	3.44	3.32	3.49	3.27	3.46	3.47	3.43	3.43	3.44	3.51
Post-Mean	3.49	3.57	3.66	3.29	3.55	3.55	3.41	3.48	3.51	3.53
SD-pre	0.29	0.29	0.25	0.34	0.30	0.24	0.31	0.32	0.31	0.22
Effect Size*	0.17	0.25	0.68	0.06	0.30	0.33	0.06	0.16	0.23	0.09
T Critical two-tail	2.60	4.03	3.25	3.11	3.50	2.72	2.70	2.72	2.68	2.76
$P(T \leq t)$ two-tail	.028	.087	.155	.807	.406	.119	.760	.189	.189	.650
X_4										
Pre-Mean	4.39	4.38	4.45	3.85	4.19	4.38	4.52	4.31	4.43	4.48
Post-Mean	4.22	2.92	3.95	3.98	4.44	4.41	4.26	4.31	4.32	3.98
SD-pre	0.71	0.65	0.39	0.62	0.42	0.59	0.75	0.72	0.63	0.98
Effect Size*	0.24	2.24	0.72	0.21	0.60	0.05	.035	-	0.17	0.51
T Critical two-tail	2.60	4.03	3.25	3.11	3.50	2.72	2.70	2.71	2.68	2.76
$P(T \leq t)$ two-tail	P<.001**	.051	.013	.521	.227	.780	.013	.954	.169	.011
X_5										
Pre-Mean	3.02	2.38	2.93	3.13	2.94	3.20	3.07	2.95	3.09	2.84
Post-Mean	3.26	2.21	3.03	3.13	3.59	3.31	3.33	3.33	3.29	3.11
SD-pre	0.85	0.80	0.71	1.03	0.97	0.57	0.97	0.98	0.73	0.94
Effect Size*	0.28	0.21	0.14	-	0.67	0.19	0.27	0.39	0.27	0.29
T Critical two-tail	2.60	4.03	3.25	3.11	3.50	2.72	2.70	2.71	2.68	2.76
$P(T \leq t)$ two-tail	P<.001**	.785	.129	1.00	.039	.417	.042	P=.001**	.035	.088

X_1 - Beliefs about the nature of mathematics and science

X_2 - Attitudes towards mathematics and science

X_3 - Beliefs about the teaching of mathematics and science

X_4 - Attitudes towards learning to teach mathematics and science

X_5 - Attitudes towards teaching mathematics and science

*Cohen's d Effect Size is based on standard deviation of the pre-survey results for matched participants, d=0.2 is a small effect, d=0.4 is a medium effect, and d=0.8 is a large effect.

** $P \leq .01$,

Appendix I

Table 11

University Physics Participants Attitudes and Beliefs with Effect Size, n=1509

Year	F2003 - S2004	S2004 - F2004	F2004 - S2005	S2005 - F2005	F2005 - S2006	S2006 - F2006	F2006 - S2007	S2007 - F2007	F2007 - S2008	F2008 - S2009
(n)	**78**	**56**	**71**	**64**	**79**	**50**	**42**	**60**	**142**	**144**
X_1	3.78	3.73	3.81	3.67	3.67	3.61	3.81	3.70	3.70	3.70
Pre-Mean	3.73	3.66	3.69	3.37	3.58	3.59	3.82	3.60	3.62	3.48
Post-Mean	0.59	0.47	0.38	0.46	0.45	0.42	0.47	0.60	0.50	0.52
SD-pre	0.09	0.15	0.32	0.65	0.20	0.05	0.02			
Effect Size*	2.64	2.67	2.65	2.66	2.64	2.68	2.70	2.66	2.61	2.61
T Critical two-tail	.403	.256	.036	P<.001	.090	.718	.889	.126	.065	P<.001
P(T ≤ t) two-tail										
X_2	4.22	4.16	3.95	3.84	4.10	4.15	4.38	4.19	4.20	4.22
Pre-Mean	4.40	4.39	4.17	4.30	4.22	4.21	4.56	4.35	4.41	4.39
Post-Mean	0.57	0.58	0.74	0.76	0.59	0.63	0.62	0.75	0.58	0.60
SD-pre	0.31	0.40	0.29	0.61	0.19	0.10				
Effect Size*	2.64	2.67	2.65	2.66	2.64	2.68	2.70	2.66	2.61	2.61
T Critical two-tail	.004*	.003*	P<.001	P<.001	.048	.470	.038	.024	P<.001	P<.001
P(T ≤ t) two-tail										
X_3	3.28	3.26	3.27	3.31	3.26	3.30	3.36	3.21	3.26	3.23
Pre-Mean	3.28	3.33	3.32	3.35	3.28	3.19	3.37	3.33	3.35	3.35
Post-Mean	0.40	0.34	0.74	0.30	0.33	0.26	0.31	0.48	0.36	0.31
SD-pre	-	0.21	0.07	0.13	0.06	0.42				
Effect Size*	2.64	2.67	2.65	2.66	2.64	2.68	2.70	2.66	2.61	2.61
T Critical two-tail	.935	.252	.333	.537	.633	.019	.849	.041	.006*	P<.001
P(T ≤ t) two-tail										
X_4	0.66	0.39	0.45	0.48	0.49	0.37	0.35	0.26	0.38	0.52
Pre-Mean	0.38	0.33	0.49	0.39	0.53	0.46	0.44	0.47	0.68	0.53
Post-Mean	1.33	1.06	1.07	1.20	1.18	1.03	1.08	1.06	1.08	1.15
SD-pre	0.11	0.06	0.04	0.08	0.03	0.09				
Effect Size*	2.64	2.67	2.65	2.66	2.64	2.68	2.70	2.66	2.61	2.61
T Critical two-tail	.053	.693	.835	.602	.830	.652	.607	.235	.015	.929
P(T ≤ t) two-tail										
X_5	0.64	0.45	0.46	0.43	0.48	0.37	0.27	0.26	0.36	0.53
Pre-Mean	0.37	0.35	0.45	0.39	0.49	0.46	0.49	0.47	0.63	0.53
Post-Mean	1.30	1.23	1.03	1.07	1.15	1.03	0.88	1.00	1.02	1.16
SD-pre	0.21	0.08	-	0.04	0.01	0.09				
Effect Size*	2.64	2.67	2.65	2.66	2.64	2.68	2.70	2.66	2.61	2.61
T Critical two-tail	.060	.538	.949	.802	.943	.666	.243	.240	.017	.943
P(T ≤ t) two-tail										

X_1 - Beliefs about the nature of mathematics and science
X_2 - Attitudes towards mathematics and science
X_3 - Beliefs about the teaching of mathematics and science
X_4 - Attitudes towards learning to teach mathematics and science
X_5 - Attitudes towards teaching mathematics and science

*Cohen's d Effect Size is based on standard deviation of the pre-survey results for matched participants, d=0.2 is a small effect, d=0.4 is a medium effect, and d=0.8 is a large effect.

** $P \leq .01$

Table 11 (Continued)

University Physics Participants Attitudes and Beliefs with Effect Size, n=1509

Year	S2009 - F2009	F2009 - S2010	S2010 - F2010	F2010 - S2011	S2011 - F2011	F2011 - S2012	S2012 - F2012	F2012 - S2013	S2013 - F2013
(n)	**41**	**132**	**37**	**126**	**32**	**160**	**43**	**130**	**22**
X_1	3.56	3.69	3.54	3.74	3.64	3.69	3.52	3.62	3.55
Pre-Mean	3.48	3.58	3.61	3.58	3.52	3.58	3.36	3.48	3.28
Post-Mean	0.51	0.44	0.57	0.50	0.52	0.43	0.47	0.51	0.58
SD-pre									
Effect Size*	2.70	2.61	2.72	2.62	2.74	2.61	2.70	2.61	2.83
T Critical two-tail	.301	.023	.412	.003*	.189	.003*	.124	.009*	.003*
$P(T \leq t)$ two-tail									
X_2	4.15	4.17	4.18	4.31	4.36	4.25	4.03	4.20	3.98
Pre-Mean	4.37	4.39	4.28	4.44	4.48	4.43	4.19	4.42	4.34
Post-Mean	0.63	0.60	0.59	0.50	0.52	0.58	0.74	0.66	0.69
SD-pre									
Effect Size*	2.70	2.61	2.72	2.62	2.74	2.61	2.70	2.61	2.83
T Critical two-tail	.005*	P<.001	.276	.007*	.106	P<.001	.158	P<.001	.007*
$P(T \leq t)$ two-tail									
X_3	3.29	3.28	3.28	3.27	3.42	3.38	3.29	3.28	3.37
Pre-Mean	3.41	3.32	3.35	3.34	3.37	3.40	3.32	3.36	3.43
Post-Mean	0.35	0.30	0.29	0.32	0.33	0.31	0.32	0.32	0.26
SD-pre									
Effect Size*	2.70	2.61	2.72	2.62	2.74	2.61	2.70	2.61	2.83
T Critical two-tail	.065	.234	.261	.022	.490	.630	.732	.023	.543
$P(T \leq t)$ two-tail									
X_4	0.28	0.64	0.59	0.70	0.22	0.60	0.79	0.51	0.28
Pre-Mean	0.63	0.45	0.70	0.39	0.31	0.43	0.51	0.49	0.50
Post-Mean	0.91	1.31	1.29	1.39	0.87	1.26	1.47	1.23	0.92
SD-pre									
Effect Size*	2.70	2.61	2.72	2.62	2.74	2.61	2.70	2.61	2.83
T Critical two-tail	.121	.160	.692	.023	.639	.145	.218	.859	.554
$P(T \leq t)$ two-tail									
X_5	0.26	0.60	0.61	0.65	0.22	0.62	0.70	0.50	00.28
Pre-Mean	0.62	0.46	0.68	0.41	0.32	0.42	0.52	0.49	0.50
Post-Mean	0.85	1.24	1.29	1.31	0.87	1.27	1.31	1.19	0.92
SD-pre									
Effect Size*	2.70	2.61	2.72	2.62	2.74	2.61	2.70	2.61	2.83
T Critical two-tail	.107	.264	.802	.069	.594	.094	.415	.961	.554
$P(T \leq t)$ two-tail									

X_1 - Beliefs about the nature of mathematics and science
X_2 - Attitudes towards mathematics and science
X_3 - Beliefs about the teaching of mathematics and science
X_4 - Attitudes towards learning to teach mathematics and science
X_5 - Attitudes towards teaching mathematics and science

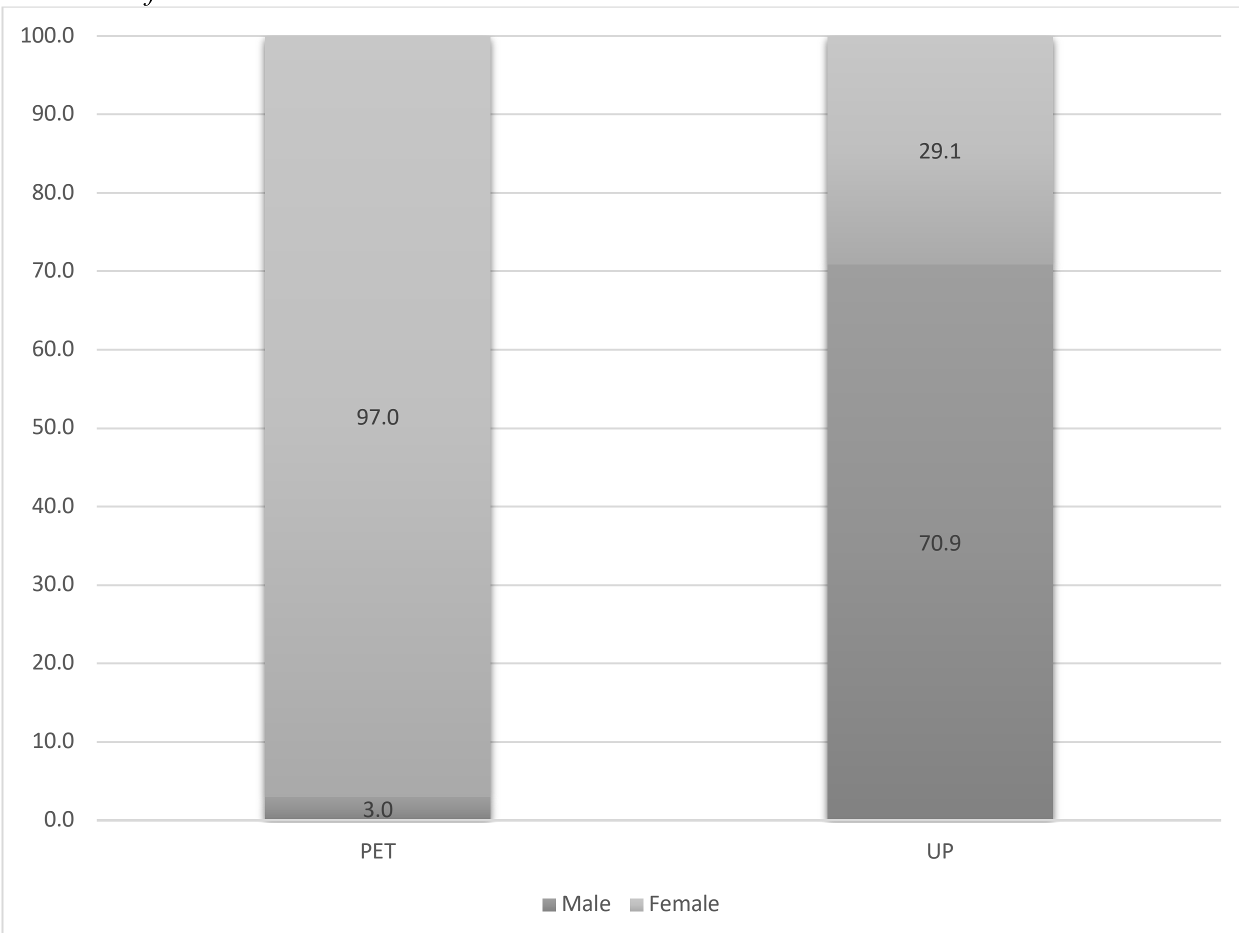
*Cohen's d Effect Size is based on standard deviation of the pre-survey results for matched participants, d=0.2 is a small effect, d=0.4 is a medium effect, and d=0.8 is a large effect.

** $P \leq .01$

Appendix J

Chart 1

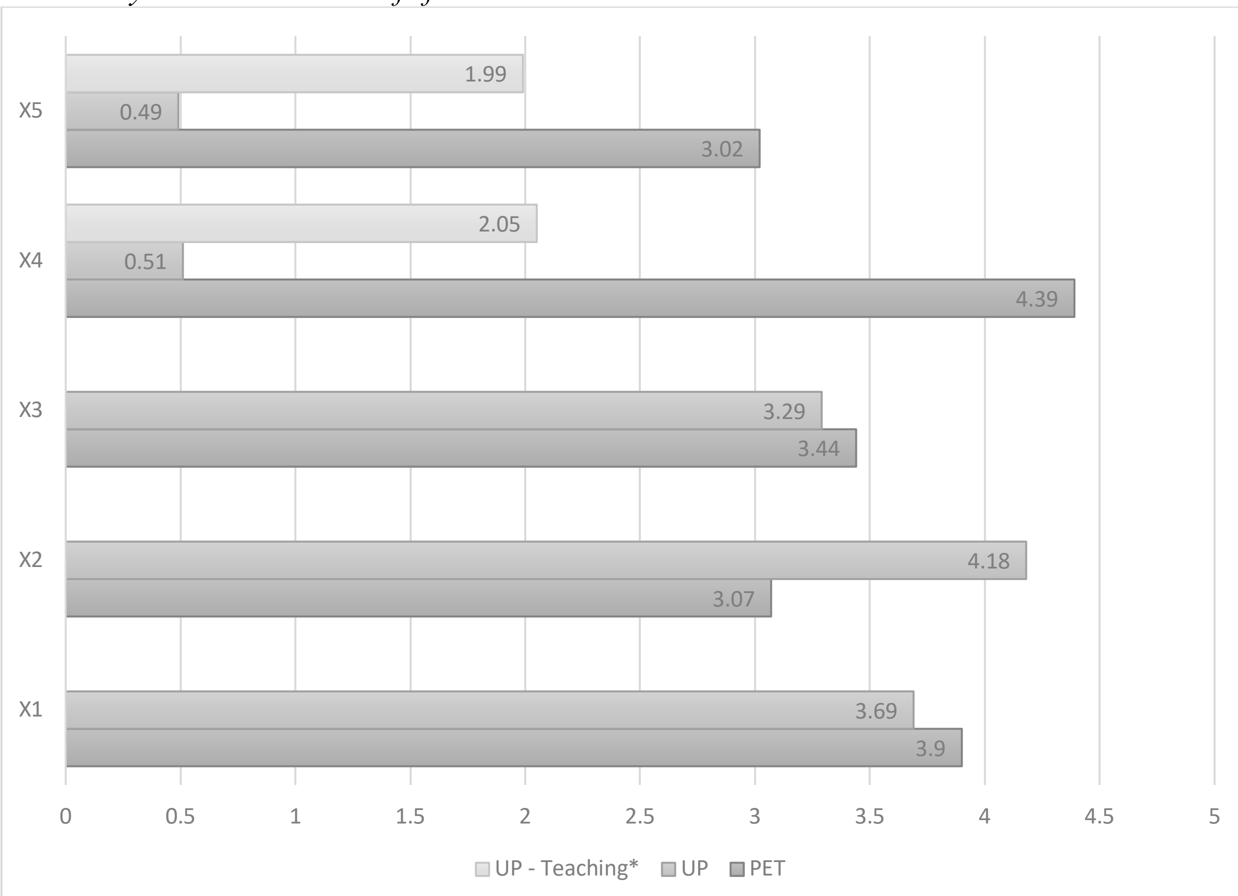
Gender % for PET and UP



Appendix K

Chart 2

Pre-Survey Attitudes and Beliefs for PET and UP



*UP – Teaching represents a subset of UP for only participants who matched pre- and post-survey data for constructs X_4 and X_5 about teaching as a future career.

X_1 - *Beliefs about the nature of mathematics and science*

X_2 - *Attitudes towards mathematics and science*

X_3 - *Beliefs about the teaching of mathematics and science*

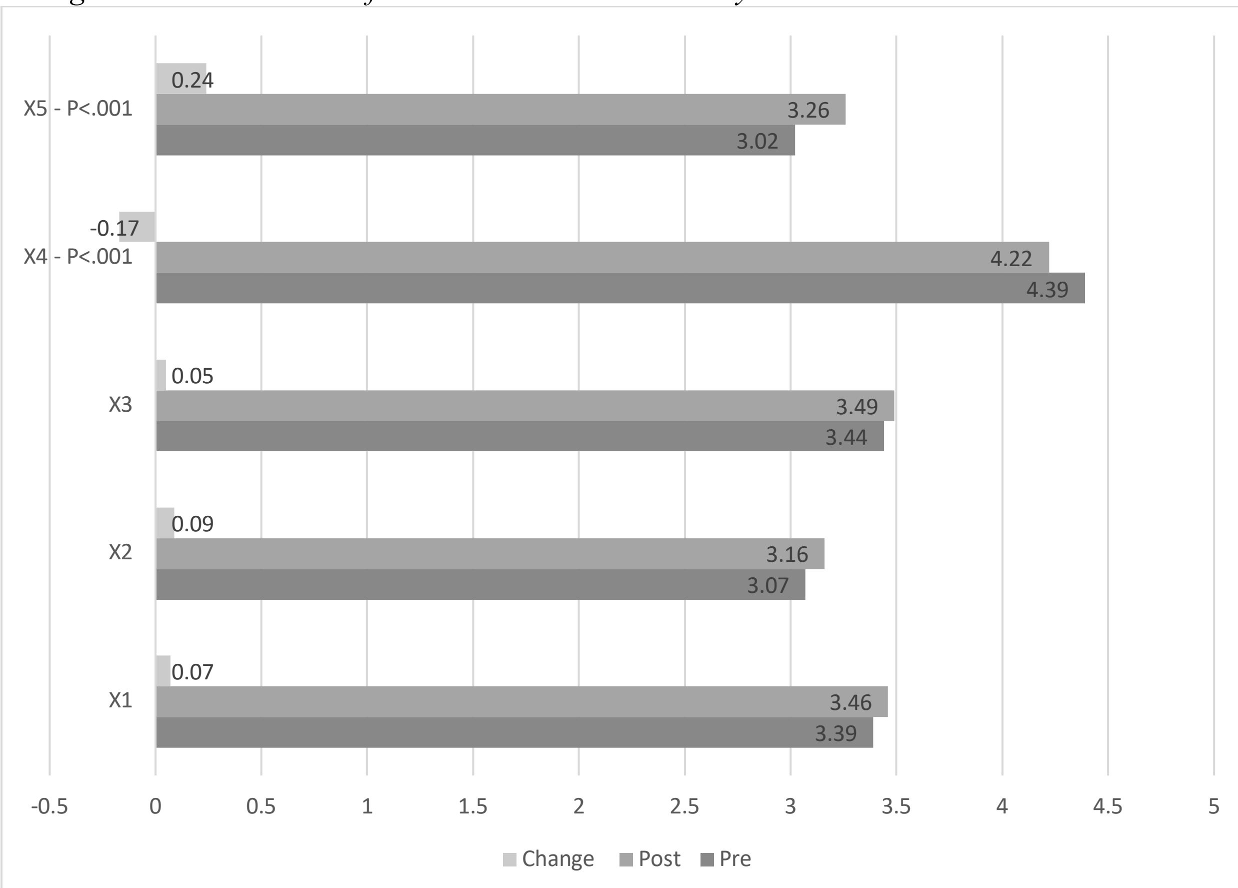
X_4 - *Attitudes towards learning to teach mathematics and science*

X_5 - *Attitudes towards teaching mathematics and science*

Appendix L

Chart 3

Change in Construct Means for PET Pre- and Post-survey

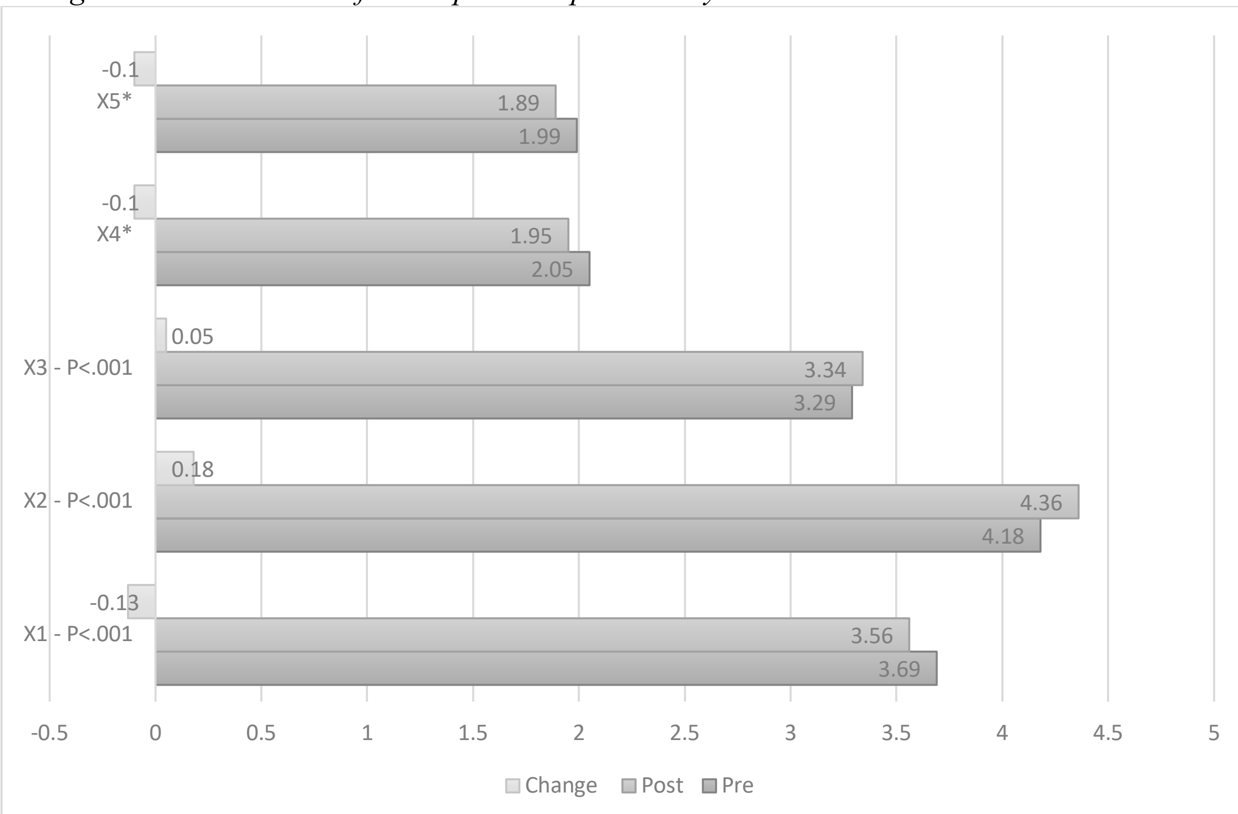


X_1 - Beliefs about the nature of mathematics and science
X_2 - Attitudes towards mathematics and science
X_3 - Beliefs about the teaching of mathematics and science
X_4 - Attitudes towards learning to teach mathematics and science
X_5 - Attitudes towards teaching mathematics and science

Appendix M

Chart 4

Change in construct means for UP pre- and post-survey



*UP – Teaching represents a subset of UP for only participants who matched pre- and post-survey data for constructs X_4 and X_5 about teaching as a future career.

X_1 - *Beliefs about the nature of mathematics and science*

X_2 - *Attitudes towards mathematics and science*

X_3 - *Beliefs about the teaching of mathematics and science*

X_4 - *Attitudes towards learning to teach mathematics and science*

X_5 - *Attitudes towards teaching mathematics and science*

Appendix N

Table 12

Significant differences in change in means for PET and UP

PET	**Pre**	**Post**	**Change**	**Significance**
X_1	Slightly +	+	+	NONE
X_2	Neutral	Slightly +	+	NONE
X_3	+	+	+	NONE
X_4	High +	High +	-	$P<.001$
X_5	Neutral	+	+	$P<.001$

UP	**Pre**	**Post**	**Change**	**Significance**
X_1	+	+	-	$P<.001$
X_2	High +	High +	+	$P<.001$
X_3	Slightly +	Slightly +	+	$P<.001$
X_4	Low -	Low -	-	NONE
X_5	Low -	Low -	-	NONE

X_1 - *Beliefs about the nature of mathematics and science*
X_2 - *Attitudes towards mathematics and science*
X_3 - *Beliefs about the teaching of mathematics and science*
X_4 - *Attitudes towards learning to teach mathematics and science*
X_5 - *Attitudes towards teaching mathematics and science*

Appendix O

IRB Approval Memo

UNIVERSITY OF ARKANSAS

To:	Stephen R Skinner SCEN 106
From:	Chair, Douglas James Adams IRB Committee
Date:	05/03/2019
Action:	**Review Not Required**
Action Date:	05/03/2019
Protocol #:	1904194850
Study Title:	College Physics Lab Survey

Please keep this form for your records. Investigators are required to notify the IRB if any changes are made to the referenced study that may change the status of this determination. Please contact your IRB Administrator if you have any questions regarding this determination or future changes to this determination.

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