

The Effects of a Summer Science Camp Teaching Experience on Preservice Elementary Teachers' Science Teaching Efficacy, Science Content Knowledge, and Understanding of the Nature of Science

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

By

Mollianne G. Logerwell  
Master of Arts  
The College of William and Mary, 1997

Director: Gary Galluzzo, Professor  
College of Education and Human Development

Spring Semester 2009  
George Mason University  
Fairfax, VA

Copyright 2009 Mollianne G. Logerwell  
All Rights Reserved

## ACKNOWLEDGEMENTS

I would like to offer my sincere gratitude to the following people for helping to make this dissertation possible: my husband, Ken, for his unending support and encouragement; our son, Nathaniel, for being so agreeable; Baby #2 for an easy pregnancy; my parents, Bob and Jan George, for instilling in me a love of learning; my in-laws, Ron and Linda Logerwell, for raising such a wonderful son; all my family and friends for providing great advice and free babysitting; Dr. Donna Sterling, Director of CREST, for the opportunity to serve as her research assistant; and, my wonderful committee, Drs. Gary Galluzzo, Anastasia Kitsantas, and Wendy Frazier, for their understanding, patience, and knowledgeable guidance.

## TABLE OF CONTENTS

	Page
List of Tables .....	v
Abstract .....	vi
1. Statement of the Problem.....	1
Research Questions .....	11
Significance of the Problem.....	12
Glossary .....	14
Summary .....	14
2. Theoretical Framework and Literature Review .....	16
Science Content Knowledge .....	16
Efficacy .....	24
Nature of Science .....	40
Summary .....	48
3. Methodology .....	49
Participants and Setting.....	49
Instruments.....	52
Data Collection and Analysis Procedures .....	55
Importance .....	56
4. Results.....	58
Demographic Information.....	58
Science Teaching Efficacy.....	61
Science Content Knowledge .....	64
Understanding of the Nature of Science .....	66
Summary .....	84
5. Discussion and Implications .....	86
Findings.....	87
Discussion .....	90
Implications.....	96
Limitations .....	100
Appendix A: Personal Data Questionnaire .....	102
Appendix B: Science Teaching Efficacy Beliefs Instrument for Preservice Teachers....	104
Appendix C: Science Content Knowledge Assessment, Version A .....	106
Appendix D: Science Content Knowledge Assessment, Version B .....	117
Appendix E: Science Content Knowledge Assessment Information.....	130
Appendix F: Views of Nature of Science Questionnaire – Form C Modified.....	132
Appendix G: Views of Nature of Science Questionnaire Scoring Rubric.....	134
References .....	136

## LIST OF TABLES

Table	Page
1. Course Schedules for the Partnership and Professional Development Schools Cohorts.....	50
2. Participants' Gender and Ethnicity Information .....	59
3. Participants' College Majors.....	60
4. Number of Participants with Science Teaching Experience .....	61
5. Science Teaching Efficacy Belief Instrument Descriptives and Analysis of Variance .....	62
6. Science Teaching Efficacy Belief Instrument Paired Samples <i>t</i> -Tests .....	63
7. Science Content Knowledge Assessment Descriptives and Analysis of Variance.....	66
8. Science Content Knowledge Assessment Paired Samples <i>t</i> -Tests .....	66
9. Views of Nature of Science Descriptives and Analysis of Variance.....	67

## ABSTRACT

### THE EFFECTS OF A SUMMER SCIENCE CAMP TEACHING EXPERIENCE ON PRESERVICE ELEMENTARY TEACHERS' SCIENCE TEACHING EFFICACY, SCIENCE CONTENT KNOWLEDGE, AND UNDERSTANDING OF THE NATURE OF SCIENCE

Mollianne G. Logerwell, PhD

George Mason University, 2009

Dissertation Director: Gary Galluzzo, PhD

The purpose of this study was to investigate the impact of a summer science camp teaching experience on preservice elementary teachers' science teaching efficacy, science content knowledge, and understanding of the nature of science. Master's degree students enrolled in the elementary Fairfax Partnership Schools (FPS,  $n = 21$ ) cohort served as the treatment group, while those enrolled in the Loudoun Partnership Schools (LPS,  $n = 15$ ) and Professional Development Schools (PDS,  $n = 24$ ) cohorts at George Mason University served as the control groups. The treatment group planned for and taught a two-week inquiry- and problem-based summer science camp as part of their science methods course, while the control groups did not. The Science Teaching Efficacy Belief Instrument (STEBI), a science content assessment, a personal data questionnaire, and a modified version of the Views of Nature of Science Questionnaire (VNOS-C) were administered to the participants at the beginning and end of their science methods course.

Analyses revealed significant increases for the FPS group in general science teaching efficacy, personal science teaching efficacy, science teaching outcome expectancy, general science knowledge, biology content knowledge, chemistry content knowledge, and understanding of NOS; the LPS group in general science teaching efficacy, personal science teaching efficacy, chemistry content knowledge, and understanding of NOS; and, the PDS group in general science teaching efficacy, personal science teaching efficacy, and chemistry content knowledge. Additionally, the FPS group had significantly higher general science teaching efficacy than both control groups, personal science teaching efficacy than the PDS group, and understanding of NOS than the LPS group. Overall, the findings indicate that course length is not as important for developing preservice teachers' teaching efficacy and understanding of content as having connected, authentic field-based teaching experiences that are based on best-practices research and coupled with methodological instruction.

## 1. Statement of the Problem

The Organisation for Economic Co-operation and Development (OECD) concluded that the United States' leadership in science and technology since World War II has significantly contributed to its economic strength and quality of life (OECD, 2003). Tassey (1999) estimates that technological developments have accounted for approximately one-half of the U.S.'s growth in the Gross Domestic Product (GDP) and at least two-thirds of the growth in productivity since 1946. Additionally, the Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology (2007) notes that as much as 85% of the growth in the United States' per capita income in the first half of the twentieth century was due to advances in science and technology. This prosperity has been attributed largely to strong academic and research traditions. In 2005, for example, with just 5% of the world's population, the United States employed nearly one-third of the world's scientific and engineering researchers, accounted for 40% of all research and development spending, published 35% of science and engineering articles, and obtained 44% of science and engineering citations (Freeman, 2005).

As international economies become increasingly interdependent, however, there is growing concern that the U.S.'s position in the global marketplace is in jeopardy. Our trade balance in high-tech manufactured goods, for example, shifted from approximately



+\$30 billion in 2000 to nearly -\$40 billion in 2006 (National Science Board, 2008).

Additionally, research and development expenditures as a percent of the GDP remained stagnant in the United States from 1991 to 2001, while they increased in Japan, the European Union, China, Canada, and South Korea during the same time period (OECD, 2005). In terms of education, in 2004 more than 25 countries had a higher percentage of 24-year-olds with degrees in science and engineering than the United States did (NSB, 2004), and it is estimated that the U.S. share of science and engineering doctorates granted will fall from more than 50% in 1970 to about 15% in 2010 (Freeman, 2005). The Center for Strategic and International Studies (CSIS, 2005) estimates that if these and other similar trends continue the foundation of the United States' technological strength will be threatened by 2020.

With such an economic outlook, attention has turned again to the state of science education. Given that it is projected that employment in the science and engineering sectors will grow at twice the rate of the general workforce between 2004 and 2014 (NSB, 2008), the United States' continued economic stability is dependent on its ability to produce sufficient numbers of graduates with backgrounds in science and mathematics. Data from national tests, however, indicate that the current education system is struggling to meet this need. The National Assessment of Educational Progress (NAEP) (Grigg, Lauko, & Brockway, 2006) showed that:

- 12<sup>th</sup> grade scores in 2005 were unchanged from 2000 but lower than 1996 with 80% of students performing below the proficient level of competency

- 8<sup>th</sup> grade scores in 2005 were unchanged from both 1996 and 2000 with 68% of students performing below the proficient level of competency

- 4<sup>th</sup> grade scores in 2005 were higher than both 1996 and 2000 with 32% of students performing at the proficient or advanced levels of competency

The growth in the 4<sup>th</sup> grade scores was due almost exclusively to minority, low income, and lower-performing students moving up to the basic level of competency; the highest-performing students showed no improvement between 1996 and 2005. Additionally, 67% of 4<sup>th</sup> graders who performed below the basic level of competency were from low income families and 42% attended central city schools. For 8<sup>th</sup> graders, 56% of students performing below the basic level were from low income families and 20% spoke a language other than English at home. In 12<sup>th</sup> grade, 35% of those who performed below the basic level of competency had at least one parent with a college degree and 18% had taken at least one Advanced Placement science course.

International tests also show a mixed picture of achievement. The results of the 2003 Trends in International Mathematics and Science Study (TIMSS) (Gonzales, Guzmán, Partelow, Pahlke, Jocelyn, Kastberg, & Williams, 2004) showed that:

- 4<sup>th</sup> and 8<sup>th</sup> grade science students in the U.S. performed above the international average

- 4<sup>th</sup> grade science scores showed no change from 1995 to 2003

- 8<sup>th</sup> grade science scores increased from 1995 to 2003

- 4<sup>th</sup> grade science students ranked 2<sup>nd</sup> in 1995 and 5<sup>th</sup> in 2003 compared to the other participating countries

- 8<sup>th</sup> grade science students ranked 14<sup>th</sup> in 1995 and 7<sup>th</sup> in 2003 compared to the other participating countries

Similarly, on the 2006 Program for International Student Assessment (PISA), fifteen-year-old students in the United States had lower science literacy scores than the international average with 22 countries performing better than the U.S. (Baldi, Jin, Skemer, Green, & Herget, 2007). The outlook for undergraduate science education does not fare much better. Through the 1990's, approximately 30% of entering college freshmen indicated their intent to major in science or engineering but only 15% of college graduates had earned a degree in those fields (Smith, 2001).

### *A Call for Reform*

In response to this picture, many have renewed the call for reforming our education system. Building upon the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), the *National Science Education Standards* (National Research Council, 1996), and the No Child Left Behind Act of 2001, several national organizations advocate focusing on improving teacher quality in order to increase student achievement. In *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, the Committee on Prospering in the Global Economy of the 21st Century's (2007) first recommendation is to strengthen the recruitment and training of K-12 science and mathematics teachers. Similarly, the Committee on Science Learning, Kindergarten through Eighth Grade, in *Taking Science to School: Learning and Teaching Science in Grades K-8* (Duschl, Schweingruber, & Shouse, 2007), makes eight suggestions for improving K-8 science education, three of

which focus on teacher education. In *Keeping America Competitive: Five Strategies to Improve Mathematics and Science Education*, the Education Commission of the States and the National Science Foundation (Coble & Allen, 2005) also lists increasing teacher knowledge and skills as a key strategy for strengthening science and mathematics education in the United States.

Improving teacher education as a means to increase student achievement has strong support in the literature. Ferguson (1991), for example, found that combined measures of teacher quality, including scores on state licensing examinations, completion of master's degrees, and years of experience, accounted for more variation in students' reading and mathematics scores than did socioeconomic status. More recently, Darling-Hammond (2000) found similar results using data from the 1993-94 Schools and Staffing Surveys and the 1992, 1994, and 1996 NAEP exams. Her analysis showed that teacher characteristics such as certification status and having a degree in the field they were teaching were significantly and positively correlated to student outcomes in mathematics and reading. Partial correlations showed that these relationships held even when controlling for student poverty and English language proficiency status. Darling-Hammond concluded that having a well-qualified teacher was the most important determinant of student achievement for all subject areas and grade levels studied.

Similar results have been found for science achievement. In a meta-analysis of 65 studies, Druva and Anderson (1983) found that students' science scores were positively related to the number of courses in both education and science content that teachers had completed. Using data from the Longitudinal Study of American Youth (LSAY), Monk

(1994) determined that teachers' content preparation in science, as measured by the number of courses in the subject field, was positively correlated to student achievement. Goldhaber and Brewer (1997) examined data from the 1998 National Education Longitudinal Study (NELS:88) and found a significant, positive relationship between teachers having a bachelor's degree in science and tenth grade students' science scores. Additionally, based on data from the 1996 NAEP, Wenglinsky (2000) found that eighth-grade science teachers who had a major or minor in the subject they were teaching, received professional development in laboratory skills, or utilized hands-on learning activities in the classroom had students who outperformed their peers by approximately 40% of a grade level. These factors together were as strongly correlated to achievement scores as socioeconomic status.

Even though teacher preparation and classroom practices have been linked to student achievement, elementary teachers have been shown to lack both the content knowledge and confidence to teach science effectively (Khalid, 1999; Newsome, 2003; Ramey-Gassert, 1993; Schulte, 2001). The *Bayer Facts of Science Education X: Are the Nation's Colleges and Universities Adequately Preparing Elementary Schoolteachers of Tomorrow to Teach Science?* (Bayer Corporation, 2004) reports that 39% of elementary teachers surveyed do not feel qualified to teach science, 71% indicated that they are somewhat, a little, or not at all science literate, and 63% wish they had received more preservice training in teaching science. This lack of confidence regarding science among elementary teachers results in less time spent teaching science. Morton and Dalton (2007) found that science was taught, on average, only 2.3 hours per week in grades one through

four during the 2003-2004 school year in the United States. This accounted for only 7.1% of the school day.

Further, it has been shown that when elementary teachers do teach science, more than a third of them use a textbook as the primary basis for their lessons instead of the learning approaches advocated by national science reform documents (AAAS, 1993; Martin, Mullis, Gonzales, & Chrostowski, 2004; NRC, 1996). Some studies indicate that elementary teachers' reliance on the textbook may be due to their lack of content knowledge (Ball & Feiman-Nemser, 1988; Dobey & Schafer, 1984; Morey, 1990). Indeed, other research has shown that elementary teachers with stronger science content knowledge are better able to plan inquiry-based lessons (Luera, Moyer, & Everett, 2005), emphasize conceptual understanding, process skills, and content accuracy (Wolffe, 1992), and utilize student-centered and cooperative learning activities (Gee, Boberg, & Gabel, 1996).

The lack of effective science teaching in elementary classrooms must be overcome if the United States hopes to meet the growing demand for scientifically literate workers. It is unlikely that enrollment in or successful completion of secondary and post-secondary science courses will increase without students receiving a strong science foundation in elementary school. Because elementary teachers have been shown to be weak in areas associated with student achievement, namely content knowledge and reform-based pedagogical practices, teacher education programs must find ways to address these deficiencies with preservice elementary teachers.

*Ways to Improve Elementary Science Teaching*

There are several modes through which the issue of elementary science teaching can be addressed. Three approaches that have support in the literature relate to increasing elementary teachers' science content knowledge, science teaching efficacy, and understanding of the nature of science.

*Content knowledge.* As cited previously, elementary teachers have demonstrated insufficient understanding of the science concepts they are expected to teach. This, in turn, may lead to them avoiding science instruction altogether or using inappropriate pedagogical techniques. Research suggests several ways to improve preservice elementary teachers' science content knowledge. Science methods courses which utilize inquiry-based, hands-on activities, for example, have been shown to increase teachers' science content knowledge (Doby, 1997; Groves & Pugh, 2002; Hypolite, 2003; Trundle, Atwood, & Christopher, 2002). Incorporating whole class reflection (Groves & Pugh, 2002) and learning content in the teaching context (Doby, 1997) have also been identified as important factors. In some cases, gains were seen for courses lasting as little as three to six weeks (Hypolite, 2002; Trundle et al., 2002). Other studies indicate that teaching science to children can also improve teachers' science content knowledge (Stein, 2006).

*Science teaching efficacy.* Increasing elementary teachers' science teaching efficacy is another approach that has the potential to improve elementary science teaching. Teaching efficacy has been positively related to student achievement (Armor, Conroy-Oseguera, Cox, King, McDonnell, Pascal, Pauly, & Zellman, 1976; Anderson, Greene, & Loewen, 1988; Ashton & Webb, 1986; Hannum, 1994; Kerley, 2004; Ledford, 2002; Midgley, Feldlaufer, & Eccles, 1989; Moore & Esselman, 1992; Muijs &

Reynolds, 2002; Ross, 1992; Ross, 1998; Staples, 2002; Watson, 1991) as well as teachers' willingness to implement innovative methods (Allinder, 1994), utilization of hands-on, inquiry-based activities in the classroom (Lee & Houseal, 2003; Ramey-Gassert, 1993), comfort level with cooperative, student-centered instruction (Lee & Houseal, 2003; Ramey-Gassert, 1993; Woolfolk & Hoy, 1990), motivation to participate in professional development activities focused on improving science teaching (Ramey-Gassert, 1993), and ability to overcome obstacles to effective teaching (Lee & Houseal, 2003).

Research has also indicated that there is a relationship between teaching efficacy and content knowledge. Downing, Filler, and Chamberlain (1997), for example, found that preservice elementary teachers who were more proficient in basic science process skills had greater confidence in their ability to learn science. Similarly, Chang (2003) noted positive correlations between preservice teachers' science teaching efficacy and general content knowledge, while Mulholland, Dorman, and Odgers (2004) discovered a positive relationship between teaching efficacy and the number of high school science courses taken. Associations have also been revealed between preservice teachers' science teaching efficacy and specific science misconceptions (Koc, 2006; Schoon & Boone, 1998) and subject-specific content knowledge (Cakiroglu, 2000).

Science methods courses have been shown to have an impact on efficacy. In particular, courses that implement constructivist-based approaches (Bleicher & Lindgren, 2005; Graves, 1999; Morrell & Carroll, 2003; Thompson, 2003), integrate science content with how to teach it (Thompson, 2003), and include opportunities to teach



science to children (Ginns, Watters, Tulip, & Lucas, 1995; Graves, 1999; Wingfield, 1998) have successfully increased preservice elementary teachers' science teaching efficacy. As with science content, gains in science teaching efficacy have been seen in courses lasting as little as six weeks (Bleicher & Lindgren, 2005).

*Nature of science.* Another approach that has the potential to improve elementary science teaching is to address elementary teachers' understanding of the nature of science (NOS). Although relationships between NOS and classroom practice or student achievement are not well developed, there are indications that an adequate understanding of NOS is necessary if teachers are to teach science effectively. National science reform documents such as the *Benchmarks for Science Literacy* (AAAS, 1993) and *National Science Education Standards* (NRC, 1995) emphasize the importance of students developing satisfactory conceptions of the nature of science. If elementary teachers are unable to successfully teach subject matter content because their knowledge about it is lacking, then the same logic should hold for NOS. Teachers cannot teach what they do not know, and studies suggest that elementary teachers have minimal understanding of NOS (Keske, 2002; Lederman, 1992; Stockton, 2002).

Research indicates that the most effective way to improve preservice teachers' understanding of NOS is through a reflective, explicit, activity-based approach (Akerson, Abd-El-Khalick, & Lederman, 2000; Matkins, Bell, Irving, & McNall, 2002) in either science content or science methods courses. Other studies suggest that including historical and philosophical perspectives (Lederman, 1992), cooperative controversy activities (Hammrich & Blouch, 2006), science research projects, and opportunities to

teach science to children (Meichtry, 1999) may also have positive impacts on teachers' conceptions of NOS.

### Research Questions

The literature indicates that teaching science to children has been associated with increases in preservice elementary teachers' science content knowledge, science teaching efficacy, and understanding of the nature of science (Ginns et al., 1995; Graves, 1999; Meichtry, 1999; Stein, 2006; Wingfield, 1998). Therefore, the purpose of this study is to examine the effects of a summer science camp teaching experience on preservice elementary teachers' science teaching efficacy, science content knowledge, and understanding of the nature of science. Specifically, the research questions are:

(1a) How does preservice elementary teachers' science teaching efficacy change during their science methods course? (1b) Is there a difference between the science teaching efficacy of preservice elementary teachers who plan for and teach a two-week inquiry-based summer science camp and preservice elementary teachers who do not participate in the camp as their fieldwork experience?

(2a) In what ways do preservice elementary teachers' general and subject-specific science content knowledge change during their science methods course? (2b) Is there a difference between the change in general science knowledge and the change in subject-specific knowledge? (2c) Is there a difference between the general or subject-specific science content knowledge of preservice elementary teachers who plan for and teach a two-week inquiry-based summer science camp and preservice elementary teachers who do not participate in the camp as their fieldwork experience?

(3a) How does preservice elementary teachers' understanding of the nature of science change during their science methods course? (3b) Is there a difference between the understanding of the nature of science of preservice elementary teachers who plan for and teach a two-week inquiry-based summer science camp and preservice elementary teachers who do not participate in the camp as their fieldwork experience?

### Significance of the Problem

Data from a variety of sources indicate that there are deficiencies in the current state of elementary science education in the United States. Students are not performing well on either national (Grigg et al., 2006) or international assessments (Gonzales et al., 2004; Baldi et al., 2007), and elementary teachers have been shown to lack both the content knowledge and confidence to teach science effectively (Bayer Corporation, 2004; Khalid, 1999; Newsome, 2003; Ramey-Gassert, 1993; Schulte, 2001). In the short-term, science teaching in elementary classrooms must improve in order to meet the mandates of the No Child Left Behind Act of 2001 because science began to be included in adequate yearly progress calculations starting with the 2005-2006 school year (NCLB, 2001). In the long term, projected growth in the science and engineering workforce (NSB, 2008) will create a demand for more people with adequate preparation in these fields.

Improving preservice elementary teachers' science content knowledge, science teaching efficacy, and understanding of the nature of science may address the issue of ineffective elementary science teaching. Teachers' content knowledge has been linked to increases in student achievement (Druva & Anderson, 1983; Goldhaber & Brewer, 1997; Monk, 1994; Wenglinsky, 2000) and to the utilization of reform-based instructional

practices (Gee et al., 1994; Luera et al., 2005; Wenglinsky, 2000; Wolffe, 1992).

Teaching efficacy has also been positively correlated to student achievement (Armor et al., 1976; Anderson et al., 1988; Ashton & Webb, 1986; Hannum, 1994; Kerley, 2004; Ledford, 2002; Midgley, Feldlaufer, & Eccles, 1989; Moore & Esselman, 1992; Muijs & Reynolds, 2002; Ross, 1992; Ross, 1998; Staples, 2002; Watson, 1991) and to the use of pedagogically appropriate teaching techniques (Allinder, 1994; Lee & Houseal, 2003; Ramey-Gassert, 1993; Woolfolk & Hoy, 1990). Understanding of the nature of science is emphasized in national science reform documents (AAAS, 1993; NRC, 1995), and some research (Lederman, 1986; Lederman & Druger, 1985) has demonstrated a relationship between teachers' adequate conceptions of NOS and implementation of appropriate learning strategies. Additionally, teachers with low science teaching efficacy have been shown to be uncomfortable with reform-based instructional practices because they want the "right" answer (Graves, 1999); increasing their understanding of NOS may help them to overcome this obstacle. It is the purpose of this study to assess the effects of a preservice teaching experience in a two-week summer camp on preservice elementary teachers' knowledge of science content, science teaching efficacy, and their conceptions of the nature of science. In this way, this study addresses several issues identified in the literature, namely elementary teachers' lack of science content knowledge (Khalid, 1999; Schulte, 2001), low science teaching efficacy (Newsome, 2003; Ramey-Gassert, 1993), and poor understanding of the nature of science (Keske, 2002; Lederman, 1992; Stockton, 2002).

## Glossary

Science Teaching Efficacy Beliefs: “Those beliefs of elementary teachers which include both outcome expectancies and self-efficacy beliefs in the area of science teaching” (Riggs, 1988, p20).

Personal Science Teaching Efficacy (PSTE): This refers to elementary teachers’ “beliefs in their ability to perform teaching behaviors in science” (Riggs, 1988, p20).

Science Teaching Outcome Efficacy (STOE): This refers to “the degree to which elementary teachers believe students can be taught science given external factors such as their family background, socioeconomic status (SES), or school conditions” (Riggs, 1988, p20).

Nature of Science (NOS): “[T]he epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development” (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002, p498). Factors that are relevant for K-12 education include the ideas that scientific knowledge is empirical, tentative, theory-laden, partly the product of human imagination and creativity, and socially and culturally embedded as well as the distinction between observation and inference, the lack of a single method for doing science, and the functions of and relationships between scientific theories and laws.

## Summary

This chapter provided the context for this study. The need for a scientifically literate workforce, the importance of having adequately prepared teachers, and the challenges facing elementary science education were outlined. An overview of the

literature related to possible ways to ameliorate the lack of effective elementary science teaching was given. Finally, examining the effects of a summer science camp teaching experience on preservice elementary teachers' science content knowledge, science teaching efficacy, and understanding of the nature of science was presented as the purpose of this study, and three main research questions were proposed.

## 2. Theoretical Framework and Literature Review

The purpose of this study is to examine the effects of a summer science camp teaching experience on preservice elementary teachers' science content knowledge, science teaching efficacy, and understanding of the nature of science. In this chapter, the relevant literature on elementary teachers' science knowledge, science teaching efficacy, and nature of science understanding will be reviewed

### Science Content Knowledge

#### *Elementary Teachers' Science Content Knowledge and Student Achievement*

Several studies have shown that teacher preparation, both in general (Darling-Hammond, 2000; Ferguson, 1991) and in the specific content area being taught (Druva & Anderson, 1983; Goldhaber & Brewer, 1997; Monk, 1994; Wenglinsky, 2000), has a positive influence on student achievement. In some cases, teacher preparation has been found to be at least as important as the student's socio-economic status (Darling-Hammond, 2000; Wenglinsky, 2000). These studies, however, examined combined elementary/secondary data sets (Darling-Hammond, 2000; Ferguson, 1991), concentrated on the middle and/or high school levels (Druva & Anderson, 1983; Goldhaber & Brewer, 1997; Monk, 1994; Wenglinsky, 2000), or were not related to science (Darling-Hammond, 2000; Ferguson, 1991). A few studies explored the relationship between elementary teachers' content knowledge and student achievement (Betts, Zau, & Rice,

2003; Croninger, Rice, Rathbun, & Nishio, 2007; Eberts & Stone, 1984), but these studies focused on reading and mathematics rather than science. No studies were found that focused on elementary teachers' science content knowledge and student achievement in science.

#### *Science Content Knowledge of Preservice Elementary Teachers*

Through a study of 113 college juniors and seniors, Khalid (1999) investigated elementary education majors' knowledge of environmental issues. Participants completed a survey on which they agreed, disagreed, or indicated that they did not know about 29 statements related to acid rain, ozone depletion, and the greenhouse effect. For each statement, participants were asked to explain their choice. Twenty-three volunteers were also interviewed in order to clarify the qualitative responses. Results indicated that only nine (31%) of the statements were answered correctly by at least 45% of the participants. Analysis of the explanations and follow-up interviews revealed that the preservice elementary teachers' misconceptions could largely be contributed to misrepresentations of information in textbooks and by the media.

In a similar study, Schulte (2001) examined preservice elementary teachers' alternative conceptions in earth/space, life, and physical science as well as their attitudes toward teaching science. One hundred and eighty-four participants completed a multiple-choice test of common science alternative concepts and a science attitude survey at the beginning of their science methods course. Results showed that 75% of the preservice elementary teachers held alternative concepts of basic concepts in earth/space, life, and physical science, and that 50% of participants held alternative concepts related to all of



the physical science concepts assessed. Additionally, correlation analysis revealed an inverse relationship between the number of alternative conceptions held and attitudes toward teaching science. In particular, participants with the highest number of alternative conceptions also had the lowest attitude toward the need for Americas to learn science ( $r = -.233, p < .05$ ), the importance of science in elementary school ( $r = -.251, p < .05$ ), and their ability to teach science effectively ( $r = -.332, p < .01$ ).

#### *Elementary Teachers' Science Content Knowledge and Classroom Practice*

Luera, Moyer, and Everett (2005) examined the relationship between preservice elementary teachers' science content knowledge and their ability to plan an inquiry-based science lesson. For this study, 234 participants enrolled in an elementary science methods course developed a lesson plan based on the 5-E learning cycle and took a content knowledge test based on released items from the 11<sup>th</sup> grade Michigan state science achievement test. Analyses of the lesson plan rubric scores and achievement test scores showed that there was a significant, positive, and modest correlation ( $r = .33, p = .000$ ) between the preservice teachers' science content knowledge and the ability to plan an inquiry-based lesson using the 5-E model. Further analysis revealed that the "constructing new scientific knowledge" sub-score on the achievement test correlated with the lesson plan rubric score ( $r = .30, p = .000$ ). Based on these findings, the authors concluded that both discipline content knowledge and inquiry content knowledge are needed for preservice elementary teachers to plan inquiry-based science lessons.

In order to examine the relationship between content knowledge and elementary science teaching, Wolffe (1992) studied two preservice teachers while they were student

teaching. Both participants were female, were student teaching in the sixth grade in the same school district, and were enrolled in the same methods course. One participant had maintained a GPA of 3.0 for the six undergraduate science courses she had taken. The other participant had earned a GPA of 2.0 for the three undergraduate science courses she had taken. Using data obtained from audiotapes of classroom instruction, field notes from observations, and interviews, Wolffe looked for differences in the science teaching of these two student teachers. During science lessons, the participant with more content knowledge included conceptual understanding and process skills, utilized student-directed and discovery activities, used questioning techniques for instructional purposes rather than review, emphasized content accuracy, and made efforts to enhance her own content knowledge when planning. In contrast, the participant with less content knowledge depended on the textbook when planning, emphasized factual knowledge, ignored or reinforced students' content errors, and spent instructional time on activities unrelated to the lesson objectives.

In a similar study, Gee, Boberg, and Gabel (1996) followed 58 senior-level elementary education majors during their student teaching experience. Based on data collected from classroom observations, lesson plans, reflections, interviews, and surveys, the authors found that most preservice teachers admitted that they had minimal content knowledge related to the science topics they were expected to teach, advocated the use of inquiry but did not practice it, and rarely incorporated teaching strategies such as cooperative learning during their science lessons. The authors noted that there appeared to be a relationship between the participants' use of pedagogically-appropriate

instructional methods and their ability to cope with classroom management concerns. Student teachers who struggled with classroom management were less likely to employ student-centered learning strategies.

Harlen (1997) conducted a multi-phase study which examined the relationship between elementary teachers' background in science, understanding of science, and confidence to teach science. A follow-up investigation explored the coping strategies used by teachers who reported low confidence in their ability to teach science and displayed lower levels of science understanding. In the first phase of the project, 514 teachers completed a questionnaire about their background in and confidence to teach science. The second phase involved interviewing a subset ( $n = 55$ ) of participants regarding their understanding of science concepts. In phase three, the follow-up portion, 33 teachers kept notes about their teaching for ten weeks and then completed another interview. Data from the first and second phases revealed that 100% of the teachers self-identified as having lower levels of science knowledge had no background in science and 67% reported low levels of confidence regarding science teaching. Analysis from the third phase revealed that teachers with low confidence and minimal knowledge utilized six primary strategies regarding science teaching: (1) avoid teaching it, (2) teach only the content with which they are comfortable (usually biology), (3) stress process over concepts, (4) rely on the book or other step-wise instructions, (5) emphasize didactic teaching, and (6) implement only simple hands-on activities.

Appleton and Kindt (1999) found comparable results in a study which focused on beginning elementary teachers. Data from interviews and observations of nine teachers

showed that participants with minimal science content knowledge usually compensated by either not teaching science at all or relying on “activities that work.” Teachers had collected such lessons from colleagues, the textbook’s teacher resource package, or independent activity books. These activities were easily managed by the teacher, focused on factual knowledge, and used a “proven” method to find “the right” answer. The authors concluded that elementary teachers with nominal understanding of science content substitute these “activities that work” for authentic knowledge of the information they are required to teach.

These studies suggest that elementary teachers who lack science content knowledge struggle not only to plan but also implement science lessons that are in accordance with the recommendations made in national reform documents, such as a focus on active inquiry into authentic questions, cooperative learning, and critical examination of evidence (e.g., AAAS, 1993; NRC, 1996).

#### *Sources of and Changes in Elementary Teachers’ Science Content Knowledge*

In order to study how elementary teachers gained their science content knowledge, Stein (2006) did case study analyses of eight early elementary school teachers identified as being exemplary science instructors by their administrators. Through a series of interviews, the participants conveyed that they had developed their science content knowledge primarily through science content courses and science-specific methods courses during their teacher preparation programs. Additionally, those participants who had taught science during their student teaching experiences felt that that opportunity also contributed to their science content knowledge. This study indicates

that content courses, subject-specific methods courses, and preservice science teaching experiences may positively impact elementary teachers' science content knowledge.

Other studies have examined the influence of various interventions on preservice elementary teachers' science content knowledge. Doby (1997), for example, investigated the influence of an experimental elementary science methods course on preservice teachers' Earth and physical science content knowledge. Eighty-nine participants enrolled in the experimental methods course were compared to 78 participants in a traditional methods course. The experimental course employed an interactive laserdisc program, multiple hands-on activities, and supplemental texts to emphasize teaching strategies and methods in the context of the science content being taught. The traditional course used textbook readings, lecture, discussion, and supplemental hands-on activities to address science content and teaching strategies. Results of the pre- and post-administrations of an elementary science concepts test revealed significantly higher gains in the experimental group's Earth and physical science content knowledge compared to the traditional group ( $F(1, 165) = 743.8, p < .025$ ).

In a similar study, Hypolite (2003) looked at the impact of an inquiry-based, six-week unit on preservice elementary teachers' knowledge of plant biology. Forty juniors and seniors enrolled in two sections of elementary science methods at the same university participated in the study. The section which completed the inquiry-based unit served as the treatment group, while the section which completed a traditional unit of study on the same content served as the control group. Both groups were taught by the researcher. Pre/posttest analysis of content tests revealed that the control group had a mean gain

score of 0.9 and the treatment group had a mean gain group of 2.6, which resulted in an effect size of 0.53. Hypolite concluded that the hands-on, inquiry approach employed in the treatment course produced significant gains in the preservice teachers' knowledge of the science content taught.

Groves and Pugh (2002) also examined the effect of an education methods course on the science content knowledge of preservice elementary teachers. Two cohorts (N = 54) of students enrolled in their science methods course the semester prior to student teaching participated in the study. After taking a 37 item pretest, participants engaged in a short term intervention which, via discussions and activities, was designed to challenge and correct their inaccurate knowledge regarding the sources of, effects of, and solutions for ozone depletion. A posttest was administered approximately eight weeks later. Analysis revealed significant improvements on the overall test score as well as on each of the three subscales' scores, thereby suggesting that even short term interventions can improve preservice teachers' understanding of complex science concepts.

Taking a more qualitative approach, Trundle, Atwood, and Christopher (2002) explored the changes in preservice elementary teachers' conceptions of moon phases during an inquiry-based physics course designed for undergraduate elementary education majors. As part of a larger study, 42 participants recorded daily observations of the moon for two months, sketched a sequence of shapes of moon phases, participated in psychomotor modeling, and verbally and in writing explained their understanding of moon phases. Data collected via structured interviews before and after the three week unit revealed an increase in the number of preservice elementary teachers demonstrating

scientifically accurate conceptions of moon phases. Before the unit, only 4.8% of the participants showed acceptable understandings, while 76.2% displayed accurate conceptions after the unit. This suggests that giving preservice elementary teachers multiple opportunities to actively engage science content and personally connect it to their lives can increase their understanding of the concepts involved.

These studies demonstrate that science methods courses, particularly those that integrate the content with how to teach it and are inquiry-based like the one in which the treatment group in this study will be enrolled, have the potential to improve preservice elementary teachers' science content knowledge. Gains were seen in a variety of science content areas and in investigations which utilized interventions lasting as little as six weeks.

## Efficacy

### *The Self-Efficacy and Teaching Efficacy Constructs*

The construct of self-efficacy emerged out of Bandura's social learning theory (1977). It posits that people are more likely to perform an action if (1) they believe it will have a favorable result (i.e., outcome expectancy) and (2) they are confident that they can perform the action successfully (i.e., self-efficacy expectation). Bandura (1997) proposed four factors that influence one's self-efficacy expectation for a specific action. The first factor, enactive mastery experiences, relates to how well one personally did in past incidents that are perceived to be similar. Vicarious experience, the second factor, is associated with comparing oneself to someone else of similar ability who completed a similar task. The third factor is verbal persuasion; it deals with the feedback one receives

from others regarding his/her task performance. The fourth factor that influences self-efficacy is one's physiological and affective state. Additionally, according to Bandura, self-efficacy is situation-specific. It is possible to be highly self-efficacious in one situation but to have low self-efficacy given another set of circumstances. For example, teachers could have high reading teaching efficacy but low science teaching efficacy.

Rooted in this conceptualization of self-efficacy, researchers began to develop instruments to measure the construct. One of the first was Gibson and Dembo's (1984) Teacher Efficacy Scale (TES). Based on data obtained from a multi-phase method that included literature review, teacher interviews, factor analysis, multitrait-multimethod matrix analysis, and classroom observations, the TES was a 30-item, 6-point Likert-type questionnaire. Two subscales, personal teaching efficacy (PTE) and general teaching efficacy (GTE), emerged from the analysis. PTE represents a teacher's belief that s/he "has the skills and abilities to bring about student learning" (p. 573). GTE represents a teacher's belief that any teacher's "ability to bring about change is significantly limited by factors external to the teacher, such as the home environment, family background, and parental influences" (p. 574).

Due to the context-specific nature of self-efficacy, researchers have built upon Gibson and Dembo's scale and created efficacy instruments to measure teachers' efficacy for specific subjects. Riggs (1988), for example, developed the Science Teaching Efficacy Belief Instrument (STEBI), a 25-item, 5-point Likert-type questionnaire with two subscales. The first subscale, personal science teaching efficacy (PSTE), is associated with a teacher's belief that s/he can effectively teach science. The other



subscale, science teaching outcome expectancy (STOE), is related to a teacher's belief that teaching, in general, can influence student achievement in science. In response to the need for an instrument to measure preservice teachers' efficacy beliefs, the STEBI-B was developed (Enochs & Riggs, 1990). It consists of 23 items written in the future tense. Two of items from the original instrument, renamed the STEBI-A, were eliminated due to cross-loading when used with preservice teacher populations.

### *Teaching Efficacy and Science Student Achievement*

Research suggests a significant, positive correlation between teacher efficacy and student achievement going back to the original RAND studies (Armor et al., 1976). More recent studies have continued to demonstrated the importance of teachers' efficacy on their students' achievement (Anderson et al., 1988; Ashton & Webb, 1986; Hannum, 1994; Kerley, 2004; Ledford, 2002; Midgley et al., 1989; Moore & Esselman, 1992; Muijs & Reynolds, 2002; Ross, 1992; Ross, 1998; Watson, 1991).

Related specifically to science, Staples (2002) looked at the science teaching efficacy, classroom practice, and student science achievement of elementary teachers who had (treatment,  $n = 8$ ) and had not (control,  $n = 7$ ) taken a non-traditional science content course during their preservice program. Data included the teachers' STEBI-A scores, observations of science lessons, and students' Stanford Achievement Test9 (SAT9) science scores. Analysis revealed that treatment participants had higher STOE scores, implemented more reform-based instructional practices in their classrooms, and had students with higher SAT9 science scores. Additionally, the treatment teachers'

students' SAT9 scores were higher than both the control teachers' students' scores and the school system's average score.

### *Elementary Teachers' Science Teaching Efficacy*

Newsome (2003) studied the science teaching efficacy beliefs of 90 educational interns at 12 colleges in six states. Elementary education majors comprised 27.1% of the sample. Participants completed the STEBI-B approximately one month into their student teaching experience. Analysis revealed that elementary education interns had significantly lower personal science teaching efficacy (PSTE) scores than science majors, science education majors, and secondary education majors. Newsome suggests that this difference could be due to the generalist nature of elementary teaching. Because elementary teachers do not specialize in the way science and science education majors do, they are less likely to have the science-specific mastery and vicarious experiences necessary to increase their science teaching efficacy.

In a similar study, Ramey-Gassert (1993) examined the relationship between elementary teachers' science teaching efficacy and various demographic and attitude variables. Phase one of the study involved administering the Science Teaching Efficacy Belief Instrument for In-service Teachers (STEBI-A), the Shrigley-Johnson Attitude Toward Science Scale, and questionnaires asking for demographic and educational information such as years of teaching experience, educational level, and number of science courses taken to 27 elementary teachers who were participating in a PDS-based preservice program at a large mid-western university. Results of the first phase were used to stratify participants into high, moderate, and low levels of efficacy for each of the two

STEBI subscales, Personal Science Teaching Efficacy Belief Scale (PSTE) and Science Teaching Outcome Expectancy Scale (STOE). A purposeful sample of ten participants with high, moderate, and low levels of PSTE and STOE were selected to be interviewed for the second phase of the study. Interview questions were open ended and focused on the teachers' science-related experiences, preparation for science teaching, professional development in science, and general teaching efficacy. Results of the first phase revealed significant correlations between PSTE scores and attitude toward science ( $r = .850, p < .01$ ), educational degree level ( $r = .522, p < .01$ ), choosing to teach science ( $r = .436, p < .05$ ), and self-rated effectiveness in science teaching ( $r = .405, p < .05$ ). STOE scores were significantly correlated to number of college science courses taken ( $r = .398, p < .05$ ) and choosing to teach science ( $r = .357, p < .05$ ). Analysis of the responses to the second phase produced composite profiles of high efficacy teachers. Participants who had high PSTE grew up in supportive homes where science was part of daily life, were professionally active, utilized hands-on activities in the classroom, relied little or not at all on textbooks, and actively pursued activities which would allow them to more effectively teach science concepts. Participants with high STOE also had strong science backgrounds, preferred hands-on, active learning in the classroom, and sought out professional development activities which expanded their science teaching skills. These results suggest that there are relationships among elementary teachers' science teaching efficacy, science background, utilization of active learning strategies, and desire to improve their science teaching.

### *Science Teaching Efficacy and Teachers' Content Knowledge*

The relationship between having basic science knowledge and a positive attitude toward science was demonstrated in Downing, Filer, and Chamberlain's (1997) study of preservice elementary teachers' proficiency with various science process skills and their attitudes toward science. Forty-six students enrolled in a mathematics and science methods course the semester before their student teaching were administered two instruments. The Test of Integrated Process Skills II (TIPS II) was a 36-item, multiple choice instrument that measures science process skills such as identifying variables, interpreting data, and designing experiments. The Science Attitude Scales (SAS) was a 72-item, five-point, Likert-scale test with six subscales related to confidence in learning science, teacher attitude, usefulness of science, science as a male domain, science anxiety, and motivation to have positive experiences in science. Pearson Product Moment Correlation Coefficients showed moderate positive correlations between the TIPS II and the overall SAS ( $r = .39, p < .05$ ) as well as the confidence in learning science ( $r = .29, p < .05$ ) and teacher attitude ( $r = .33, p < .05$ ) subscales. Those who were more proficient in basic science process skills had greater confidence in their ability to learn science and believed that their teachers felt that they performed better and/or had more potential to do well in science.

Similarly, Chang (2003) found a relationship between science content knowledge and science teaching efficacy. Using a posttest only, quasi-experimental research design, 109 senior students in teacher preparation programs at the University of Idaho and National Hsin Chu teachers College in Taiwan completed a science content assessment

based upon the 1994 TIMMS test and the STEBI-B. Results showed a significant, positive correlation between science content knowledge and personal science teaching efficacy ( $r = .20, p < .001$ ). Additionally, participants enrolled in elementary education programs had significantly lower science content knowledge ( $F(3, 105) = 12.95, p < .001$ ) and science teaching efficacy ( $F(3, 105) = 17.77, p < .001$ ) than participants enrolled in secondary science education programs.

Mulholland, Dorman, and Odgers (2004) examined the factors that influence the science teaching efficacy of preservice elementary teachers. Demographic information and STEBI-B scores were collected from 314 undergraduate elementary education majors. Participants were distributed evenly across the four years of the program. Analysis revealed that participants who had completed more high school science courses had higher personal science teaching efficacy ( $F(2, 305) = 2.80, p < .05$ ). Participants who had completed more college-level science education courses also had higher scores on the STEBI-B ( $F(1, 305) = 5.55, p < .05$ ). These results indicate that both science content courses and science education courses can positively impact preservice teachers' science teaching efficacy.

Schoon and Boone (1998) studied the relationship between elementary teachers' science teaching efficacy and whether or not they held certain misconceptions about specific science content. In the first weeks of their science methods class, 619 preservice elementary teachers completed the STEBI-B and a multiple-choice test for common alternative conceptions of science. Data were analyzed with the stochastic Rasch model. Results indicated that those with the fewest number of misconceptions had the highest

science teaching efficacy score while those with large numbers of misconceptions had low science teaching efficacy scores. There were no significant differences on either STEBI subscale between participants with less than four misconceptions and those with greater than eight misconceptions ( $t_{\text{PSTE}} = .015, p > .05$  ;  $t_{\text{STOE}} = .61, p > .05$ ). However, participants who held five particular misconceptions were significantly more likely to have lower science teaching efficacy. Overall, this study showed that specific science knowledge is correlated with science teaching efficacy.

Building upon Schoon and Boone's (1998) study, Koc (2006) administered the same misconceptions-based content test along with the STEBI-B and a demographic questionnaire to 86 preservice elementary teachers enrolled in four sections of a science methods course. Twelve participants, purposefully selected to represent high, moderate, and low scores on the two instruments, completed a follow-up interview. The mean on the content test was 33.3% with only three of the 12 questions being answered correctly by at least 50% of the participants. In the interviews, the preservice elementary teachers cited personal experience and textbooks as the main sources of their science knowledge. Other analyses revealed significant positive relationships between the participants' personal preference for teaching science and their perceived effectiveness in teaching science, PSTE and preference for teaching science, and PSTE and perceived effectiveness in teaching science. There were also significant relationships found between the number of misconceptions and PSTE ( $r = -.286, p < .05$ ) as well as between number of misconceptions and total STEBI-B score ( $r = -.257, p < .05$ ). There was no relationship, however, between number of misconceptions and STOE ( $r = -.094, p < .05$ ).

Looking at specific content areas, Cakiroglu (2000) studied the relationship between preservice elementary teachers' science teaching efficacy and content knowledge of photosynthesis and inheritance. Seventy-nine preservice elementary teachers enrolled in four sections of science methods courses completed a demographic questionnaire, 23-item multiple-choice content test, and the STEBI-B. Eleven participants representing high/low content and efficacy scores were also interviewed. The mean score on the content test was 51.7% with only 13 of the questions being answered correctly by at least 50% of the participants. Comparison of the content and efficacy scores showed that participants with few misconceptions about photosynthesis had higher PSTE than those with many misconceptions ( $t = 3.17, p < .05$ ). Analysis of the qualitative responses revealed that most interviewees thought that science was fun and exciting, that although they had limited knowledge they knew enough to teach at the elementary level, that good teaching involved making students interested in science, and that their field experiences and methods courses had helped them gain confidence to teach science effectively.

These studies suggest relationships between preservice elementary teachers' science teaching efficacy and their science content knowledge. Significant correlations have been found between STE and general science content knowledge, specific science misconceptions, and specific fields of science knowledge.

#### *Teaching Efficacy and Classroom Practice*

Woolfolk and Hoy (1990) explored the relationship between preservice teachers' teaching efficacy and beliefs about control and motivation. A modified version of Gibson and Dembo's Teacher Efficacy Scale (TES), the Pupil Control Ideology (PCI) scale, the

Problems in Schools Inventory (PSI), and the Work Environment Preference Schedule (WEPI) – which measure teachers’ beliefs about pupil control, motivation for control, and commitment to bureaucracy, respectively – were given to 182 preservice teachers of which 104 were elementary education majors and 78 were secondary education majors. Correlation analysis showed significant relationships between teaching efficacy and pupil control ideology ( $r = -.50, p < .01$ ), teaching efficacy and bureaucratic orientation ( $r = -.42, p < .01$ ), and personal efficacy and bureaucratic orientation ( $r = .18, p < .05$ ). These results indicate that teachers with high general teaching efficacy are more likely to believe students learn best through cooperative experiences and to make individual decisions rather than deferring to their superiors. Teachers with high personal teaching efficacy, on the other hand, are more likely to follow administrative orders.

In a qualitative study, Lee and Houseal (2003) examined how four fifth-grade teachers taught science and why they made the instructional choices they did. Each participant was observed teaching a science lesson three times over the course of five months. Each observation was followed up with a semi-structured interview. Analysis of the four cases showed that those teachers with self-reported low science teaching efficacy utilized more teacher-centered and didactic modes of instruction compared to the teachers with self-reported high science teaching efficacy, who incorporated more student-centered and inquiry methods of instruction. Data from the interviews indicate that the teachers with higher efficacy were better able and more willing to overcome obstacles to science teaching, including availability of materials, space, time, and lack of content knowledge, especially related to district, state, and national benchmarks. This study



suggests that elementary teachers with higher levels of efficacy are more likely to implement science lessons that are in accordance with national reform documents (e.g., AAAS, 1993; NRC, 1996).

### *Sources of and Changes in Teaching Efficacy*

Recently, Woolfolk-Hoy and her colleagues (Knoblauch & Woolfolk-Hoy, 2008; Tschannen-Moran & Woolfolk-Hoy, 2007) explored the sources of teachers' teaching efficacy, particularly related to Bandura's (1997) aspects of mastery experience, vicarious experience, and verbal persuasion. In the first study (Tschannen-Moran & Woolfolk-Hoy, 2007), 74 novice (those with 3 or less years' experience) and 181 experienced K-12 teachers completed the Teachers' Sense of Efficacy Scale (TSES), a demographic questionnaire, and a survey which asked them to rate the quality of various forms of support as well as their satisfaction with their professional performance. Regression analyses showed that the verbal persuasion offered by administrators, colleagues, parents, and the community ( $R^2 = .14$ ,  $F = 2.23$ ,  $p < .02$ ) and personal mastery experiences ( $R^2 = .19$ ,  $F = 2.90$ ,  $p < .00$ ) were significant predictors of teaching efficacy for experienced teachers, while only personal mastery experiences ( $R^2 = .49$ ,  $F = 3.81$ ,  $p < .00$ ) was a significant predictor of teaching efficacy for novice teachers.

In the second study (Knoblauch & Woolfolk-Hoy, 2008), 240 student teachers (elementary = 77, secondary = 75) also completed the TSES along with the Perceived Cooperating Teachers' Efficacy Scale and other instruments. Regression analyses revealed that the student teachers' beliefs about their cooperating teachers' efficacy was a significant predictor of the student teachers' teaching efficacy ( $B = .27$ ,  $t = 3.89$ ,  $p <$

.001). Knoblauch and Hoy posit that the vicarious experiences and verbal persuasion offered by cooperating teachers are important factors in developing student teachers' teaching efficacy. Together, these two studies suggest that the teaching efficacy of preservice and early career teachers is influenced by personal teaching success and the personalized modeling and feedback offered by cooperating teachers.

Ginns, Watters, Tulip, and Lucas (1995) examined how preservice elementary teachers' science teaching efficacy changed over the course of the first half of their university program. Enoch and Riggs' Elementary Science Teacher Efficacy Belief Instrument for Preservice Teachers (STEBI-B) was administered to 72 students at the beginning of their program and at the end of their third semester of study. Participants' grades from their science content and science methods courses were also collected. Twenty participants were randomly selected and interviewed after the posttest to explore explanations for any change in efficacy. Analysis of the pretest and posttest scores on the STEBI-B's two subscales, Personal Science Teaching Efficacy Belief Scale (PSTE) and Science Teaching Outcome Expectancy Scale (STOE), showed that preservice elementary teachers showed significant improvement on STOE ( $t(71) = -2.1, p = .04$ ) but not the PSTE. Additionally, there were no significant correlations between either of the subscales' scores and the science content course grade or the science methods course grade. Based on data from the interviews, the authors suggest that the positive change in the participants' belief that teachers can impact student learning could be due to successful experiences with children during the science methods course. The lack of change for the participants' confidence in their personal ability to teach science, on the

other hand, is most likely due to most participants' negative experiences with science at all levels of their education.

Looking at the effects of constructivist-oriented teaching on the science teaching efficacy of preservice elementary teachers, Bleicher and Lindgren (2005) studied 49 students enrolled in two sections of a science methods class. The instructors utilized hands-on activities, discussion, demonstrations, discrepant events, and cooperative learning to teach core science concepts over the six-week summer course. Participants completed a content test and the STEBI-B on the first and last days of the course. Other data sources included the participants' reflective journals and notes from the focus groups interviewed at the end of the course. Analysis of the data showed significant growth in content knowledge ( $t = 16.63, p = .001$ ), PSTE ( $t = 8.38, p = .001$ ), and STOE ( $t = 3.06, p = .002$ ). Additionally, there were significant positive relationships between pre-content and pre-PSTE ( $r = .313, p < .05$ ) as well as post-content and post-PSTE ( $r = .320, p < .05$ ). Significant differences in PSTE were also found between participants having positive K-12 science experiences and those having negative K-12 science experiences on both the pre- and posttests ( $t_{\text{pre}} = 3.90, p < .001$ ;  $t_{\text{post}} = 2.80, p < .008$ ). Information from the journal entries and focus groups suggest that the preservice teachers felt that the hands-on approach coupled with discussion helped them to understand the science concepts being taught.

Graves (1999) also investigated the impact of a constructivist-based methods course on the science teaching efficacy, science content knowledge, and attitudes toward constructivist learning environments of 58 preservice elementary teachers. Various

instruments were administered on the first and last day of a science methods course which focused on deconstructing the participants' science misconceptions while building their expertise in developing and implementing constructivist-based science lessons. Results from the STEBI-B, Constructivist Learning Environment Survey (CLES), and Alternate Concepts in Science test (ACS) showed that participants demonstrated significant growth in their science content knowledge ( $t = 7.77$ ;  $p = .000$ ) and personal science teaching efficacy ( $t = 6.24$  ;  $p = .000$ ). Regression analysis also revealed that PSTE changed 1.19 units for every unit change in content ( $p = .026$ ) and that attitude toward constructivist learning environments changed .27 units for every unit change in PSTE ( $p = .011$ ). Qualitative data from journals, observation notes, and interviews indicated that some participants, however, held deep-seated beliefs about science and science teaching which prevented them from changing their attitudes. A few preservice teachers, for example, expressed frustration over the unstructured nature of constructivist learning environments and noted that it would be easier to just give students the correct answers.

In a similar study, Thompson (2003) explored the effect of an intervention on the science teaching efficacy and science content knowledge of preservice elementary teachers. One treatment group and two control groups of undergraduates enrolled in an environmental science lab completed a content test and the STEBI-B at the beginning and end of the course. The treatment group ( $n = 46$ ) consisted of preservice elementary teachers enrolled in a special section of the lab which utilized in-context, constructivist approaches to teach environmental science. The control groups were formed from

students enrolled in the regular sections of the lab. One control group ( $n = 232$ ) included the preservice elementary teachers, and the other control group ( $n = 62$ ) was comprised of the non-education majors. Analysis revealed that participants in the treatment group demonstrated significantly more growth in content knowledge than both the first control group ( $F(1, 276) = 7.67, p = .006$ ) and the second control group ( $F(1, 106) = 8.30, p = .005$ ) as well as having a significantly greater increase in science teaching efficacy than both the first control group ( $F(1, 276) = 10.22, p = .002$ ) and the second control group ( $F(1, 106) = 9.50, p = .003$ ).

Looking at the effect of site based experiences on preservice elementary teachers' science teaching efficacy, Wingfield (1998) asked undergraduate students in the final year of their elementary education program ( $n = 131$ ) to complete the STEBI-B at the beginning and end of the site based semester of their program. Demographic questionnaires and a site based experiences ranking survey were also collected. Additionally, representative participants were interviewed after completing the post surveys. Analysis showed significant increases in the participants' overall science teaching efficacy ( $t = 11.52, p < .001$ ), PSTE, ( $t = 10.67, p < .001$ ) and STOE ( $t = 8.56, p < .001$ ). Data from the ranking survey indicated that participants rated the science methods course and teaching experiences as being the most influential. This finding was supported by the interviews which found that participants who experienced an increase in efficacy cited practice teaching in classrooms and implementing hands-on instruction as key variables in their growth, while participants who did not experience an increase in efficacy complained about limited opportunities to teach and observe.

In a similar study, Morrell and Carroll (2003) investigated the effect of science content courses, science methods courses, and student teaching on the science teaching efficacy of preservice elementary teachers. A total of 171 elementary education majors completed the STEBI-B at the beginning and end of their science content course, science methods course, or student teaching placement. Analysis revealed that participants enrolled in the science methods course demonstrated significant growth in PSTE ( $p < .01$ ). Additionally, participants with low efficacy at the beginning of their science content course showed a significant increase in PSTE ( $p < .05$ ). There were no significant changes in STOE for any group. The authors speculate that the lack of increase in either PSTE or STOE among the student teachers was due to a ceiling effect; that is, those participants had very high science teaching efficacy at the beginning of their fieldwork experience, so it may not be possible to produce a significant change over the course of one semester.

These studies indicate that it is possible to positively influence preservice elementary teachers' efficacy for science teaching in a variety of learning settings. In particular, science methods courses which utilize hands-on, cooperative learning, content courses that are structured around contextualized inquiry, and experiences teaching science to children have been linked to increases in science teaching efficacy. The treatment group in this study will be enrolled in a science methods course which incorporates these practices.

## Nature of Science

### *Tenets of Nature of Science*

Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) describe nature of science (NOS) as “the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development” (p498). Although there can never be complete agreement as to all the facets of NOS, recent national reform documents (AAAS, 1990, 1993; NRC, 1996) and reviews of literature on NOS (Lederman et al., 2002) conclude that there are core similarities between the various perspectives that are relevant for K-12 education. These central tenets include the ideas that scientific knowledge is empirical, tentative, theory-laden, partly the product of human imagination and creativity, and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of a single method for doing science, and the functions of and relationships between scientific theories and laws.

*Empirical.* Scientific knowledge is advanced by data collected through observation and/or experimentation. An individual’s beliefs about a phenomenon will not be accepted by the scientific community unless they are substantiated with evidence.

*Tentative.* Although scientific laws and theories are strongly supported by the available data, they can never be absolute. Technological advances that produce better instrumentation, as well as new ways of thinking about existing evidence, have the potential to alter currently accepted scientific knowledge.

*Theory-laden.* Scientists, like all humans, approach their work based on their previous experiences. Their beliefs, prior knowledge, and training shape their way of thinking, which, in turn, affects how they approach their investigations. For example, physicists and chemists bring different perspectives to research on atomic structure.

*Imagination and creativity.* Although science is based on empirical evidence, it is still a human endeavor. Scientists use imagination and creativity when they decide what questions to ask, which methods to use, and how to interpret the results.

*Socially and culturally embedded.* Scientists do not work in a vacuum. Politics, socioeconomic factors, philosophy, religion, etc. all play a role in not only what scientific knowledge is pursued but also whether or not it is accepted as valid by society.

*Observation and inference.* Although data can sometimes be observed directly through the senses, scientists also may infer information about a phenomenon indirectly through its effects. It is possible, for example, to see that objects released from above ground level usually will fall to the ground. However, scientists are not able to see atoms directly, so they must make inferences about atomic structure based on information obtained from atoms' interactions with light and other particles.

*Scientific methods.* There is no single way of “doing” science. The nature of the question being explored dictates how evidence will be gathered. Additionally, there is no set sequence of steps that all scientists follow.

*Theories and laws.* Theories and laws are equally valid and important aspects of science. Laws, which can usually be represented mathematically, describe a relationship among observable phenomena, while theories explain why phenomena occur. Boyle's



law, for example, relates the pressure of a gas at constant temperature to its volume. The kinetic molecular theory, on the other hand, describes why that relationship works. One is not more legitimate or more substantiated than the other; they have inherently different functions in science.

### *Elementary Teachers' Understanding of NOS*

In a review of literature dating back to 1950, Lederman (1992) found consistent evidence that science teachers have inadequate understandings of NOS. Although most of the studies focused on secondary science teachers, those that included elementary teachers came to similar conclusions. Two studies that compared secondary students and teachers found that as many as 68% of high ability 11<sup>th</sup> and 12<sup>th</sup> graders demonstrated more sophisticated understandings of NOS than 25% of the teachers (Miller, 1963, and Schmidt, 1967, as cited in Lederman, 1992). Other investigations found that the level of teachers' understanding of NOS was not significantly correlated to academic variables such as grade point average, years of teaching experience, or number of science courses taken.

More recently, Keske (2002) explored the conceptions of NOS of seven elementary teachers who, by either choice or default, were considered the "science" teacher in their schools. The participants had various years' experience and taught grades three through six. Based on data from semi-structured interviews, all the participants presented inaccurate ideas about NOS. In particular, they all thought that there was one systematic scientific method, theories became laws once there was sufficient evidence, and that scientists were completely objective. Although the participants agreed that

scientific knowledge was tentative, they believed that the absolute “truth” would eventually be found.

As part of another study, Stockton (2002) examined undergraduate students’ understanding of NOS. Eighty-one students were interviewed using the VNOS-C (Lederman et al., 2002), and the data were assessed using a five point Likert scale. Participants were then grouped by major (science, elementary education, and non-science non-education) and their scores compared. Analysis showed that elementary education majors had significantly lower understanding of NOS than science majors ( $p < .05$ ), but not non-science non-education majors, for seven of the eight central tenets as well as for the instrument overall. The only tenet for which there was no significant difference between the three groups was the socio-cultural nature of science.

#### *Teachers’ Understanding of NOS and Classroom Practice*

Investigations into the relationship between teachers’ understanding of NOS and their classroom practice have reached somewhat disparate conclusions. Lederman and Zeidler (1987), for example, studied 18 high school biology teachers using numerous field observations and an assessment of the teachers’ perceptions of NOS and found no correlation between 44 identified classroom variables and teachers’ conceptions of NOS. Similarly, Duschl and Wright (1989), through several observations and interviews with 13 high school science teachers, concluded that institutional and instructional constraints (e.g., administrative policies, supplies, curricula, and students’ needs) were more important to teachers’ educational decisions than their perspective on NOS.

Brickhouse (1990) used a case approach and found that beginning teachers' classroom practices are in less accord with their NOS beliefs than experienced teachers', which indicates that there is a relationship between teachers' level of experience and their ability to match their conceptions of NOS with their instructional techniques. In a similar study, Lederman (1999) conducted a multiple case study of five teachers who all had sophisticated understandings of NOS but varying years of teaching experience. Analysis of semi-structured interviews, numerous classroom observations and artifacts, and VNOS-B responses showed that the newer teachers struggled to implement instructional strategies consistent with their conceptions of NOS due to classroom management concerns. More experienced teachers, on the other hand, utilized approaches consistent with well-developed NOS beliefs even though they did not intentionally consider NOS when making pedagogical decisions. Additionally, other studies (Lederman, 1986; Lederman & Druger, 1985) which looked into the relationship between the classroom practices of high school teachers and their students' understanding of NOS found that teachers who utilized inquiry-based, hands-on problem solving activities, had frequent teacher-student interactions, deemphasized memorization, and rarely used independent seat work were more likely to have students who showed gains in their understanding of NOS. Given the conflicting results, and the lack of studies on elementary science teaching practices, more studies are needed in this area.

#### *Changes in Elementary Teachers' Understanding of NOS*

Lederman (1992) also reviewed studies which investigated how to improve teachers' understanding of NOS. The findings of nine such studies suggest that successful

techniques to further teachers' conceptions of NOS include methods courses that explicitly address NOS or include the historical and philosophical perspectives of science as well as inquiry-based science content courses. More recent studies support these conclusions.

Hammrich and Blouch (2006), for example, explored the effect of using cooperative controversy to improve preservice elementary teachers' understandings of NOS. As part of the study, 47 participants completed questionnaires and interviews before and after their science methods course. During the course, the technique of cooperative controversy was used to expose and challenge the participants' conceptions of NOS. Specifically, pairs of participants were given a position statement regarding one aspect of NOS and were asked to develop an argument in support of it (e.g., science is about learning facts about nature). That pair would then debate another pair of participants who had developed an argument for the opposite position. Afterwards, the pairs would switch positions and debate again. In the ensuing whole group discussion, the entire class would come to conclusion as to which position was more accurate. Analysis of the data showed that before the methods course, nearly all of the preservice elementary teachers believed that science was an objective, impersonal quest for facts about how the universe works and that good science teachers were knowledgeable, engaging lecturers. After the course, the overwhelmingly majority of participants viewed science as a humanistic endeavor searching for global concepts and that good science teachers enable each student to individually construct his/her own understanding through hands-on, inquiry-based activities.

Meichtry (1999) also examined the impact of a science methods course on preservice elementary teachers' understandings of NOS. Sixty-seven students completed a short questionnaire regarding the nature of science and science teaching as well as the Modified Nature of Scientific Knowledge Scale (MNSKS) at the beginning and end of the course. Over the course of the semester, participants (1) planned and taught a learning-cycle-based science lesson to both their peers and elementary students, (2) designed, implemented, and presented the results of a science research experiment, and (3) reflected on their experiences. Analysis of the MNSKS data revealed a significant increase ( $p < .01$ ) in the participants' overall understanding of NOS as well as on each of the instrument's four subscales (i.e., developmental, testable, creative, and unified). Qualitative analysis of the questionnaire and reflections showed that the preservice elementary teachers began the course thinking that science was a body of factual knowledge that was to be transmitted to students. By the end, however, the majority of participants viewed it as a creative, flexible process that can best be learned by actually doing science.

Akerson, Abd-El-Khalick, and Lederman (2000) examined the influence of a reflective, explicit, activity-based approach on undergraduate ( $n = 25$ ) and graduate ( $n = 25$ ) students' NOS conceptions. Analysis of pre/post interviews and VNOS-B data obtained from participants enrolled in science methods courses showed that the majority of undergraduates began the course with adequate understandings of only one of seven NOS aspects and ended the course with adequate understandings of five of seven NOS aspects. Likewise, the majority of the graduate students began the course with adequate

understandings of only one of seven NOS aspects and ended the course with adequate understandings of six of seven NOS aspects.

Similarly, Matkins, Bell, Irving, and McNall (2002) explored the differences in NOS understandings between preservice elementary teachers who completed an explicit activity-based approach in their science methods course ( $n = 33$ ) and those who completed an implicit activity-based approach ( $n = 42$ ). Data from a modified VNOS survey revealed that 27% - 80% of participants receiving explicit NOS instruction improved in their understanding of various aspects of NOS, while only 5% of participants receiving implicit instruction demonstrated improved understanding.

Cochrane (2003) also looked at the effect of explicit instruction during a science methods course on preservice elementary teachers' understanding of NOS. Fifteen participants completed the VNOS-C at the beginning and end of the course. Their responses to each question were coded as being naïve, partially developed, or well developed. Independent t-tests results show significant improvements on the four items which were explicitly addressed through multiple course assignments, namely the empirical nature of science ( $t = 3.25$ ,  $p = .003$ ), the tentative nature of science ( $t = 2.21$ ,  $p = .039$ ), the difference between theories and laws ( $t = 3.45$ ,  $p = .002$ ), and the difference between observations and inferences ( $t = 2.99$ ,  $p = .006$ ). There was no significant growth on the six items that were explicitly addressed through only one course assignment.

These studies suggest that approaches used in the science methods course, such as explicit instruction and the use of hands-on activities, reflection, and discussion, can

improve teachers' conceptions of NOS. These types of approaches will be tested with the treatment group in the present study.

### Summary

In this chapter, the literature highlighting elementary teachers' science content knowledge, science teaching efficacy, and understanding of the nature of science was reviewed. Evidence was also presented that linked teachers' content knowledge and science teaching efficacy to reform-based instructional practices and student achievement. Additionally, connections between teachers' content knowledge and science teaching efficacy and their understanding of the nature of science and use of pedagogically appropriate teaching strategies were made. Finally, research-based methods for increasing elementary teachers' science content knowledge, science teaching efficacy, and understanding of the nature of science were offered.

### 3. Methodology

The purpose of this study was to examine the effects of a summer science camp teaching experience on preservice elementary teachers' science content knowledge, science teaching efficacy, and understanding of the nature of science. This chapter describes the participants and setting, instruments, and data collection and analysis procedures utilized.

#### Participants and Setting

Students in the masters-level preservice elementary education programs of a large, public university located in an urban/suburban area of a mid-Atlantic state were recruited to participate in this study. Because there were two elementary programs comparison groups could be obtained, resulting in a quasi-experimental research design. Admission requirements were identical for both programs, and most of the university's elementary education faculty taught in both programs. Preservice teachers enrolled in the Partnership Schools (PS) program completed a five semester program that included a traditional 15 week student teaching experience. The PS program had two cohorts, one for the Fairfax campus (FPS) and one for the Loudoun campus (LPS), at the time of this study. Preservice teachers in the Professional Development Schools (PDS) program completed a four semester program that included a site-based, year-long internship (see Table 1). Only the Fairfax campus had a PDS cohort at the time of this study.



Table 1

*Course Schedules for the Partnership and Professional Development Schools Cohorts*

	Partnership Schools (FPS and LPS)	Professional Development Schools (PDS)
Fall 2007	<ul style="list-style-type: none"> <li>• EDUC 542: Introduction to Elementary Curriculum (3 credits)</li> <li>• EDUC 543: Children, Family, Culture, and Schools, 4-12 Year Olds (3 credits)</li> </ul>	
Spring 2008	<ul style="list-style-type: none"> <li>• EDCI 555: Literacy Teaching and Learning in Diverse Elementary Classrooms I (3 credits)</li> <li>• EDCI 554: Social Studies Methods for the Elementary Classroom (3 credits)</li> </ul>	<ul style="list-style-type: none"> <li>• EDUC 542: Introduction to Elementary Curriculum (3 credits)</li> <li>• EDUC 543: Children, Family, Culture, and Schools, 4-12 Year Olds (3 credits)</li> </ul>
Summer 2008	<ul style="list-style-type: none"> <li>• EDCI 553: Science Methods for the Elementary Classroom (3 credits)</li> <li>• EDCI 558: Integrating Fine Arts and Movement in Elementary Education (3 credits)</li> </ul>	<ul style="list-style-type: none"> <li>• EDCI 552: Mathematics Methods for the Elementary Classroom (1 credit)</li> <li>• EDCI 553: Science Methods for the Elementary Classroom (1 credit)</li> <li>• EDCI 554: Social Studies Methods for the Elementary Classroom (1 credit)</li> <li>• EDCI 555: Literacy Teaching and Learning in Diverse Elementary Classrooms I (3 credits)</li> </ul>
Fall 2008	<ul style="list-style-type: none"> <li>• EDCI 552: Mathematics Methods for the Elementary Classroom (3 credits)</li> <li>• EDCI 556: Literacy Teaching and Learning in Diverse Elementary Classrooms II (3 credits)</li> </ul>	<ul style="list-style-type: none"> <li>• EDCI 552: Mathematics Methods for the Elementary Classroom (2 credits)</li> <li>• EDCI 553: Science Methods for the Elementary Classroom (2 credits)</li> <li>• EDCI 554: Social Studies Methods for the Elementary Classroom (2 credits)</li> <li>• EDCI 556: Literacy Teaching and Learning in Diverse Elementary Classrooms II (1 credit)</li> <li>• EDCI 790: Internship in Education (3 credits)</li> </ul>

	Partnership Schools (FPS and LPS)	Professional Development Schools (PDS)
Spring 2009	<ul style="list-style-type: none"> <li>• EDCI 557: Integrating Technology in the Elementary Curriculum (3 credits)</li> <li>• EDCI 790: Internship in Education (6 credits)</li> </ul>	<ul style="list-style-type: none"> <li>• EDCI 556: Literacy Teaching and Learning in Diverse Elementary Classrooms II (2 credits)</li> <li>• EDCI 557: Integrating Technology in the Elementary Curriculum (3 credits)</li> <li>• EDCI 558: Integrating Fine Arts and Movement in Elementary Education (3 credits)</li> <li>• EDCI 790: Internship in Education (3 credits)</li> </ul>

All three cohorts took a science methods course that was taught by the same faculty member. The course was identical for all three groups with the exception of the length of the course and the fieldwork component. The course for the Fairfax Partnership Schools (FPS) program ( $n = 21$ ), which served as the treatment group in this study, met for seven weeks in June and July. For their field experience, participants in the treatment group collaboratively planned and implemented an inquiry- and problem-based summer science camp for upper elementary students (Sterling, Matkins, Frazier, & Logerwell, 2007). During the summer in which the study took place, there were two camps, each lasting two weeks. Half of the cohort was responsible for the “Exploring Space” camp. The preservice teachers in this group designed a problem-based unit in which the students worked to figure out the location of a lost space probe. The content of this camp included astronomy, Earth science, and chemistry. The other half of the cohort was responsible for the “Watershed Mysteries” camp. The preservice teachers in this group designed a problem-based unit in which students worked to figure out what was causing ducks in a

local pond to get sick. The content of this camp included chemistry, biology, and Earth science.

The methods course for the Loudoun Partnership Schools (LPS) program ( $n = 15$ ), which served as one comparison group in this study, met for three weeks in May and June. Participants in this group did not participate in the summer science camp. Instead, they completed 15 hours of classroom observation in a public elementary school and taught one lesson from a self-designed two-week integrated science/social studies unit to their peers during class. The methods course for the Professional Development Schools (PDS) program ( $n = 24$ ), which also served as a comparison group in this study, met for three days in June and then during the regular fall semester for a total of 16 weeks. Participants in this group did not participate in the summer science camp. Instead, they participated in a site-based year-long internship experience and taught one lesson from a self-designed two-week integrated science/social studies unit to students at their PDS site as well as to their peers during class.

### Instruments

This study utilized a mixed methods approach. Two quantitative – one Likert-type and one multiple choice – and two open response qualitative instruments were administered.

#### *Personal Data Questionnaire (PDQ)*

This instrument asked preservice elementary teachers for information regarding their age, gender, ethnicity, educational background, and teaching experience.

*Science Teaching Efficacy Beliefs Instrument for Preservice Teachers (STEBI-B) (Enochs & Riggs, 1990)*

This instrument was a 23-item Likert-type survey with five possible responses (1 = strongly agree, 5 = strongly disagree). There were two subscales, the Personal Science Teaching Efficacy Belief Scale (PSTE) and the Science Teaching Outcome Expectancy Scale (STOE). Items in the PSTE included statements like “I will find it difficult to explain to students why science experiments work,” and, “I understand science concepts well enough to be effective in teaching elementary science.” Items in the STOE included statements like “When a student does better than usual in science, it is often because the teacher exerted a little extra effort,” and, “The teacher is generally responsible for the achievement of students in science.” Thirteen items were positively worded, and ten items were negatively worded. Psychometric analyses have produced Cronbach’s alphas of .92 for the PSTE and .77 for the STOE (Riggs, 1998). As cited in Chapter Two, numerous studies have utilized the STEBI-B.

*Science Content Knowledge Assessment (SCKA)*

This instrument was a 40-item multiple choice test that used questions from the Virginia Standards of Learning Earth science, biology, and chemistry high school end-of-course exams and the Harvard University Project MOSART grade 9-12 physics test. The Jefferson Lab’s Virginia State Standards of Learning practice test website (<http://education.jlab.org/solquiz/index.html>) was used to randomly generate ten questions each for the Earth science, biology, and chemistry portions of Version A. Ten questions were also randomly selected from a hardcopy of Project MOSART’s grade 9-

12 physics test form 741. Version B was created by selecting additional topic-matched questions from the Jefferson Lab website and Project MOSART test. Face validity of both versions were obtained by a panel of experts which included science and science education faculty. Each assessment was also administered to a pilot group of preservice teachers ( $n = 19$ ) in order to identify any typographical errors and determine the time needed to complete the instrument. Analyses produced Cronbach's alphas of .53 for Form A and .86 for Form B.

#### *Views of Nature of Science Questionnaire (VNOS)*

This instrument, comprised of eight open-ended questions, was a modified version of the ten-item VNOS-C development by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002). The validity of the VNOS-C was established by Abd-El-Khalick (1998, 2001) through the use of systematic comparison of participants' NOS profiles which had been independently generated through separate analyses of corresponding questionnaire and interview transcripts. Studies which have administered the VNOS-C to preservice elementary teachers include Abd-El-Khalick (2001), Abd-El-Khalick and Lederman, (2000), Cochrane (2003), Lederman, Schwartz, Abd-El-Khalick, and Bell (2001), and Schwartz, Lederman, and Crawford (2000). Because the targeted tenets of NOS were addressed by multiple items on the VNOS-C (Abd-El-Khalick, 2001), the version used in this study eliminated two items which had considerable overlap with the remaining items in order to reduce the estimated time it takes to complete the questionnaire.

## Data Collection and Analysis Procedures

One-way analysis of variance tests were run to ascertain between group differences for age and number of science courses taken. For all other variables, a mixed analysis of variance (ANOVA) with time (pretest, posttest) as a within-subject factor and group (FPS, LPS, PDS) as a between subjects factor was performed. Tukey post hoc analyses were done to explore differences between each pair of groups. Follow-up paired-samples *t* tests were performed when there were significant within-group differences. SPSS 15.0© was used for all quantitative analysis, and an alpha level of .05 was used for all statistical tests. Qualitative data from the VNOS was also coded for concurrence with central tenets of the nature of NOS (Lederman et al., 2002).

### *Personal Data Questionnaire (PDQ)*

This instrument was administered in class on the first day and last day of the science methods course. Analyses were conducted to ascertain differences between the FPS, LPS, and PDS groups on demographic variables such as age, gender, ethnicity, college major, number of science courses completed, and science teaching experience.

### *Science Teaching Efficacy Beliefs Instrument for Preservice Teachers (STEBI-B)*

Participants completed this instrument during class on the first and last day of their science methods course. Participants' scores on the negatively worded items (3, 6, 8, 10, 13, 17, 19, 20, 21, and 23) were reversed prior to analysis. Analyses were done for the whole instrument and for each subscale. Items 2, 3, 5, 6, 8, 12, 17, 18, 19, 20, 21, 22, and 23 comprise the PSTE, while the remaining items comprise the STOE.

### *Science Content Knowledge Assessment (SCKA)*

This instrument was administered two times. Participants completed Version A on the first day of their science methods course and Version B on the last day of their science methods course. Analyses were done for both the whole instrument and for each content subscale. The biology subscale corresponded to questions 1-10, the chemistry subscale corresponded to questions 11-20, the Earth science subscale corresponded to questions 21-30, the physics subscale corresponded to questions 31-40.

### *Views of Nature of Science Questionnaire (VNOS)*

This open-ended response instrument was administered during class on the first and last day of the science methods course. In order to obtain a general overview of the participants' views of the nature of science, a rubric (see Appendix G) was used to rank the responses to each question on a 5-point scale (1 = naïve view, 5 = sophisticated view) and a composite rubric score for the entire instrument was calculated. In order to explore differences between the groups' responses as well as change within each group in more depth, participants' responses were also coded for concurrence with central tenets of the nature of scientific knowledge (Lederman et al., 2002). An independent rater with NOS expertise verified the rubric scores and coding for a representative sample of participants' responses.

### *Importance*

There will be an increasing need for a scientifically literate workforce within the coming decades. Additionally, increased accountability in education has put a spotlight on student achievement. Evidence suggests, however, that elementary students in the

United States are not performing well on national or international science assessments and that elementary teachers are not prepared to effectively teach science. Therefore, studies that identify variables which have the potential to increase elementary teachers' ability to successfully teach science and, correspondingly, increase student achievement in science are needed. The present investigation examined the effects of a summer science camp teaching experience on preservice elementary teachers' science content knowledge, science teaching efficacy, and understanding of the nature of science. These three variables have been linked either directly or indirectly to increased student learning.



## 4. Results

This chapter describes the results of the quantitative and qualitative analyses conducted to address the research questions. One-way analysis of variance tests were run to ascertain differences among the groups for age and number of science courses taken. For all other variables, mixed ANOVA tests using within (i.e., pre, post) and between (i.e., group) factors were performed. Tukey post hoc analyses were done to explore differences between each pair of groups. Follow-up paired-samples *t* tests were performed when there were significant within-group differences. SPSS 15.0© was used for all quantitative analysis, and an alpha level of .05 was used for all statistical tests. Qualitative data from the VNOS was also coded for concurrence with central tenets of NOS (Lederman et al., 2002).

### Demographic Information

Gender and ethnicity information for each group is provided in Table 2. All three groups were predominately white and female. The LPS group had the highest percentage of males, and the PDS group had the highest percentage of non-white participants. For age, one-way ANOVA results revealed no significant differences,  $F(2) = .56, p = .58$ , among the groups ( $M_{FPS} = 30.70, SD_{FPS} = 8.07$ ;  $M_{LPS} = 28.13, SD_{LPS} = 10.16$ ;  $M_{PDS} = 28.08, SD_{PDS} = 7.82$ ).

Table 2

*Participants' Gender and Ethnicity Information*

	Fairfax Partnership Schools (FPS) ( <i>n</i> = 21)	Loudoun Partnership Schools (LPS) ( <i>n</i> = 15)	Professional Development Schools (PDS) ( <i>n</i> = 24)
Male	3 (14.29) <sup>a</sup>	3 (20.00)	1 (4.17)
Female	18 (85.71)	12 (80.00)	23 (95.83)
Asian	0	0	1 (4.17)
Black	0	0	1 (4.17)
Hispanic	1 (4.76)	1 (6.67)	3 (12.50)
White	20 (95.23)	13 (86.67)	18 (75.00)
Other	0	1 (6.67)	0
Not Reported	0	0	1 (4.17)

<sup>a</sup>Numbers in parentheses are percentages.

Information regarding the participants' college major is given in Table 3.

Humanities/Arts included majors such as English, communications, studio arts, integrated studies, and history. Social Sciences included majors such as sociology, political science, and psychology. Marketing, business, management majors were included in the Business category. In terms of number of science courses taken, one-way ANOVA results revealed no significant differences among the groups at the pretest,  $F(2) = 2.16$ ,  $p = .12$  ( $M_{FPS} = 3.14$ ,  $SD_{FPS} = 1.39$ ;  $M_{LPS} = 3.87$ ,  $SD_{LPS} = 3.40$ ;  $M_{PDS} = 2.42$ ,  $SD_{PDS} = 1.61$ ), or the

posttest,  $F(2) = 1.41, p = .25$  ( $M_{\text{FPS}} = 3.43, SD_{\text{FPS}} = 1.66; M_{\text{LPS}} = 3.93, SD_{\text{LPS}} = 3.52; M_{\text{PDS}} = 2.70, SD_{\text{PDS}} = 1.66$ ).

Table 3

*Participants' College Majors*

	FPS	LPS	PDS
	( $n = 21$ )	( $n = 15$ )	( $n = 24$ )
Humanities/Arts	9 (42.86) <sup>a</sup>	6 (40.00)	14 (58.33)
Social Science	5 (23.81)	5 (33.33)	6 (25.00)
Business	5 (23.81)	3 (20.00)	3 (12.50)
Engineering/Computer Science	1 (4.76)	0	1 (4.17)
Science	1 (4.76)	1 (6.67)	0

<sup>a</sup>Numbers in parentheses are percentages.

Information regarding the participants' K-6 science teaching experience is provided in Table 4. Data were analyzed with a mixed ANOVA with time (pretest, posttest) as a within-subject factor and group (FPS, LPS, PDS) as a between subjects factor. Results revealed significant differences among the groups,  $F(2, 56) = 29.29, p = .001$ . Tukey post hoc tests showed that participants in the LPS group had significantly less science teaching experience than participants in both the FPS group,  $MD = -.50, p = .001$ , and PDS group,  $MD = -.45, p = .001$ . There were also significant within-group differences, Wilks'  $\Lambda = .22, F(1, 56) = 201.19, p = .001$ , partial  $\eta^2 = .78$ . Follow-up

paired-samples  $t$  tests showed that both the FPS group,  $t(20) = 10.95, p = .001$ , and the PDS group,  $t(23) = 12.69, p = .001$ , had significantly more science teaching experience at the posttest compared to the pretest.

Table 4

*Number of Participants with Science Teaching Experience*

	FPS	LPS	PDS
	( $n = 21$ )	( $n = 15$ )	( $n = 24$ )
Pre	3	1	2
Post	21	1	23

Science Teaching Efficacy

The first research question asked (a) how does preservice elementary teachers' science teaching efficacy change during their science methods course and (b) is there a difference between the science teaching efficacy of preservice elementary teachers who plan for and teach a two-week inquiry-based summer science camp and preservice elementary teachers who do not participate in the camp as their fieldwork experience? Both within- and between group analyses were performed to answer these questions.

Descriptive statistics on the participants' Science Teaching Efficacy Belief Instrument for Preservice Teachers (STEBI) data are provided in Table 5. A mixed ANOVA with time (pretest, posttest) as a within-subject factor and group (FPS, LPS, PDS) as a between subjects factor was performed. Results revealed significant

differences among the groups on the Personal Science Teaching Efficacy (PSTE) subscale,  $F(2, 55) = 4.66, p = .01$ , and overall STEBI,  $F(2, 55) = 5.77, p = .005$ , but not the Science Teaching Outcome Expectancy (STOE) subscale,  $F(2, 55) = 1.99, p = .15$ . Tukey post hoc tests showed that participants in the FPS group had significantly higher PSTE scores than the PDS group,  $MD = .33, p = .01$ , and significantly higher STEBI scores than both the PDS group,  $MD = .25, p = .007$ , and LPS group,  $MD = .23, p = .04$ .

Table 5

*Science Teaching Efficacy Belief Instrument Descriptives and Analysis of Variance*

		FPS		LPS		PDS		<i>F</i>
		<i>(n = 21)</i>		<i>(n = 15)</i>		<i>(n = 24)</i>		
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
PSTE								
	pre	3.78	.41	3.55	.50	3.46	.39	4.66*
	post	4.35	.38	4.17	.42	4.01	.39	
STOE								
	pre	3.71	.44	3.52	.43	3.68	.34	1.99
	post	3.90	.46	3.54	.60	3.64	.38	
STEBI								
	pre	3.75	.30	3.54	.29	3.55	.27	5.77**
	post	4.16	.33	3.90	.39	3.85	.21	
* <i>p</i> < .05; ** <i>p</i> < .01								

There were also significant within-group effects for the PSTE, Wilks'  $\Lambda = .32$ ,  $F(1, 55) = 116.24$ ,  $p = .001$ , partial  $\eta^2 = .68$ , and STEBI,  $\Lambda = .37$ ,  $F(1, 55) = 92.68$ ,  $p = .001$ , partial  $\eta^2 = .63$ . Follow-up paired-samples  $t$  tests (see Table 6) revealed that all three groups had significant, positive changes in both their PSTE and overall STEBI from the pretest to the posttest. Additionally, the FPS group had a significant, positive change in their STOE from pretest to posttest.

Table 6

*Science Teaching Efficacy Belief Instrument Paired Samples  $t$  Tests*

	FPS		LPS		PDS	
	(n = 21)		(n = 15)		(n = 24)	
	<i>t</i>	<i>p</i>	<i>t</i>	<i>p</i>	<i>t</i>	<i>p</i>
PSTE	6.79	.001	6.49	.001	6.17	.001
STOE	2.07	.05	.34	.74	.48	.64
STEBI	7.13	.001	5.21	.001	4.95	.001

Related to science teaching efficacy, the analysis revealed significant differences among the groups, with the treatment group (FPS) having higher general science teaching efficacy than both comparison groups and higher personal science teaching efficacy than the PDS group. Additionally, all three groups experienced significant increases in general and personal science teaching efficacy, while only the treatment group experienced a significant increase in science teaching outcome expectancy.

## Science Content Knowledge

The second research question asked (a) in what ways do preservice elementary teachers' general and subject-specific science content knowledge change during their science methods course, (b) is there a difference between the change in general science knowledge and the change in subject-specific knowledge, and (c) is there a difference between the general or subject-specific science content knowledge of preservice elementary teachers who plan for and teach a two-week inquiry-based summer science camp and preservice elementary teachers who do not participate in the camp as their fieldwork experience? Both within- and between group analyses were performed to answer these questions.

Descriptive statistics on the participants' Science Content Knowledge Assessment (SCKA) data are provided in Table 7. A mixed ANOVA with time (pretest, posttest) as a within-subject factor and group (FPS, LPS, PDS) as a between subjects factor was performed. Results revealed no significant differences among the groups on the overall SCKA or any of the subscales. However, there were significant within-group effects for the chemistry subscale, Wilks'  $\Lambda = .60$ ,  $F(1, 57) = 37.68$ ,  $p = .001$ , partial  $\eta^2 = .40$ , and overall SCKA instrument, Wilks'  $\Lambda = .88$ ,  $F(1, 57) = 7.84$ ,  $p = .007$ , partial  $\eta^2 = .12$ . Follow-up paired-samples  $t$  tests (see Table 8) revealed that participants in both the LPS and PDS groups had significant positive changes on the chemistry subscale, while participants in the FPS group had significant positive changes from pretest to posttest on the instrument overall as well as the biology and chemistry subscales.

Table 7

*Science Content Knowledge Assessment Descriptives and Analysis of Variance*

		FPS		LPS		PDS		<i>F</i>
		(n = 21)		(n = 15)		(n = 24)		
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Biology								
	pre	6.81	1.36	7.13	1.13	7.00	1.35	1.59
	post	8.00	1.26	6.89	2.61	6.42	2.32	
Chemistry								
	pre	3.29	1.68	3.40	1.99	3.21	1.74	.31
	post	5.57	1.86	5.20	2.62	4.92	2.06	
Earth Science								
	pre	6.38	1.02	6.00	1.69	6.71	1.71	1.14
	post	6.90	1.58	5.80	2.27	5.89	2.23	
Physics								
	pre	5.05	1.66	4.47	1.77	4.25	1.59	2.27
	post	5.48	1.66	5.47	2.26	4.50	2.27	
SCKA								
	pre	21.52	3.98	21.00	3.63	21.17	4.12	1.40
	post	25.95	4.74	23.33	8.35	21.71	7.65	



Table 8

*Science Content Knowledge Assessment Paired Samples t Tests*

	FPS		LPS		PDS	
	(n = 21)		(n = 15)		(n = 24)	
	<i>t</i>	<i>p</i>	<i>t</i>	<i>p</i>	<i>t</i>	<i>p</i>
Biology	3.34	.001	-.37	.72	-1.15	.26
Chemistry	5.67	.001	2.16	.05	3.81	.001
Earth Science	1.42	.17	-.36	.72	-1.78	.09
Physics	.88	.39	1.50	.16	.48	.64
SCKA Total	4.47	.001	1.17	.26	.36	.72

Related to science content knowledge, the analyses showed that there were no significant differences among the groups. However, the treatment group experienced significant improvement in overall knowledge as well as biology- and chemistry-specific knowledge, while the comparison groups only experienced significant improvement in chemistry-specific knowledge.

#### Understanding of the Nature of Science

The third research question asked (a) how does preservice elementary teachers' understanding of the nature of science change during their science methods course and (b) is there a difference between the understanding of the nature of science of preservice elementary teachers who plan for and teach a two-week inquiry-based summer science camp and preservice elementary teachers who do not participate in the camp as their

fieldwork experience? Both within- and between group quantitative analyses, as well as qualitative analysis, were performed to answer these questions.

Descriptive statistics on the participants' Views of Nature of Science (VNOS) data are provided in Table 9. The average rubric score for all groups was in the "somewhat naïve view" range on both the pre- and posttest. A mixed ANOVA with time (pretest, posttest) as a within-subject factor and group (FPS, LPS, PDS) as a between subjects factor was performed. Results revealed no significant differences among the groups on the VNOS. However, Tukey post hoc tests revealed that participants in the FPS group had significantly higher VNOS scores than participants in the LPS group,  $MD = 1.82, p = .05$ .

Table 9

*Views of Nature of Science Descriptives and Analysis of Variance*

	FPS		LPS		PDS		<i>F</i>
	<i>(n = 21)</i>		<i>(n = 15)</i>		<i>(n = 24)</i>		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
pre	14.14	2.85	14.13	3.80	15.00	1.77	2.95
post	18.57	2.54	15.50	2.38	16.09	2.86	

The results also indicated that there were significant within-group effects, Wilks'  $\Lambda = .56, F(1, 55) = 42.90, p = .001$ , partial  $\eta^2 = .44$ . Follow-up paired-samples *t* tests revealed that there were significant positive changes in the VNOS rubric scores from the

pretest to the posttest for participants in both the FPS,  $t(20) = 8.85, p = .001$ , and LPS,  $t(13) = 2.31, p = .04$ , groups, but not the PDS group,  $t(22) = 1.80, p = .09$ .

VNOS data were also qualitatively analyzed. Responses to each question were coded to determine their concurrence with central tenets of NOS (Lederman et al., 2002). A matrix (Krippendorff, 1980; Miles & Huberman, 1994) was developed to organize the data by question number, group (i.e., FPS, LPS, PDS), and time period (i.e., pre and post). All responses to Question 1 were coded first, followed by all responses to Question 2, etc. During coding, data was examined phrase-by-phrase in terms of their meaning interpreted by the rater (Krippendorff, 1980). Information categories, or “nodes” as termed by Gibbs (2002), were created that summarized the perceived meaning of each phrase in the context of the entire response. For example, in response to Question 2 one participant said, “Scientists need to experiment because it’s the only way to obtain proof.” This statement was coded as “proof.” Once all coding was complete, similar nodes were categorized together in order to aid in further analysis (Leech & Onwuegbuzie, in press). For example, for Question 2 the nodes “proof,” “support,” and “facts” were categorized together. Next, the total number of responses coded at each category by group and time period were determined (Krippendorff, 1980). Categories for each question were then examined to determine patterns in the responses between the groups at each time period and changes within each group from pre- to posttest (Krippendorff, 1980).

*Question 1: What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?*

At the pretest, nearly all participants in all three groups used words like “factual,” “concrete,” “proven,” “experiments,” and “testable” to describe science. The next most common description – given by 33% of the FPS group, 13% of the LPS group, and 21% of the PDS group – was that science is a way of inquiring about or studying the world around us. There were no differences in posttest responses across all groups except that a small number of participants in the FPS and PDS groups included the word “empirical” in their description.

*Question 2: Does the development of scientific knowledge require experiments? Explain your response and give examples to defend your position.*

Approximately 60% of each group on the pretest said that experimentation was required in order to provide evidence to support a theory, and around 30% of each group said that experimentation was necessary because it was the best way for students to learn. Only a small number from each group indicated that experimentation was not required. Fourteen percent of the FPS group, 7% of the LPS group, and 8% of the PDS group said that experimentation was helpful, but not required. Only one person in each group stated on the pretest that scientists can use observations instead of experimentation.

On the posttest, there were slightly different patterns of responses. Approximately 55% of each group indicated experimentation was necessary to provide evidence to support a theory, while about 22% of each group stated that experimentation was

necessary because it was the best way for students to learn. In the FPS and LPS groups, however, more participants – 19% and 13%, respectively – indicated that observations can be used instead of experimentation, while all members of the PDS group indicated that experimentation was required on the posttest.

*Question 3: After scientists have developed a scientific theory (e.g., plate tectonic theory, evolution theory), does the theory ever change? If you believe that scientific theories do not change, explain why and defend your answer with examples. If you believe that scientific theories do change explain why theories change and defend your answer with examples.*

The most frequently given response on the pretest – by approximately 83% of each group – was that theories can change as new evidence becomes available. Around 17% of each group indicated that since they are “only” or “just” theories, they are very likely to change. Only 5% of the FPS group, 7% of the LPS group, and 12% of the PDS group indicated that theories are based on strong evidence.

On the posttest, more participants in each group – approximately 92% – indicated that theories can change as new evidence become available. Fewer participants – 10% of the FPS group, 13% of the LPS group, and 4% of the PDS group – noted that since they are “only” or “just” theories, they are very likely to change. No participants stated on the posttest that theories are based on strong evidence.

*Question 4: Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.*

On the pretest, approximately 65% of each group described laws with words such as “proven,” “concrete,” and “universally accepted” while describing theories with words such as “unproven,” “opinions,” and “accepted by a few scientists.” About 35% of each group also said that laws cannot change, while theories can. Fourteen percent of the FPS group and 4% of the PDS group indicated that theories become laws when they gain sufficient evidence, and 10% of the FPS group and 8% of the PDS group described theories as explanations for scientific phenomena.

There were different patterns of responses on the posttest. Fifty-six percent of the PDS group and 40% of the LPS group continued to describe laws as proven facts and theories as unproven opinion, while only 15% of the FPS group continued to do so. More members of the PDS group (58%) indicated that laws cannot change and theories can, while fewer members of the LPS and FPS groups – 20% and 10%, respectively – indicated such on the posttest. Regarding whether theories became laws, 13% of the LPS group, 10% of the FPS group, and 4% of the PDS group noted that they did after gaining sufficient evidence. Nearly 30% of the FPS group described theories as explanations for scientific phenomena, while no one in either the LPS or PDS group did. Additionally, 14% of the FPS group stated that there were no differences between laws and theories.

*Question 5: Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?*

There were slightly different patterns of responses between the groups on the pretest. The FPS group tended to indicate that scientists are very certain of the structure of the atom because they had seen it with a microscope (52%), had data from some type of experiment (15%), or inferred it from studies of how atoms reacted/behaved (10%). Twenty-four percent of the FPS group stated that they did not know what evidence scientists used as the basis for atomic structure, and 5% said that the model described in the question was either outdated or too simple. The LPS group tended to indicate that scientists are very certain of the structure of the atom because they had seen it with a microscope (33%), had data from some type of experiment (33%), or inferred it from studies of how atoms reacted/behaved (13%). Seven percent of the LPS group stated that they did not know what evidence scientists used as the basis for atomic structure, and 13% said that atomic theory was all speculation. The PDS group tended to indicate that scientists are very certain of the structure of the atom because they had seen it with a microscope (38%) or had data from some type of experiment (54%). No one in this group stated that scientists inferred atomic structure from studies of how atoms reacted/behaved. Thirteen percent of the LPS group stated that they did not know what evidence scientists used as the basis for atomic structure, 8% said that the model described in the question was either outdated or too simple, and 8% noted that atomic theory was all speculation.

On the posttest, there continued to be slightly different patterns of responses between the groups. Compared to the pretest, fewer members of the FPS group stated that scientists had seen atoms with a microscope (38%), more indicated that scientists based

atomic structure on some sort of experiment (39%), and an equal number noted that scientists inferred the model from studies of how atoms reacted/behaved (10%). While no one in the FPS indicated that they did not know what evidence scientists used as the basis for atomic structure on the posttest, 24% stated that scientists were very certain of the model without giving any explanation. The LPS group was nearly evenly divided on the posttest between saying that scientists had seen the atom with a microscope (33%), had evidence from some sort of experiment (33%), or that they did not know what evidence scientists used as the basis for atomic structure (27%). The pattern within the PDS group was more mixed. Fewer from that group stated that scientists had seen atoms with a microscope (25%) or had evidence from some sort of experiment (42%). Similarly, fewer members of the PDS group indicated on the posttest that they did not know what evidence scientists used as the basis for atomic structure (8%), that the model described in the question was either outdated or too simple (4%), or that atomic theory was all speculation (4%). However, more participants in this group stated that scientists inferred the model from studies of how atoms reacted/behaved (4%).

*Question 6: It is believed that about 65 million years ago dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different*



*conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?*

On the pretest, there were slightly different patterns of responses between the groups. Approximately 30% of each group indicated that scientists can arrive at different conclusions because they have different perspectives or interpretations of the data, about 10% of each group said that no one knows what really happened because no one was there to directly observe it, and another 10% of each group noted that because they were only theories everyone had their own opinion. However, more members of the PDS and FPS groups – 33% and 24%, respectively – said that the different conclusions were the result of old or lost evidence than did members of the LPS group (13%). Similarly, 26% of the PDS group and 24% of the FPS group said that both conclusions are possible with no further explanation compared to 7% of the LPS group.

On the posttest, there was even more difference between the groups' responses. Over 70% of the FPS group attributed the different conclusions to differing perspectives or interpretations of the data, 13% said the disagreement was because no one was there to observe it, 12% noted that both theories were possible with no further explanation, and only 5% stated that lost or old evidence was responsible for the different conclusions. For the LPS group, 47% attributed the different conclusions to differing perspectives or interpretations of the data, 20% said it was due to old or lost evidence, 13% noted that both were possible with no further explanation, 7% indicated that scientists had manipulated the data to support their person opinion, and 7% stated that they did not know why the scientists disagreed. In the PDS group, 38% attributed the different

conclusions to differing perspectives or interpretations of the data, 25% said it was due to old or lost evidence, 21% noted that both were possible with no further explanation, and 8% stated that because they were only theories everyone had their own opinion.

*Question 7: Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values or intellectual norms of the culture in which it is practiced. Which perspective do you agree with? Explain your response and give examples to defend your position.*

The patterns between groups' responses were different at the pretest. For the FPS group, 29% indicated that science is culturally influenced and 19% said it was universal. Forty-three percent noted that science is mostly universal but has some elements that are cultural. The cultural aspects indicated in this group's responses included what science was taught in school (33%) and what research received funding (14%). Nine percent of this group noted that theories are cultural whereas laws are universal. For the LPS group, 67% indicated that science is culturally influenced, 13% said it was universal, and 13% stated it was a combination of both. Twenty percent of this group responded that science should be universal. The cultural aspects indicated in this group's responses included what research received funding (7%), and the idea that religion distorts or prejudices people against science (7%). For the PDS group, 50% indicated that science is culturally influenced, 21% said it was universal, and 29% stated it was both. The cultural aspects

indicated in this group's responses included what science was taught in school (25%), what research received funding (12%), and the idea that religion distorts or prejudices people against science (8%). Eight percent of the PDS group noted that laws are universal whereas theories are cultural and 21% stated that the practice of science is cultural but the facts produced by science are universal.

Differences between the groups continued on the posttest. For the FPS group, 81% indicated science was culturally influenced, 8% stated it was universal, and 8% said it was a combination of both. The only cultural aspect mentioned by this group on the posttest was what science was taught in schools (4%). For the LPS group, 53% indicated science was culturally influenced and 27% stated it was universal. The only cultural aspect mentioned by this group on the posttest was what science was taught in schools (7%). Additionally, 13% of this group continued to say that science should be universal. For the PDS group, 46% indicated science was culturally influenced, 12% stated it was universal, and 21% said it was a combination of both. The only cultural aspect mentioned by this group on the posttest was what science was taught in schools (16%). Four percent of this group continued to say that the practice of science is cultural but the facts produced by science are universal. Unlike the pretest, however, 4% of the PDS group stated that science should be universal on the posttest.

*Question 8: Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use creativity and imagination during their investigations? If you believe that scientists do not use imagination and creativity, please explain why and give examples as necessary. If yes, then at which stages of their*

*investigations do you believe scientists use imagination and creativity: planning and design, data collection, and/or after data collection? Please explain your response and give examples as necessary.*

On the pretest, approximately 45% of each group indicated that scientists only use creativity and imagination during the planning and design of their investigations, while about 25% of each group said that scientists use creativity throughout the investigation. For the FPS group, 8% said scientists use creativity during data collection, 8% stated scientists use creativity during theory formation, 8% noted scientists do not use creativity, and 4% indicated that scientists did use creativity but gave no further explanation. For the LPS group, 13% said scientists use creativity after data collection, 7% stated that scientists did use creativity but gave no further explanation, and 7% indicated that they did not know if scientists used creativity or not. For the PDS group, 3% said scientists use creativity during data collection, 3% stated scientists use creativity after data collection, and 24% indicated that scientists did use creativity but gave no further explanation.

On the posttest, there were different patterns in the responses of the groups. For the FPS group, 55% said that scientists use creativity throughout the investigation, 30% indicated that scientists only use creativity and imagination during the planning and design of their investigations, 12% stated that scientists use creativity during data collection, 7% noted that scientists use creativity after data collection, and 7% indicated that scientists did use creativity but gave no further explanation. For the LPS group, 70% indicated that scientists only use creativity and imagination during the planning and design of their investigations, 18% said that scientists use creativity throughout the

investigation, 12% stated that scientists use creativity during data collection, and 6% noted that scientists use creativity after data collection. For the PDS group, 55% indicated that scientists only use creativity and imagination during the planning and design of their investigations, 26% said that scientists use creativity throughout the investigation, 13% noted that scientists did use creativity but gave no further explanation, and 3% stated that scientists use creativity while organizing data.

### *Patterns Across Groups*

All three groups responded similarly on the pretest for most of the VNOS questions, with only three questions – five, six, and seven – showing somewhat different patterns of responses. For question five, the three groups were similar except that a higher percentage of participants in the FPS group indicated that scientists had seen an atom with a microscope, while a higher percentage of participants in both the LPS and PDS groups noted that atomic theory was all speculation. Likewise, for question six, all three groups responded similarly except that more members of the FPS and PDS groups said that the different theories were a result of old or lost evidence or stated that both theories were possible without giving any further explanation. For question seven, more participants in the LPS group believed that science was culturally influenced, followed by the PDS group, and then the FPS group. The pattern was reversed when looking at who said that science is a combination of universal and cultural elements, and approximately equal percentages of each group thought science was universal.

There were more differences between the groups at the posttest compared to the pretest, with only questions one and three having similar patterns of responses across all

three groups. For question two, all members of the PDS group stated that science required experimentation, while a growing number of participants in the FPS and LPS groups indicated that science can be based on observations instead of experimentation. For question four, large percentages of both comparison groups continued to believe that laws were proven facts while theories were unproven opinions. Members of the FPS group, however, tended to describe theories as explanations for scientific phenomena. For question five, participants in the FPS and LPS groups were approximately equally divided between saying that scientists had seen atoms with a microscope, atomic theory was based upon evidence from some sort of experiment, or they did not know what the basis for atomic theory was. More members of the PDS group, however, indicated that atomic theory was based on evidence from experiments, while fewer members stated that scientists had seen atoms with microscopes or that they did not know what evidence scientists used. For question six, over two-thirds of the FPS group attributed the different theories to differing perspectives, while just less than half of the LPS group and just over a third of the PDS group did so. Similarly, about a quarter of each comparison group indicated that the difference was due to lost or old evidence, while only 5% of FPS did so. For question seven, a much higher percentage of the FPS group indicated that science is culturally influenced compared to the LPS and PDS groups (81%, 53%, and 46%, respectively), while a higher percentage of the LPS group stated that science is universal compared to the PDS and FPS groups (27%, 12%, and 8%, respectively). No members of the LPS group noted that science is a combination of cultural and universal elements on the posttest, while over one-fifth of the PDS group and a few members of the FPS group

did. For question eight, a higher percentage of the FPS group stated that scientists use creativity throughout their investigations compared to the PDS and LPS groups (55%, 26%, and 18%, respectively), while more members of the LPS group indicated that scientists only use creativity during the planning and design stages compared to the PDS and FPS groups (70%, 55%, and 30%, respectively).

Overall, the analysis showed that all three groups had similar understanding regarding NOS on the pretest. However, on the posttest, the treatment group had demonstrated the most growth toward a more informed view of NOS, followed by the LPS group, and, finally, the PDS group.

#### *Patterns Within Groups*

*FPS group.* The treatment group experienced some growth on all eight questions except the first one, for which the responses remained unchanged. When comparing the posttest to the pretest responses, the following patterns were found. For question two, nearly four times as many group members indicated that observations can be used instead of experiments. For question three, approximately ten percent more of the group stated that theories can change if new evidence becomes available. For question four, three times as many group members described theories as explanations for scientific phenomena, while a third as many described laws as unchangeable, proven facts and theories as unproven opinions. For question five, while there were not more informed responses per se, fewer members of the FPS group indicated that scientists had seen atoms with microscopes or that they did not know what evidence scientists used as the basis for atomic theory. For question six, over twice as many group members indicated

that different theories are the result of differing perspectives and backgrounds. For question seven, nearly three times as many group members indicated that science is culturally influenced. For question eight, over twice as many group members stated that scientists use creativity throughout their investigations.

Even with these improvements, some misconceptions regarding NOS persisted among members of the FPS group on the posttest. For question two, nearly a fifth of the group continued to state that science requires experimentation. For question three, ten percent still noted that theories can change because they are “only” theories, indicating that theories are not legitimate scientific explanations. On question four, 15% of the FPS group continued to describe laws as unchangeable, proven facts and theories as unproven opinions, while 10% still believed that theories became laws once they had garnered enough supporting evidence. For question five, over a third of the group continued to state that scientists had seen atoms with microscopes, and nearly a quarter of the group did not provide any explanation at all. On question six, 13% of the FPS group still attributed differences in the theories to the fact that no one was there to observe the phenomenon directly. For question seven, nearly 10% of the group continued to depict science as devoid of cultural influence. On question eight, nearly half the group persisted in believing that scientists use creativity only in select aspects of their investigations.

Overall, the treatment group demonstrated growth toward a more informed understanding of NOS on seven of the eight questions. Even though some misconceptions remained at the posttest, they were limited to less than a third of the group on all but the last question.



*LPS group.* When comparing the posttest to the pretest responses, the following patterns were found. This comparison group did not change on question one and regressed on questions five, seven, and eight. On question five, no members of the LPS group indicated that scientists based atomic theory on indirect evidence and 20% more stated that they did not know the basis for atomic theory. On question seven, 14% more group members depicted science as devoid of cultural influence. For question eight, nearly twice as many said that scientists use creativity only in select aspects of their investigations.

The LPS group did experience some growth on questions two, three, four, and six. On question two, over twice as many group members stated that science can be based on observations. For question three, nearly 10% more indicated that theories can change if sufficient new evidence becomes available. On question four, 15% fewer group members described laws as unchangeable, proven facts and theories as unproven opinions. For question six, nearly a fifth more group members attributed the different theories to scientists' differing perspectives and backgrounds, while no group members stated that the true explanation can never be known because no one was there to directly observe the phenomenon.

Even on the questions where some growth was noted, some misconceptions regarding those aspects of NOS persisted among members of the LPS group on the posttest. On question two, over half the group continued to say that science requires experimentation. For question three, 13% of the group still noted that theories can change because they are "only" theories, indicating that theories are not legitimate scientific

explanations. On question four, nearly a third of the group continued to describe laws as unchangeable, proven facts and theories as unproven opinions, while 13% still believed that theories became laws once they had garnered enough supporting evidence. For question six, seven percent of the group stated that the different theories were the result of scientists manipulating that data to support their position.

Participants in the LPS group regressed toward a more naïve understanding of NOS on three of the eight questions. Although growth toward a more informed understanding of NOS was demonstrated on half the questions, between 7% and 100% of group the maintained misconceptions regarding NOS on the posttest.

*PDS group.* When comparing the posttest to the pretest responses, the following patterns were found. This comparison group did not change on questions one or eight, but regressed on questions two, four, and seven. On question two, all group members stated that science requires experimentation. For question four, no group members describe theories as explanations for scientific phenomena and a quarter more of the group indicated that laws cannot change. On question seven, four percent fewer group members believed that science was culturally influenced and four percent more group members stated that science is not universal, but should be.

The PDS group did experience some growth on questions three, five, and six. For question three, nearly 10% more the group indicated that theories can change when sufficient new evidence becomes available. On question five, four percent more group members stated that scientists based atomic theory on indirect evidence, while 13% fewer group members noted that scientists had seen atoms with microscopes. For question six,

eight percent more of the group attributed the different theories to the scientists' differing perspectives and backgrounds, while 10% fewer group members said that the true explanation can never be known because no one was there to directly observe the phenomenon.

Even on the questions where some growth was noted, some misconceptions regarding those aspects of NOS persisted among members of the PDS group on the posttest. On question three, four percent of the group still noted that theories can change because they are “only” theories, indicating that theories are not legitimate scientific explanations. For question five, a quarter of the group continued to believe that scientists had seen atoms with microscopes. On question six, over 10% of the group still depicted science as devoid of cultural influence.

The PDS group regressed toward a more naïve view of NOS on three of the eight questions. Additionally, despite experiencing some growth toward a more informed understanding of NOS on three questions, between 4% and 100% of the group maintained misconceptions regarding NOS on the posttest.

### Summary

This chapter described the results of the quantitative and qualitative analyses conducted to address the research questions. Significant increases were seen for the treatment (FPS) group in general science teaching efficacy, personal science teaching efficacy, science teaching outcome expectancy, general science knowledge, biology content knowledge, chemistry content knowledge, and understanding of NOS; the LPS group in general science teaching efficacy, personal science teaching efficacy, chemistry

content knowledge, and understanding of NOS; and, the PDS group in general science teaching efficacy, personal science teaching efficacy, and chemistry content knowledge. Additionally, the FPS group had significantly higher general science teaching efficacy than both comparison groups, personal science teaching efficacy than the PDS group, and understanding of NOS than the LPS group.

## 5. Discussion and Implications

The purpose of this study was to examine the effects of a summer science camp teaching experience on preservice elementary teachers' science teaching efficacy, science content knowledge, and understanding of the nature of science. Specifically, there were three research questions.

(1a) How does preservice elementary teachers' science teaching efficacy change during their science methods course? (1b) Is there a difference between the science teaching efficacy of preservice elementary teachers who plan for and teach a two-week inquiry-based summer science camp and preservice elementary teachers who do not participate in the camp as their fieldwork experience?

(2a) In what ways do preservice elementary teachers' general and subject-specific science content knowledge change during their science methods course? (2b) Is there a difference between the change in general science knowledge and the change in subject-specific knowledge? (2c) Is there a difference between the general or subject-specific science content knowledge of preservice elementary teachers who plan for and teach a two-week inquiry-based summer science camp and preservice elementary teachers who do not participate in the camp as their fieldwork experience?

(3a) How does preservice elementary teachers' understanding of the nature of science change during their science methods course? (3b) Is there a difference between

the understanding of the nature of science of preservice elementary teachers who plan for and teach a two-week inquiry-based summer science camp and preservice elementary teachers who do not participate in the camp as their fieldwork experience?

The findings, implications, and limitations of the study are discussed in this chapter.

## Findings

### *Science Teaching Efficacy*

Analysis of participants' pre- and posttest data on the overall Science Teaching Efficacy Belief Instrument (STEBI), as well as its two subscales for Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE), indicate that all three groups experienced significant increases in their science teaching efficacy during their science methods course. Both comparison groups (i.e., LPS and PDS) had significant increases on the PSTE and STEBI, while the treatment group (i.e., FPS) had significant increases on the PSTE, STOE, and STEBI. This finding indicates that it is possible to increase preservice elementary teachers' science teaching efficacy through a science methods course, including one that is only three-weeks in duration. However, an increase in the STOE subscale was only seen for the treatment group, whose methods course field experience involved teaching at an inquiry-based summer science camp.

Analyses revealed significant differences among the three groups on the PSTE and STEBI, with the treatment group having significantly higher PSTE and STEBI scores than the PDS group as well as significantly higher STEBI scores than the LPS group. This finding indicates that the group that taught at an inquiry-based summer science camp had higher science teaching efficacy than the groups that did not. Additionally, the

length of the methods course may not be related to increasing science teaching efficacy because the treatment group, which completed a seven-week methods course, had higher science teaching efficacy than groups with both longer (i.e., PDS, 16 weeks) and shorter (i.e., LPS, 3 weeks) methods course experiences.

### *Science Content Knowledge*

Analysis of participants' pre- and posttest data on the Science Content Knowledge Assessment (SCKA), as well as its subscales for biology, chemistry, Earth science, and physics, showed that all three groups experienced a significant increase in their knowledge of chemistry during their science methods course. The treatment group also experienced a significant increase on the biology subscale and for the total SCKA instrument. Overall, the participants did not experience a significant increase in their science content knowledge in several specific content areas. Although not reaching statistical significance, both comparison groups actually had lower post- than pretest scores on the biology and Earth science subscales. Further, even though each group demonstrated an increase in their total SCKA score, participants barely answered more than half the items correctly on the posttest – members of the treatment group answered an average of 65% correctly, with the LPS and PDS groups answering 58% and 54% correctly, respectively. These findings indicate that preservice elementary teachers' content knowledge can be improved during their science methods course. However, the mixed results by content area and less-than-desirable posttest scores indicate that elementary preservice teachers' knowledge of science content areas is unevenly

distributed and that more work is needed in order to help preservice elementary teachers reach an acceptable level of science content knowledge.

Analyses revealed no significant differences among the three groups on the total SCKA instrument or any of the subscales. This finding indicates that both the length of the methods course and the type of field experience may not be related to increasing preservice teachers' science content knowledge. Alternatively, the methods courses and corresponding field experiences in this study may not have been long enough or did not cover enough science content in order for there to be observable differences among the groups.

#### *Understanding of the Nature of Science*

Analysis of participants' pre- and posttest data on the Views of the Nature of Science Questionnaire (VNOS) showed the members of the FPS and LPS groups experienced significant increases in their understanding of NOS from the pre- to posttest, while members of the PDS group did not. These results were supported by the qualitative analysis, which showed that the FPS group experienced growth on seven questions, the LPS group experienced growth on four questions and regressed on three questions, and the PDS group experienced growth on three questions and regressed on three questions. This finding indicates that participants in the group that had a seven-week methods course and taught at an inquiry-based summer science camp as well as participants in the group that had a three-week methods course and completed 15 hours of classroom observations improved their understanding of NOS, while participants in the group that completed a site-based long-term field experience did not.



Even though each group demonstrated some improvement, there were still major misconceptions regarding NOS at the posttest, including the beliefs that science requires experimentation, laws are proven facts while theories are unproven opinions, theories become laws once they have garnered sufficient support, scientists have seen atoms with microscopes, differing scientific theories are attributable to the fact that scientists either did not observe the phenomenon first-hand or manipulated the data to support their opinion, science is devoid of cultural influence, and scientists only use creativity in select aspects of their investigations. This indicates that more explicit instruction in NOS is most likely necessary in order to help preservice elementary teachers achieve a more complete understanding of NOS.

Analyses showed no significant differences among the three groups on the VNOS. However, Tukey post hoc tests did reveal that the FPS group had higher VNOS scores than the LPS group. Again, these results were supported by the qualitative analysis, which showed that the FPS group experienced growth on more questions and held fewer misconceptions on the posttest than the other groups. This finding indicates that participants in the group that had a seven-week methods course and taught at an inquiry-based summer science camp had a more informed understanding of NOS than participants in the group that had a three-week methods course and completed 15 hours of classroom observations.

## Discussion

This study examined the effects of a summer science camp teaching experience on preservice elementary teachers' science teaching efficacy, science content knowledge,

and understanding of the nature of science. The analyses revealed that preservice elementary teachers who taught in a two-week, inquiry- and problem-based summer science camp as part of their science methods course did experience improvement in their science teaching efficacy, science content knowledge, and understanding of NOS. More specifically, the treatment group (FPS) demonstrated significant, positive pre- to posttest changes in their general science teaching efficacy, personal science teaching efficacy, science teaching outcome expectancy, overall science content knowledge, biology content knowledge, chemistry content knowledge, and understanding of NOS. Both comparison groups (i.e., LPS and PDS) also experienced significant, positive pre- to posttest changes in their general science teaching efficacy, personal science teaching efficacy, and chemistry content knowledge, while the LPS group also had a significant, positive pre- to posttest change in its understanding of NOS. Additionally, the FPS group had significantly higher science teaching efficacy than both comparison groups and significantly higher understanding of NOS than the LPS group, but did not have significantly higher science content knowledge overall or in any specific content area than either comparison group.

#### *Science Teaching Efficacy*

The findings indicate that the type of field experience included in science methods courses is an important factor for preservice elementary teachers' science teaching efficacy. In this study, treatment participants who taught in an inquiry- and problem-based summer science camp as their field experience had significantly higher science teaching efficacy than comparison participants who completed either a site-based long-

term field experience or a more traditional field experience involving 15 hours of classroom observations. Further, the treatment group experienced significant gains in all aspects of science teaching efficacy, including both personal science teaching efficacy and science teaching outcome expectancy, while the comparison groups only experienced significant gains in general and personal science teaching efficacy. Science teaching efficacy does not seem to be affected strongly, or at all, by the length of the methods course, however. The treatment group, which completed a seven-week methods course, had higher science teaching efficacy than groups with both longer (i.e., PDS, 16 weeks) and shorter (i.e., LPS, 3 weeks) methods courses.

Overall, the findings support previous research, which shows that science teaching efficacy can be positively impacted by science methods courses (Morrell & Carroll, 2003), constructivist-based teaching and learning experiences (Bleicher & Lindgren, 2005; Graves, 1999; Thompson, 2003), and teaching science to students (Ginns et al., 1995; Wingfield, 1998). In the present study, significant increases in science teaching efficacy were seen for courses lasting only three weeks; however, participants who taught in an inquiry- and problem-based summer science camp ended their methods course with significantly higher science teaching efficacy than participants who did not have that experience. This proves evidence that field experiences that require preservice elementary teachers to plan and implement connected, reform-based science lessons with students are better able to improve science teaching efficacy than either traditional classroom observation experiences or long-term, site-based experiences.

### *Science Content Knowledge*

Based on the results of this study, type of field experience does not seem to have a clear effect on science content knowledge. The treatment group demonstrated significant increases in general science content knowledge as well as biology and chemistry knowledge, while the comparison groups only showed significant increases in their chemistry knowledge. This finding is interesting because all three courses were taught by the same instructor, who implemented the same content-related activities in class. One possible explanation is that the treatment group's field experience focused on particular content areas, while the comparison groups' did not. The camp in which the treatment group participated had two sections with different themes: space and watersheds. Because participants in the treatment group were required to not only teach in one of these sections but also understand how the content of their lesson fit into the entire theme, it is possible that they were exposed to a greater depth and breadth of science content knowledge during their field experience than participants in the comparison groups. Participants in the LPS group observed whatever science content was being taught during their 15 hours of observation, and participants in the PDS group taught a lesson on whatever topic their cooperating teacher had scheduled.

There were no differences, however, among the three groups' general or subject-specific science content knowledge. Even though participants in the treatment group experienced gains in more areas of their knowledge than participants in the comparison group, this was not sufficient for there to be significant differences among the groups overall. Therefore, although individual group gains appear to indicate that teaching in an

inquiry- and problem-based summer science camp can improve preservice elementary teachers' general science knowledge and subject-specific knowledge in some content areas more than completing either a site-based, long-term field experience or a more traditional classroom observation experience, the between-group analyses indicate that type of field experience does not matter in terms of general or subject-specific science content knowledge. One explanation for this could be the instrument used to measure content knowledge. Because it was created for this study, the reliability and validity for both forms of the SCKA have not been well established. Another possibility is that, although the methods courses and corresponding field experiences provided enough information to improve participants' science knowledge in some areas, they did not focus on content knowledge enough for there to be observable differences among the groups within the time period studied.

Overall, these results support previous research, which shows that preservice elementary teachers have inadequate science content knowledge (Khalid, 1999; Schulte, 2001) and that methods courses can improve their subject-specific knowledge (Doby, 1997; Goves & Pugh, 2002; Hypolite, 2003; Trundle et al., 2002). In the current study, all three groups showed significant improvement on the chemistry subscale, which was the content area for which they had the least amount of knowledge at the pretest. However, no group showed significant improvement on the Earth science or physics subscales. The discrepancies among the groups' gains in subject-specific knowledge may be due to the fact that the methods course in the current study did not focus on one particular content area; instead, it covered topics from all four of the subject areas included on the content

assessment. This is reinforced by the mean subscale scores (see Table 7), which show that all three groups had more evenly distributed knowledge across the four subject areas on the posttest than on the pretest. It is possible that because participants in all three groups began the methods course with very poor chemistry knowledge compared to the other content areas, they focused on improving their knowledge in that domain to the exclusion of the others.

### *Understanding of the Nature of Science*

The findings indicate that the type of field experience included in science methods courses is a factor for preservice elementary teachers' understanding of NOS. All three groups had similar understandings of NOS at the pretest. However, on the posttest, the FPS group had the highest VNOS score of the three groups, with the difference being significant compared to the LPS group but not the PDS group. Further, both the FPS and LPS groups experienced significant improvement in their understanding of NOS, while the PDS group did not. This demonstrates that the group that taught in an inquiry- and problem-based summer science camp (FPS) and the group that completed 15 hours of classroom observations (LPS) both experienced significant improvement in their understanding of NOS as a result; however, the FPS group still had significantly higher VNOS scores than the LPS group. Additionally, even though the participants in PDS group, which completed a site-based, long-term field experience, did not have significantly lower VNOS scores than participants in the FPS group, they did not experience a significant improvement in their understanding of NOS during their methods course. As with science teaching efficacy, understanding of NOS does not seem

to be affected strongly, or at all, by the length of the methods course. The treatment group, which completed a seven-week methods course, had a better understanding of NOS than the comparison group with a shorter methods course (i.e., LPS, 3 weeks) but not the comparison group with a longer methods course (i.e., PDS, 16 weeks).

Overall, the results support previous research, which shows that preservice elementary teachers have a naïve understanding of NOS (Keske, 2002; Lederman, 1992; Stockton, 2002) and that science methods courses can positively influence preservice teachers' understanding of NOS (Akerson et al., 2000; Cochrane, 2003; Matkins et al., 2002; Meichtry, 1999). In the current study, two of the three groups (FPS and LPS) demonstrated significant improvement in their understanding of NOS during their science methods course. Interestingly, participants in the group with the longest methods course (PDS) did not experience a significant increase in their understanding of NOS. One explanation for this is that because participants in the FPS and LPS groups experienced more intensive, short-term methods courses, they were exposed to NOS concepts on a more consistent and constant basis than participants in the PDS group.

### Implications

This study has implications, in general, for elementary science teacher education and, more specifically, for field experience requirements in preservice teacher education. The results show that science methods courses can improve preservice elementary teachers' science teaching efficacy, subject-specific science content knowledge, and understanding of the nature of science regardless of the duration of the methods courses. All three groups had significant increases in their general and personal science teaching

efficacy as well as their chemistry content knowledge, and two groups demonstrated significant growth in their understanding of NOS. Gains were seen for methods courses lasting as little as three weeks.

For elementary science teaching education, in general, the findings support the continued use of content-specific methods courses for preservice elementary teachers in order to address content-specific efficacy and knowledge. The findings provide evidence that preservice elementary science methods classes, regardless of duration, positively affect participants' knowledge of some content, sense of efficacy in teaching science, and understandings of the nature of science. However, they also indicate that methods classes cannot compensate for a lack of science content knowledge. If elementary teachers are to be responsible for teaching particular subject matter, teacher education programs must address this issue and investigate possible solutions, such as increasing the number of science content courses required for program completion or considering integrated content/methods courses. Additionally, even though growth was observed regarding NOS, all three groups still had misconceptions on the posttest. This suggests, as reported in other studies (Akerson et al., 2002; Cochrane, 2003; Lederman, 1992; Matkins et al., 2000), that the methods courses may need to incorporate more explicit instruction in order to help preservice teachers achieve a more complete understanding of NOS.

This study also provides evidence that the length of methods courses may not be a critical factor to the development of preservice teachers' science teaching efficacy and understanding of NOS. Improvement in these variables were seen for groups enrolled in courses lasting three, seven, or 16 weeks. Despite more evenly distributed subject-



specific knowledge at posttest than pretest, however, there were limited and discrepant gains in the participants' content knowledge. Therefore, it is not possible to reach a conclusion regarding the relationship between the length of methods courses and content knowledge without additional studies and better instruments for measuring teachers' science content knowledge.

Specifically related to field experiences, the current study provides evidence that the type, and not duration, of field experiences required of preservice elementary teachers may be central to improving their teaching efficacy and understanding of certain content knowledge. The findings suggest that having preservice elementary teachers participate in inquiry- and problem-based teaching experiences with elementary students can improve their science teaching efficacy and understanding of NOS more than either long-term, site-based field experiences or more traditional classroom observation experiences. Additionally, this study provides evidence that just requiring preservice teachers to teach during their field experience may not be enough. Both the FPS and PDS groups were required to teach during their field experiences, but the FPS group demonstrated significant growth in more areas than the PDS group and had significantly higher science teaching efficacy at the posttest. Participants in the FPS group planned and implemented a connected two-week inquiry- and problem-based unit based on best-practice research (Sterling, et al., 2007). Participants in the PDS group, however, taught a single lesson on whatever content their participating teacher had selected. Therefore, it may be the type and/or length of the teaching experience that matters. For science content knowledge, the mixed results indicate that type of field experience may not influence general or subject-

specific science content knowledge. However, more data are needed on more participants in order to identify the relationships between preservice teacher content knowledge and field experiences in teacher education programs.

Previous research has shown that teaching efficacy (Armor et al., 1976; Anderson et al., 1988; Ashton & Webb, 1986; Hannum, 1994; Kerley, 2004; Ledford, 2002; Midgley et al., 1989; Moore & Esselman, 1992; Muijs & Reynolds, 2002; Ross, 1992; Ross, 1998; Staples, 2002; Watson, 1991) and teachers' content knowledge (Druva & Anderson, 1983; Goldhaber & Brewer, 1997; Monk, 1994; Wenglinsky, 2000) are positively associated with student achievement. The current study provides evidence that teacher education programs that provide preservice elementary teachers with opportunities to plan and implement connected, reform-based science lessons with students within the context of methods courses may produce more effective science instructors than programs with either short-term, observation-based field experiences or long-term professional development models. Overall, the findings of this study indicate that course length is not as important for developing preservice teachers' teaching efficacy and understanding of content as having connected, authentic field-based teaching experiences that are based on best-practices research and coupled with methodological instruction.

*Areas for future research.* There are several opportunities to continue and improve upon the current study. One area for future research would be to determine if the effects of the two-week summer camp teaching experience that served as the treatment condition in the current study could be achieved through other settings, such as programs

that meet on weekends or after school during the academic year. Because the methods courses in the current study differed in two ways (i.e., course length and type of field experience), future investigations are needed to examine these variables separately. Studies could look at courses of equal length that incorporate different field experiences or courses of various lengths that incorporate the same field experience. Additionally, studies which follow preservice teachers beyond their methods courses would provide evidence as to the sustainability of the current findings. Longitudinal research that traces teacher efficacy and knowledge, as well as other variables such as instructional practices, from preservice programs into full-time teaching situations could be invaluable for helping to shape more effective teacher education programs. Further, more research needs to be done concerning factors that can improve preservice elementary teachers' general and subject-specific science content knowledge. As noted before, the results of this study are inconclusive regarding this variable. Therefore, additional investigations that examine ways to increase preservice elementary teachers' science content knowledge would be useful for determining how many and/or the type of science content courses that are needed to ensure that elementary teachers have an adequate level of science knowledge.

### Limitations

This study does have several limitations. First of all, pre-existing groups were used. Although an effort was made to identify differences among the groups on variables relevant to the study, participants self-selected into the various groups; therefore, there may be disparities among the groups which were beyond the purview of the study but did

affect it. Additionally, there were differences in the Partnership Schools (PS) and Professional Development Schools (PDS) programs outside the purview of this study. The PS groups, for example, completed a five semester program that included a traditional 15 week student teaching experience. The PDS group, on the other hand, completed a four semester program that included a site-based year-long internship. Another difference between the groups relates to their science methods course. Both the FPS and LPS cohorts completed their science methods course the summer before their student teaching experience. The LPS cohort completed the course in three weeks during May and June, while the FPS cohort completed it in seven weeks during June and July. The PDS group began their science methods course in June before their internship started but did not complete it until one semester into the internship (i.e., December). While it is anticipated that these differences did not impact the results of this study, no attempt was made to control for the variances in the programs in which the participants were enrolled. Secondly, the study examined a small sample of participants enrolled in a master's degree program at a large, public university located in an urban/suburban area of a mid-Atlantic state. No claim can be made as to the generalizability of the results to other contexts. Finally, the pretest form of the Science Content Knowledge Assessment had a Cronbach's alpha of .53, which is less-than-desirable. Future studies should either improve Form A or only use Form B, which had an acceptable Cronbach's alpha of .86. Because one cannot teach what one does not know, this limitation reinforces the need for appropriate instrumentation for assessing elementary teachers' science content knowledge.

## Appendix A – Personal Data Questionnaire

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

Identifying Code: \_\_\_\_\_

Age: \_\_\_\_\_

Gender: (circle one)                      Male                      Female

Ethnicity: (circle one)                      Asian                      Black                      Hispanic

White                      Other (indicate): \_\_\_\_\_

Degree(s) earned, including  
major(s) and minor(s): \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Science content courses taken: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

[illegible]

Appendix B – Science Teaching Efficacy Beliefs Instrument for Preservice Teachers  
(Enochs & Riggs, 1990)

Identifying Code: \_\_\_\_\_

Please circle the number that most closely matches your level of agreement with each statement below.

- 1=Strongly Disagree (SD)  
2=Disagree  
3=Neither agree nor disagree  
4=Agree  
5=Strongly Agree (SA)

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

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



Appendix C – Science Content Knowledge Assessment, Version A

Identifying Code: \_\_\_\_\_

Write the letter of the best response on the line provided.

- \_\_\_\_\_ 1. In rabbits, short fur (F) is dominant to long fur (f). According to the Punnett square, what is the chance of two heterozygous short-haired rabbits having offspring with short fur?

	F	f
F	FF	Ff
f	Ff	ff

- A. One in four  
B. Two in four  
C. Three in four  
D. Four in four
- \_\_\_\_\_ 2. One method of determining the classification of an animal is by comparing the amino acid sequence. Which of these animals most closely resembles the unknown animal?

Unknown animal: Met-Gly-Ser-Tyr-Tyr-Arg-His-His-Glu-Lys-Asp
---

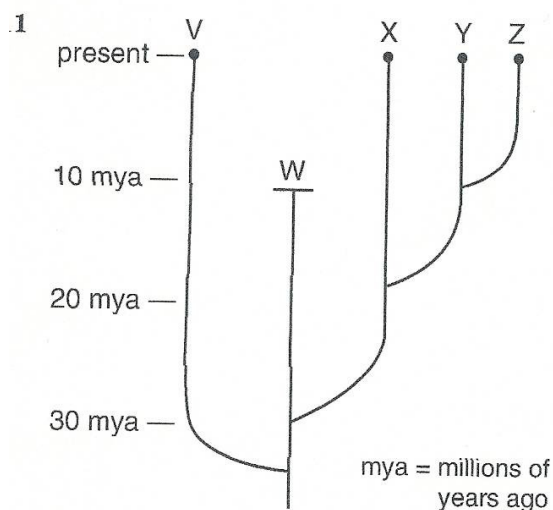
- A. Horse: Met-Gly-Ser-Ser-Tyr-Arg-Arg-Asp-His-Glu-Lys-Asp  
B. Dog: Met-Gly-Ser-Tyr-Tyr-Arg-His-Asp-Glu-Lys-Asp  
C. Cat: Met-Gly-Ser-Tyr-Tyr-Arg-His-His-Arg-Cys-Thre-Asp  
D. Mouse: Met-Gly-Ser-Tyr-Tyr-Arg-His-Glu-Val-Val-Leu
- \_\_\_\_\_ 3. The concentration of glucose must be maintained within a fairly narrow range in most vertebrates. This statement is an example of —
- A. homeostasis  
B. excretion  
C. glycolysis  
D. fermentation

- \_\_\_\_\_ 4. Bacteria are tremendously successful unicellular organisms, yet all large organisms are multicellular. Unicellular organisms cannot grow very large because the —
- A. energy expenditures would be too great
  - B. locomotion of the organisms would be too slow
  - C. diffusion of nutrients into the cell's interior would be too slow
  - D. respiratory rate would be too high
- \_\_\_\_\_ 5. Around hot-water vents deep in the ocean live specialized communities. Bacteria turn hydrogen sulfide into sugars by a chemical process. The bacteria then provide food to other life forms. Compared to food chains on land, the bacteria fill the same role as —
- A. hawks
  - B. rabbits
  - C. mushrooms
  - D. green plants
- \_\_\_\_\_ 6. Compared to a skin cell, a muscle cell is likely to have more —
- A. Golgi bodies
  - B. mitochondria
  - C. cell membranes
  - D. chloroplasts
- \_\_\_\_\_ 7. Blood is considered a tissue because blood —
- A. flows inside arteries and veins
  - B. is necessary to carry oxygen and nutrients to the cells
  - C. is pumped from the heart and is carried to the cells through arteries
  - D. is composed of red and white blood cells working together and having specific functions
- \_\_\_\_\_ 8. In which biome do the evaporation rates exceed the precipitation rates?
- A. Desert
  - B. Tropical jungle
  - C. Grassland
  - D. Hardwood forest

\_\_\_\_\_ 9. Which of these could be successfully treated with antibiotics?

- A. Common cold
- B. Influenza
- C. HIV
- D. Strep throat

\_\_\_\_\_ 10. Which statement is best supported by the phylogenetic tree shown?



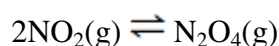
- A. Species V is still alive today and is the oldest species.
- B. Species W is still developing from a prior species.
- C. Species X, Y, and Z became extinct 20 million years ago.
- D. Species W first came into existence 10 million years ago.

\_\_\_\_\_ 11. If the heat of fusion is 32.2 kJ/mol, the amount of heat energy required to melt 5.67 grams of FeO is –

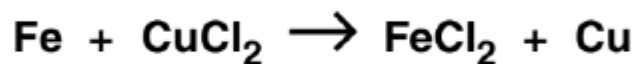
- A. 3.26 kJ
- B. 5.32 kJ
- C. 18.3 kJ
- D. 2.54 kJ

- \_\_\_\_\_ 12. According to Charles' law, the volume of a fixed amount of gas is directly proportional to –
- A. barometric pressure
  - B. kelvin temperature
  - C. isoelectric mixture
  - D. vapor concentration

- \_\_\_\_\_ 13.  $\text{NO}_2$  and  $\text{N}_2\text{O}_4$  undergo the reaction shown. When a sealed container of  $\text{NO}_2$  reaches chemical equilibrium, which must be true?



- A. The maximum number of molecules has been reached.
  - B. No chemical reactions are occurring.
  - C. The rates of the forward and reverse reactions are equal.
  - D. No  $\text{N}_2\text{O}_4$  is present.
- \_\_\_\_\_ 14. The type of reaction represented by the equation below is –



- A. single-replacement
  - B. double-replacement
  - C. decomposition
  - D. synthesis
- \_\_\_\_\_ 15. Which of the following properties decreases from left to right across a period?
- A. Ionization energy
  - B. Atomic radius
  - C. Atomic number
  - D. Electronegativity

\_\_\_\_\_ 16. Which is the base in the reaction?



- A.  $\text{H}_2\text{O}$
- B.  $\text{H}_2\text{SO}_4$
- C.  $\text{KOH}$
- D.  $\text{K}^+$

\_\_\_\_\_ 17. How does the radioactive isotope C-14 differ from its stable counterpart C-12?

- A. It has the same number of protons and two more electrons than C-12.
- B. It has a different number of protons and two more neutrons than C-12.
- C. It has the same number of protons but two more neutrons than C-12.
- D. It has a different number of protons and two less neutrons than C-12.

\_\_\_\_\_ 18. Which of the following is a balanced equation?

- A.  $\text{C}_3\text{H}_8(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
- B.  $\text{C}_3\text{H}_8(\text{g}) + \text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
- C.  $\text{C}_3\text{H}_8(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$
- D.  $\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$

\_\_\_\_\_ 19. The type of formula that shows the arrangements of atoms and bonds is called –

- A. molecular
- B. structural
- C. empirical
- D. chemical

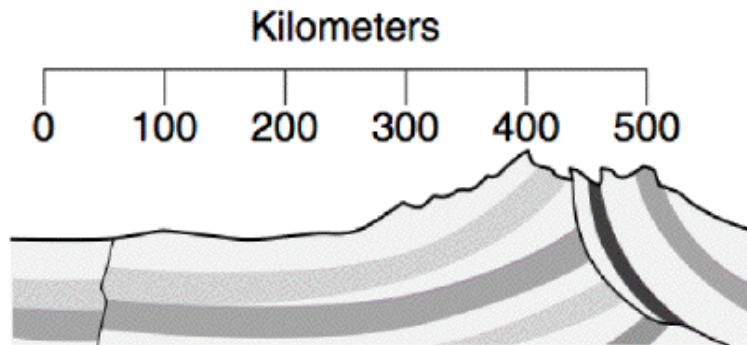
\_\_\_\_\_ 20. Sodium iodide exhibits what type of bond?

- A. hydrogen
- B. covalent
- C. ionic
- D. metallic

- \_\_\_\_\_ 21. Which of these measurements allows scientists to compare the brightness of stars?
- A. Orbital velocity
  - B. Absolute magnitude
  - C. Red shift
  - D. Critical density

- \_\_\_\_\_ 22. Metamorphic rocks with a layered or banded look are called –
- A. foliated
  - B. striated
  - C. unfoliated
  - D. evaporated

- \_\_\_\_\_ 23. The mountain shown is composed of deformed sedimentary layers. They are located near a tectonic plate boundary and are still increasing in elevation due to –

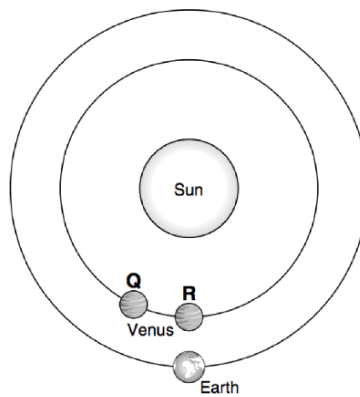


- A. seafloor spreading of tectonic plates
  - B. transform faulting of a tectonic plate
  - C. subduction of a tectonic plate
  - D. colliding tectonic plates
- \_\_\_\_\_ 24. If matter from Saturn would float in water, while matter from Earth would sink in water, which of the following is true?
- A. Saturn is smaller than Earth.
  - B. Saturn is smaller than the sun.
  - C. Saturn has a higher density than Earth.
  - D. Saturn has a lower density than Earth.

\_\_\_\_\_ 25. On clear nights in late summer and early fall in the Shenandoah Valley, why does ground fog form in the low areas near the Shenandoah River?

- A. Warm winds bring moisture from the hills down into the valley.
- B. Cool, moist air ascends from the river to the hilltops.
- C. Cool, descending air meets moist air in the low areas near the river.
- D. There is more air pollution in the evenings.

\_\_\_\_\_ 26. Based on the drawing below, what is the main reason that Venus would appear brighter at point Q rather than at point R as seen from the Earth?



- A. The planet is closer to the Earth at point Q than at point R.
- B. The planet appears overhead against a dark sky when it is at point Q but not at point R.
- C. Light from the planet at point Q is less affected by the sun's gravity than at point R.
- D. More of the visible side of the planet is illuminated at point Q than at point R.

\_\_\_\_\_ 27. Which of these would come next in the water cycle?

Ocean → Evaporation → Condensation

- A. Sedimentation
- B. Precipitation
- C. Deposition
- D. Aeration

- \_\_\_\_\_ 28. What property is shared by many gemstones, such as diamonds, rubies, sapphires, emeralds, and topaz?
- A. Extreme hardness
  - B. Ductility
  - C. Carbon as the primary element
  - D. High specific gravity
- \_\_\_\_\_ 29. Rocky objects, measuring millimeters to kilometers in diameter, generally orbit the Sun in a region located between –
- A. Neptune and Pluto
  - B. Mercury and Venus
  - C. Earth and Mars
  - D. Mars and Jupiter
- \_\_\_\_\_ 30. In Virginia and some other parts of the world, water has carved vast caverns out of underground limestone deposits. Water, however, must contain dissolved carbon dioxide in order to break down the limestone. What role does the carbon dioxide play?
- A. It reduces the viscosity so the water flows more quickly.
  - B. It raises the freezing point so the underground water continues to flow all winter.
  - C. In water it forms an acid which reacts with the limestone to produce a water-soluble substance.
  - D. It supports the microscopic plant life that destroys the limestone.
- \_\_\_\_\_ 31. Copper is a good electrical conductor because:
- A. it has a high melting temperature.
  - B. no electrons can flow through it.
  - C. few electrons can flow through it.
  - D. electrons flow readily through it.



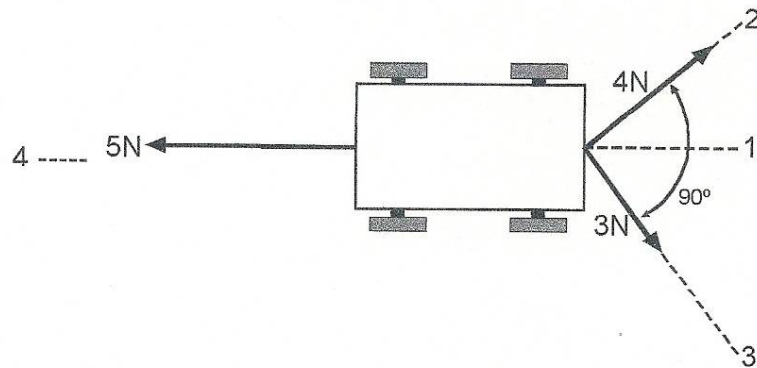
\_\_\_\_\_ 32. An astronaut weighs 150 pounds on the surface of the Earth. How much would he weigh standing on a planet exactly like Earth except it is one-half as far from the Sun?

- A. More than 150 pounds.
- B. 150 pounds.
- C. Less than 150 pounds.
- D. He would be weightless.

\_\_\_\_\_ 33. If the amplitude of a wave were increased:

- A. the energy transferred would increase.
- B. the frequency of the wave would increase.
- C. the wavelength would increase.
- D. the velocity of the wave would increase.

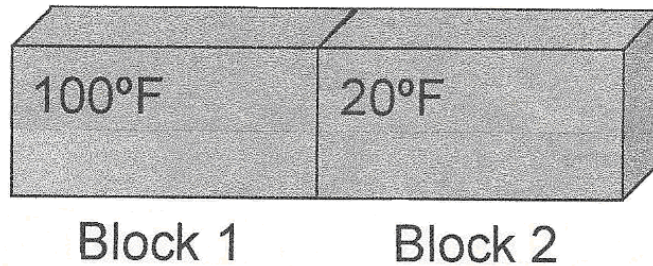
\_\_\_\_\_ 34. If the cart is being pulled simultaneously toward points 2, 3 and 4, toward which point will the cart most likely move?



- A. 1
- B. 2
- C. 4
- D. The cart won't move.

- \_\_\_\_\_ 35. If you are at rest and are watching a moving object and it suddenly changes direction, you can be sure that the object:
- A. was acted on by a net force.
  - B. was not acted on by a net force.
  - C. is losing kinetic energy.
  - D. is gaining kinetic energy.
- \_\_\_\_\_ 36. A battery works by:
- A. storing electrical energy.
  - B. creating chemical energy.
  - C. converting chemical energy into electrical energy.
  - D. converting electrical energy into chemical energy.
- \_\_\_\_\_ 37. A baseball is hit into the air. At the top of its trajectory:
- A. the baseball is not subject to a net force.
  - B. the baseball is subject to a net force.
  - C. the baseball is not accelerating.
  - D. Both a and c are true.
- \_\_\_\_\_ 38. An electric charge moving at right angles to magnetic field lines experiences:
- A. a force at right angles to its direction of motion.
  - B. a force parallel to its direction of motion.
  - C. a force that opposes its motion.
  - D. a force in the direction of the source of the magnetic field.
- \_\_\_\_\_ 39. After a light wave has reflected from a smooth glass mirror hanging on a wall:
- A. it may be traveling in a different direction.
  - B. it is traveling at a different speed than before it hit the mirror.
  - C. its wavelength is different.
  - D. its energy is greater.

- \_\_\_\_\_ 40. Metal block 1 is at a temperature of  $100^{\circ}\text{F}$ ; identical metal block 2 is at  $20^{\circ}\text{F}$ . If the blocks are in contact, as shown below, what will happen?



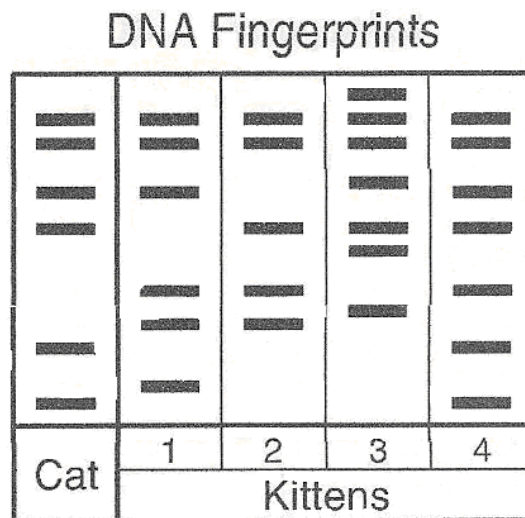
- A. Cold will flow from block 2 to block 1.
- B. Only heat will flow from block 1 to block 2.
- C. Heat will flow from block 1 to block 2; cold will flow from block 2 to block 1.
- D. Cold will be absorbed by block 1; heat will be absorbed by block 2.

Appendix D – Science Content Knowledge Assessment, Version B

Identifying Code: \_\_\_\_\_

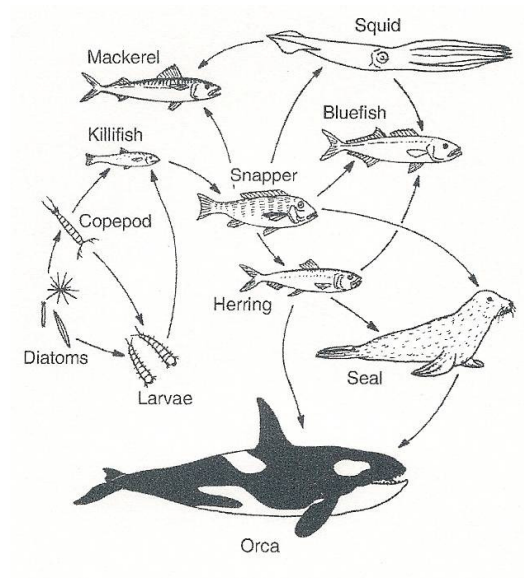
Write the letter of the best response on the line provided.

- \_\_\_\_\_ 1. In a plant that has red flowers, red flower color, R, is completely dominant to white flower color, r. If the plant is heterozygous for flower color, which alleles will be carried by the gametes it produces?
- A. R and r  
B. R only  
C. r only  
D. Rr only
- \_\_\_\_\_ 2. The picture shows a segment of DNA from a cat. Which of these is most likely the kitten of this cat?



- A. 1  
B. 2  
C. 3  
D. 4

- \_\_\_\_\_ 3. If transpiration stopped completely, how would a plant's homeostasis first be affected?
- A. More carbon dioxide molecules would be taken in by leaves.
  - B. Fewer sugars stored in roots and stems would diffuse into the soil.
  - C. Carbohydrates would no longer be formed.
  - D. Water molecules would not be released from leaves.
- \_\_\_\_\_ 4. Some plant roots grow with mycorrhizal fungi. The fungi absorb water and minerals and pass them on to the plant and receive carbohydrates from the plant. This is an example of —
- A. predation
  - B. mutualism
  - C. competition
  - D. parasitism
- \_\_\_\_\_ 5. In the diagram, which organism provides nutrients for the largest number of other organisms?



- A. Herring
- B. Bluefish
- C. Snapper
- D. Seal

\_\_\_\_\_ 6. Bones do all of the following EXCEPT —

- A. make nerve cells
- B. make blood cells
- C. protect organs
- D. store calcium

\_\_\_\_\_ 7. What is the body's first line of defense against disease?

- A. Enzymes
- B. Blood
- C. Antibodies
- D. Skin

\_\_\_\_\_ 8. Shenandoah National Park is home to many different types of ecosystems. According to the characteristics shown below, which ecosystem would most likely be home to a mixture of wildlife species from northern, cooler ranges and southern, warmer ranges?

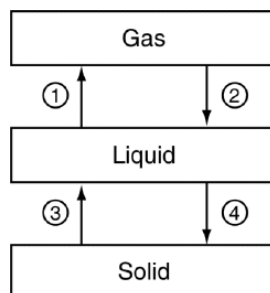
Transition forest – overlap zones between needleleaf forests and deciduous forests
Appalachian Cove forest – climax forests known for high humidity and lush foliage
Northern Needleleaf forest – spruce-fir forests found on the highest, coolest peaks
Oak-Hickory forest – classic deciduous forests with abundant food and shelter

- A. Transition forest
- B. Appalachian Cove forest
- C. Northern Needleleaf forest
- D. Oak-Hickory forest

\_\_\_\_\_ 9. Which method of fly control would be most harmful to other organisms in the environment?

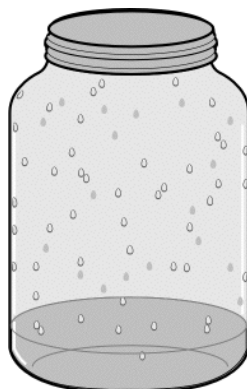
- A. Using fly traps
- B. Spraying broad-range insecticides
- C. Planting carnivorous plants
- D. Releasing sterilized male flies

- \_\_\_\_\_ 10. Scientists hypothesize that oxygen began to accumulate in Earth's atmosphere after the appearance of living things with the ability to —
- A. form tissues
  - B. reproduce sexually
  - C. photosynthesize
  - D. breathe air
- \_\_\_\_\_ 11. Solid magnesium has a specific heat of  $1.01 \text{ J/g}^\circ\text{C}$ . How much heat is given off by a 20.0 gram sample of magnesium when it cools from  $70.0^\circ\text{C}$  to  $50.0^\circ\text{C}$ ?
- A. 1010 J
  - B. 404 J
  - C. 202 J
  - D. 808 J
- \_\_\_\_\_ 12. Which numbered process represents condensation?



- A. 4
  - B. 3
  - C. 2
  - D. 1
- \_\_\_\_\_ 13. A gas has a volume of  $50.0 \text{ cm}^3$  at a temperature of  $-73^\circ\text{C}$ . What volume would the gas occupy at a temperature of  $-123^\circ\text{C}$  if the pressure stays constant?
- A.  $37.5 \text{ cm}^3$
  - B.  $50.0 \text{ cm}^3$
  - C.  $3.75 \text{ cm}^3$
  - D.  $5.0 \text{ cm}^3$

\_\_\_\_\_ 14. A heated liquid placed in a closed container will vaporize until –



- A. all the liquid molecules become vapor molecules
- B. the vapor pressure is greater than the atmospheric pressure
- C. the number of liquid molecules vaporizing equals the number of vapor molecules condensing
- D. the boundary between liquid and vapor disappears

\_\_\_\_\_ 15. Oxygen and sulfur are in the same group (16) in the periodic table. This means that, in general, oxygen and sulfur -

- A. will react only with each other
- B. combine only with elements in periods of 4 or higher
- C. can only react with elements in group 16
- D. undergo similar reactions with other elements

\_\_\_\_\_ 16. How many different elements are in ammonium hydroxide ( $\text{NH}_4\text{OH}$ )?

- A. 2
- B. 3
- C. 4
- D. 7



\_\_\_\_\_ 17. The data below indicate that –

	Protons	Neutrons	Electrons
Substance A	8	8	8
Substance B	8	9	8

- A. A and B are isotopes of the same element
- B. A and B are different elements
- C. A has a greater charge than B
- D. A is more reactive than B

\_\_\_\_\_ 18. Which of these is the balanced equation for the reaction described below?

iron (III) chloride + sodium carbonate → iron (III) carbonate + sodium chloride

- A.  $\text{FeCl}_3 + \text{Na}_2\text{CO}_3 \rightarrow \text{Fe}_2(\text{CO}_3)_3 + \text{NaCl}$
- B.  $2\text{FeCl}_3 + 2\text{Na}_2\text{CO}_3 \rightarrow 3\text{Fe}_2(\text{CO}_3)_3 + 3\text{NaCl}$
- C.  $2\text{FeCl}_3 + 3\text{Na}_2\text{CO}_3 \rightarrow \text{Fe}_2(\text{CO}_3)_3 + 6\text{NaCl}$
- D.  $3\text{FeCl}_3 + 2\text{Na}_2\text{CO}_3 \rightarrow 3\text{Fe}_2(\text{CO}_3)_3 + 6\text{NaCl}$

\_\_\_\_\_ 19. According to the Lewis diagram, a nitrogen molecule has a –

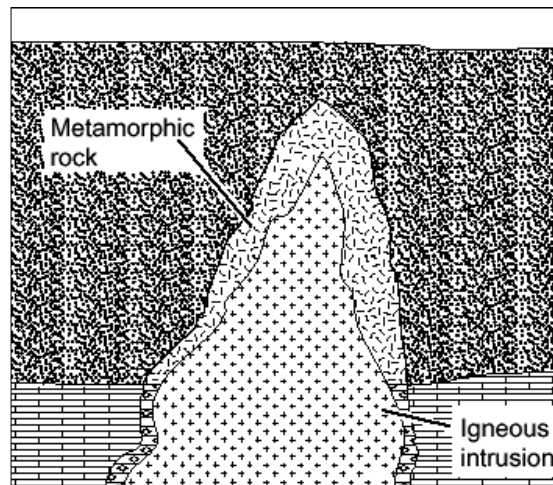


- A. bent structure and a double bond
- B. linear structure and a triple bond
- C. polar structure and a triple bond
- D. circular structure and an ionic bond

\_\_\_\_\_ 20. Bonding between two elements of equal electronegativity would be –

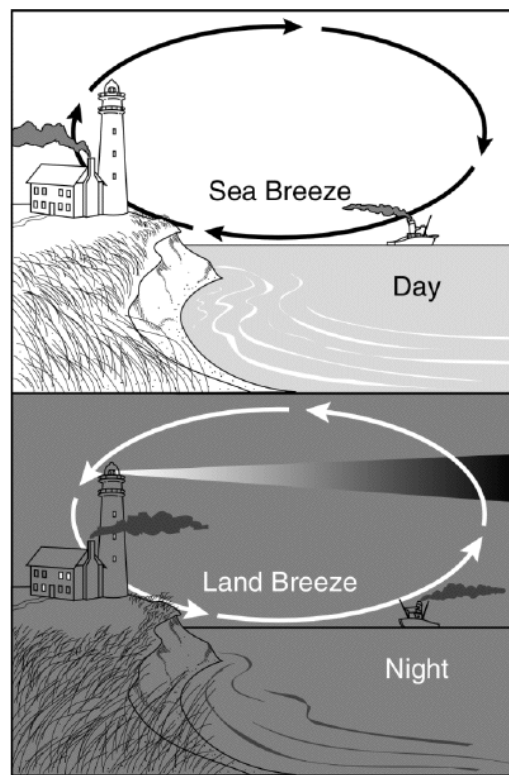
- A. metallic in character
- B. primarily ionic
- C. 100% covalent
- D. 50% ionic

- \_\_\_\_\_ 21. The sun emits energy by converting hydrogen into helium. What is this process called?
- A. Fusion
  - B. Fission
  - C. Solar wind
  - D. Sunspot formation
- \_\_\_\_\_ 22. Which of these provides the **best** evidence of the environment in which an igneous rock was formed?
- A. Texture
  - B. Thickness
  - C. Color
  - D. Size
- \_\_\_\_\_ 23. Sometimes metamorphic rock is found adjacent to an igneous intrusion, as shown in the drawing. According to geologists, what causes this phenomenon?



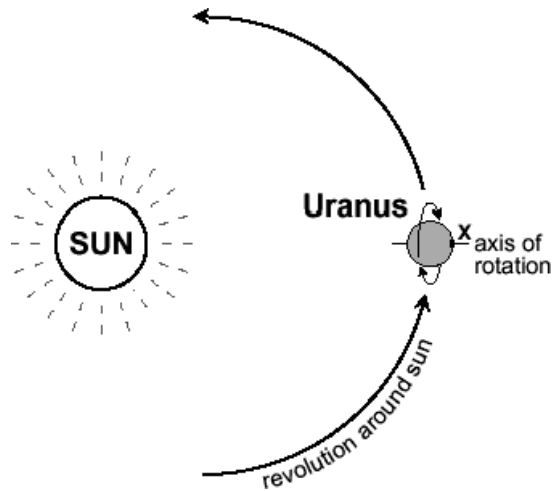
- A. The metamorphic rock was lighter than the magma and floated to the top and sides.
- B. The surrounding rock was metamorphosed when it came into contact with the hot magma.
- C. Vapor from the magma condensed to form metamorphic rock.
- D. The magma replaced all but the outer edge of existing metamorphic rock.

- \_\_\_\_\_ 24. Which of these *best* describes the composition of a nebula such as the Crab Nebula?
- A. Planets and moons
  - B. Large asteroids
  - C. Ice crystals
  - D. Clouds of dust and gas
- \_\_\_\_\_ 25. What would explain the change in the direction of air movement from daytime to night?



- A. Land temperature changes more quickly than water temperature.
- B. Cool air rises more quickly than warm air.
- C. The sun warms the moist ocean air more than the dry land air.
- D. Water is always cooler than land.

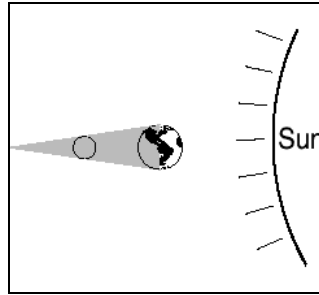
- \_\_\_\_\_ 26. The planet Uranus is unusual because its axis of rotation lies almost in the plane of its revolution. If the axis is pointing toward the sun as in the picture, what would occur at point X when the planet turns once on its axis?



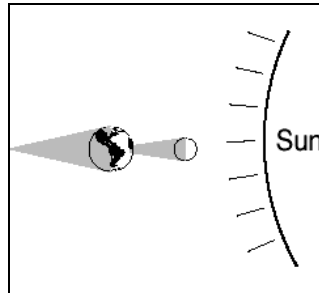
- A. The point would be in twilight for the full rotation.  
B. The point would be in daylight for the full rotation.  
C. The point would be in darkness for the complete rotation of the planet.  
D. The point would be in daylight for half the time and in darkness for half the time.
- \_\_\_\_\_ 27. The accumulated salts in seawater make the seawater much more dense than fresh water. One of the characteristics of salt water is that it has –
- A. higher levels of dissolved oxygen than fresh water  
B. a lower freezing point than fresh water  
C. decrease buoyancy for swimmers  
D. ninety elements that are easily extracted from seawater
- \_\_\_\_\_ 28. Each mineral has a unique crystal shape because of the –
- A. arrangement of its atoms  
B. hardness being between 1 and 10  
C. streak being constant  
D. variations in its color

- \_\_\_\_\_ 29. Which diagram represents the placement of the sun, Earth, and moon during a lunar eclipse?

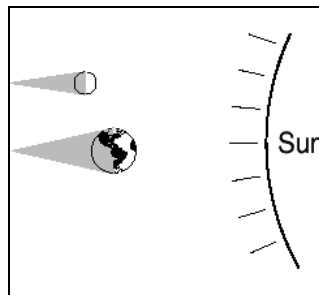
A.



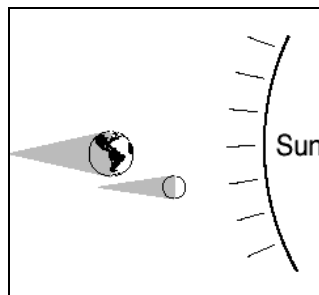
B.



C.

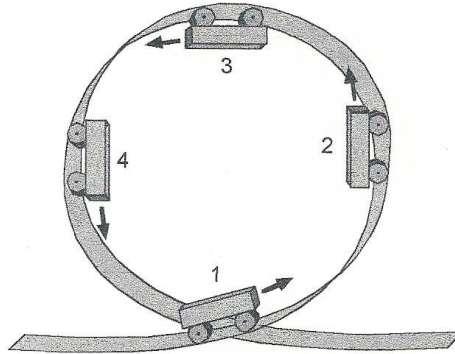


D.



- \_\_\_\_\_ 30. Which of the following are some of the major mineral resources of Virginia?
- A. Diamonds, sapphires, and rubies
  - B. Coal, granite, and limestone
  - C. Sulfur, fluorite, and cobalt
  - D. Gold, silver, and copper
- \_\_\_\_\_ 31. Materials that make good electrical conductors must:
- A. be solid.
  - B. be flexible enough to bend easily.
  - C. allow electrons to flow easily.
  - D. Only a and c.
- \_\_\_\_\_ 32. An astronaut weighs 150 pounds on the surface of the Earth. How much would he weigh standing on a planet exactly like Earth except it is twice as far from the Sun?
- A. More than 150 pounds.
  - B. Less than 150 pounds.
  - C. He would be weightless.
  - D. 150 pounds.
- \_\_\_\_\_ 33. If you looked at a continuous spectrum in a darkened room through a red filter, the spectrum would appear:
- A. the same except the red portion would be black.
  - B. black except the red portion would remain red.
  - C. as shades of red except the red portion would be black.
  - D. as shades of red except the red portion would be a brighter red.

- \_\_\_\_\_ 34. A roller coaster cart goes through a loop as shown below. At which point is there no gravity?



- A. Gravity is the same everywhere.  
B. 2  
C. 3  
D. 4
- \_\_\_\_\_ 35. A car with a full tank of gasoline is driven non-stop until the tank is empty. What happened to the gasoline's energy?
- A. All of it could have been used to move the car.  
B. Some moved the car and some powered the stereo, lights and other equipment.  
C. Some moved the car, some powered the car's equipment, and some heated the engine.  
D. Some moved the car, some powered the car's equipment, some heated the engine, and some went into noise and friction.
- \_\_\_\_\_ 36. The primary purpose of an electric motor is to convert:
- A. electrical energy to heat energy.  
B. magnetic energy to electrical energy.  
C. electric energy to mechanical energy.  
D. mechanical energy to heat energy.

\_\_\_\_\_ 37. In a hydrogen atom, an electron orbits a proton. What is true about the forces between the electron and proton?

- A. Gravity is stronger than the electric force.
- B. There is no force between the electron and proton.
- C. The electric force is stronger than gravity.
- D. The electric force is equal to gravity in strength.

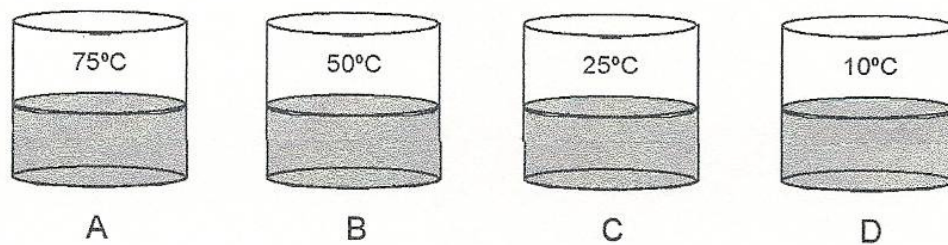
\_\_\_\_\_ 38. Light waves:

- A. do not oscillate.
- B. oscillate in proportion to their velocity.
- C. oscillate in the direction they are moving.
- D. oscillate at right angles to the direction they are moving.

\_\_\_\_\_ 39. People wear light-colored clothes in the summer because the clothes:

- A. prevent sweating.
- B. reflect more radiation.
- C. are not as heavy as dark clothes.
- D. let more air in.

\_\_\_\_\_ 40. Four containers of water with different temperatures as shown below are placed on a table in a room where the temperature is  $25^{\circ}\text{C}$ . After four hours, which beaker of water will have lost the most heat energy to the room?



- A. A
- B. B
- C. C
- D. D



## Appendix E – Science Content Knowledge Assessment Information

<b>Question Number</b>	<b>Content Area</b>	<b>Form A Answer</b>	<b>Form B Answer</b>
1	biology	C	A
2	biology	B	D
3	biology	A	D
4	biology	C	B
5	biology	D	C
6	biology	B	A
7	biology	D	D
8	biology	A	A
9	biology	D	B
10	biology	A	C
11	chemistry	D	B
12	chemistry	B	C
13	chemistry	C	A
14	chemistry	A	C
15	chemistry	B	D
16	chemistry	C	B
17	chemistry	C	A
18	chemistry	D	C
19	chemistry	B	B
20	chemistry	C	C
21	earth science	B	A
22	earth science	A	A
23	earth science	D	B
24	earth science	D	D
25	earth science	C	A
26	earth science	D	C
27	earth science	B	B
28	earth science	A	A
29	earth science	D	A
30	earth science	C	B
31	physics	D	C
32	physics	B	D
33	physics	A	B
34	physics	D	A
35	physics	A	D
36	physics	C	C
37	physics	B	C
38	physics	A	D

<b>Question Number</b>	<b>Content Area</b>	<b>Form A Answer</b>	<b>Form B Answer</b>
39	physics	A	B
40	physics	B	A

Appendix F – Views of Nature of Science Questionnaire – Form C Modified  
(adapted from Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002)

Identifying Code: \_\_\_\_\_

Please respond to each question in the space provided. Be as specific as possible.

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
2. Does the development of scientific knowledge require experiments? Explain your response and give examples to defend your position.
3. After scientists have developed a scientific theory (e.g., plate tectonic theory, evolution theory), does the theory ever change?
  - If you believe that scientific theories do not change, explain why and defend your answer with examples.
  - If you believe that scientific theories do change explain why theories change and defend your answer with examples.
4. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
5. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

6. It is believed that about 65 million years ago dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?
7. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values or intellectual norms of the culture in which it is practiced. Which perspective do you agree with? Explain your response and give examples to defend your position.
8. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use creativity and imagination during their investigations?
- If you believe that scientists do not use imagination and creativity, please explain why and give examples as necessary.
  - If yes, then at which stages of their investigations do you believe scientists use imagination and creativity: planning and design, data collection, and/or after data collection? Please explain your response and give examples as necessary.

# Appendix G – Views of Nature of Science Questionnaire Scoring Rubric

Score	Description
0	Incomprehensible or irrelevant answer; an answer that could not be categorized
1	Naïve view; uses phrases such as: science is about the facts, an experiment is a test to prove whether a theory is right or wrong, science demands definitive answers with right & wrong, theories change all the time because they are only a guess, theories become laws when proven “true,” a law has been tested and cannot change, scientists reach different hypothesis because no one was there to see what happened, scientists do not have/use imagination/creativity, science is about facts so it is not influenced by culture and society, scientists are certain about the structure of the atom because they observed atoms using powerful microscopes, a list of defined steps for “The Scientific Method”
2	Somewhat naïve view; uses phrases such as: an experiment has some elements of control or manipulation (but no clear explanation), still uses “prove,” theories change but laws don’t, laws are somewhat set while theories are apt to change, scientists reach different conclusions because everyone has their own opinion, scientists use creativity only in experiment design, don’t want creativity in data interpretation, society does not fund some scientific research so in that sense it influences science but scientific knowledge is universal and does not change from one place to another (e.g., atoms are atoms everywhere), scientists are not certain about the structure of the atom because we cannot be certain about anything
3	Somewhat informed view; uses phrases such as: science is based on observations (but no clear explanation), theories change because of new technologies, theories and laws are different sorts of knowledge (but no articulation of that difference), scientists reach different conclusions because they looked at the data differently (but no clear explanation), scientists use imagination/creativity before and after OR before and during (but no explanation), hope that science isn’t influenced by society/culture, science is influenced by society/culture but it shouldn’t be, infers that atoms cannot be observed but no clear explanation, lots of different ways to do science (but no explanation), testing of hypothesis but still uses “prove”
4	Informed view; uses phrases such as: science is different from religion in that science depends on observations of the natural world, an experiment is a controlled test to provide support for a certain hypothesis, experiments are not necessarily required for the development of scientific knowledge because some scientific theories/disciplines are observational in nature, theories and laws are different kinds of knowledge whereby the

	latter describes patterns in natural phenomena and the former provides explanations of those patterns, both laws and theories are subject to change if sufficient evidence is provided, scientists reach different conclusions because they tend to interpret the data based on different theoretical backgrounds, scientists use imagination and creativity throughout their investigations, scientists are part of their society/culture so there is an influence, the atom is a model inferred from indirect evidence, there are different ways of doing science (e.g., experimentation, observations, etc.)
5	Sophisticated view; uses phrases such as: the goal of science is not the accumulation of observable facts but involves abstractions, science strives to ask questions and is fueled by the desire to answer such questions, the acceptance that science is not absolute, theories and laws change due to sufficient new data, changing ideas/perspectives, and/or societies' view of the world changes, different interpretations occur because of differences in background/education or what one scientist believes is an inconsistency in another scientist's idea; similar answers to 4 but with relevant, accurate examples and/or a more articulated argument

## REFERENCES

## REFERENCES

- Abd-El-Khalick, F. (1998). The influence of history of science courses on students' conceptions of the nature of science. *Dissertation Abstracts International*, 59(07). (UMI No. 984244)
- Abd-El-Khalick, F. (2001). Embedding nature of science instruction in preservice elementary science courses: Abandoning scientism, but... *Journal of Science Teacher Education*, 12, 215-233.
- Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, 37, 1057-1095.
- Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective, explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching*, 37, 295-317.
- Allinder, R. M. (1994). The relationship between efficacy and instructional practices of special education teachers and consultants. *Teacher Education and Special Education*, 17, 86-95.
- American Association for the Advancement of Science. (1990). *Science for all Americans*. New York: Oxford University Press.
- American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.
- Anderson, R., Greene, M., & Loewen, P. (1988). Relationships among teachers' and students' thinking skills, sense of efficacy, and student achievement. *Alberta Journal of Educational Research*, 34(2), 148-165.
- Appleton, K., & Kindt, I. (1999, March). *How do beginning elementary teachers cop with science: Development of pedagogical content knowledge in science*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA.



- Armor, D., Conroy-Oseguera, P., Cox, M., King, N., McDonnell, L., Pascal, A., Pauly, E., & Zellman, G. (1976). *Analysis of the school preferred reading programs in selected Los Angeles minority schools*. Retrieved February 28, 2008 from <http://www.rand.org/pubs/reports/2005/R2007.pdf>
- Ashton, P. T., & Webb, R. B. (1986). *Making a difference: Teachers' sense of efficacy and student achievement*. New York: Longman.
- Baldi, S., Jin, Y., Skemer, M., Green, P.J., & Herget, D. (2007). *Highlights from PISA 2006: Performance of U.S. 15-Year-Old Students in Science and Mathematics Literacy in an International Context*. National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.
- Ball, D. L., & Feiman-Nemser, S. (1988). Using textbooks and curriculum guides: A dilemma for beginning teachers and teacher educators. *Curriculum Inquiry*, 18(4), 401- 422.
- Bandura, A. (1977). Self-efficacy: Towards a unifying theory of behavioral change. *Psychological Review*, 84, 191-215.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman.
- Bayer Corporation. (2004). *The Bayer facts of science education X: Are the nation's colleges and universities adequately preparing elementary schoolteachers of tomorrow to teach science?* Retrieved January 31, 2008 from <http://www.bayerus.com/msms/news/facts.cfm?mode=detail&id=survey04>
- Betts, J. R., Zau, A. C., & Rice, L. A. (2003). *Determinants of student achievement: New evidence from San Diego*. San Francisco: Public Policy Institute of California. Accessed February 27, 2008 at <http://www.ppic.org/main/publication.asp?i=321>
- Bleicher, R. E., & Lindgren, J. (2005). Success in science learning and preservice science teaching self-efficacy. *Journal of Science Teacher Education*, 16, 205–225.
- Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education*, 41(3), 53-62.
- Cakiroglu, J. (2000). Preservice elementary teachers' self-efficacy beliefs and their conceptions of photosynthesis and inheritance. *Dissertation Abstracts International*, 61(08). (UMI No. 9980981)
- Center for Strategic and International Studies (2005). *Technology Futures and Global Power, Wealth and Conflict*. Washington, DC: Author.

- Chang, Y. (2003) An examination of knowledge assessment and self-efficacy ratings in teacher preparation programs in Taiwan and the United States. *Dissertation Abstracts International*, 64(06). (UMI No. 3095143)
- Coble, C., & Allen, M. (2005). *Keeping America Competitive: Five Strategies to Improve Mathematics and Science Education*. Denver, CO: Education Commission of the States.
- Cochrane, B. (2003, February). *Developing preservice elementary teachers' views of the nature of science (NOS): Examining the effectiveness of intervention types*. Paper presented at the Annual International Conference of the Association for the Education of Teachers of Science, St. Louis, MO.
- Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology. (2007). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Available at <http://www.nap.edu/catalog/11463.html>
- Croninger, R. G., Rice, J. A., Rathbun, A., & Nishio, M. (2007). Teacher qualifications and early learning: Effects of certification, degree, and experience on first-grade student achievement. *Economics of Education Review*, 26, 312–324.
- Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives*, 8(1). Retrieved March 1, 2008 from <http://epaa.asu.edu/epaa/v8n1/>
- Dobey, D. C., & Schafer, L. E. (1984). The effects of knowledge on elementary science inquiry teaching. *Science Education*, 68, 39-51.
- Doby, J. K. (1997). Teacher content knowledge in the context of science education reform. *Dissertation Abstracts International*, 58(02). (UMI No. 9722612)
- Downing, J., Filer, J., & Chamberlain, R. (1997, November). *Science process skills and attitudes of preservice elementary teachers*. Paper presented at the meeting of the Mid-South Educational Research Association, Memphis, TN.
- Druva, C. A., & Anderson, R. D. (1983). Science teacher characteristics by teacher behavior and by student outcome: A meta-analysis of research. *Journal of Research in Science Teaching*, 20, 467-479.

- Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. Eds. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8*. Washington, DC: National Academy Press.
- Duschl, R. A., & Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. *Journal of Research in Science Teaching*, 26, 467-501.
- Eberts, R. W., & Stone, J. A. (1984). *Unions and public schools: The effect of collective bargaining on American education*. Lexington, MA: Heath.
- Enochs, L.G., & Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. *School Science and Mathematics*, 90, 694-706.
- Ferguson, R. F. (1991). Paying for public education: New evidence on how and why money matters. *Harvard Journal on Legislation*, 28, 465-498.
- Freeman, R. B. (2005, June). *Does Globalization of the Scientific/Engineering Workforce Threaten US Economic Leadership?* Working Paper 11457. Cambridge, MA: National Bureau of Economic Research.
- Gee, C. J., Boberg, W. S., & Gabel, D. L. (1996, April). *Preservice elementary teachers: Their science content knowledge, pedagogical knowledge, and pedagogical content knowledge*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, St. Louis, MO.
- Gibson, S., & Dembo, M. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology*, 76(4), 569-582.
- Gibbs, G. (2002). *Qualitative data analysis: Explorations with NVivo*. Philadelphia, PA: Open University Press.
- Ginns, I., Watters, J., Tulip, D., & Lucas, K. (1995). Changes in preservice elementary teachers' sense of efficacy in teaching science. *School Science and Mathematics*, 95, 394-400.
- Goldhaber, D. D., & Brewer, D. J. (1997). Evaluating the effect of teacher degree level on educational performance. In W. J. Fowler (Ed.), *Developments in School Finance 1996* (pp. 197-210). Washington, DC: National Center for Educational Statistics.
- Gonzales, P., Guzmán, J. C., Partelow, L., Pahlke, E., Jocelyn, L., Kastberg, D., & Williams, T. (2004). *Highlights from the Trends in International Mathematics*

*and Science Study (TIMSS) 2003*. U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

- Graves, S. M. (1999). Alternative conceptions in science and science teaching efficacy: Remediating preservice teachers' alternative conceptions and their effect on science teaching efficacy and reflective judgment. *Dissertation Abstracts International*, 60(12). (UMI No. 9954102)
- Grigg, W., Lauko, M., & Brockway, D. (2006). *The Nation's Report Card: Science 2005*. U.S. Department of Education, National Center for Education Statistics. Washington, D.C.: U.S. Government Printing Office.
- Groves, F. H., & Pugh, A. F. (2002). Cognitive illusions as hindrances to learning complex environmental issues. *Journal of Science Education and Technology*, 11, 381-390.
- Hammrich, P. L., & Blouch, K. K. (1996, March). *Elementary teachers candidates' conceptions of the nature of science and science teaching*. Paper presented at the Annual Meeting of the National Science Teachers Association, St. Louis, MO.
- Hannum, J. W. (1994). The organizational climate of middle schools, teacher efficacy, and student achievement. *Dissertation Abstracts International*, 55(12). (UMI No. 9514121)
- Harlen, W. (1997). Primary teachers' understanding in science and its impact in the classroom. *Research in Science Education*, 27, 323-337.
- Hypolite, C. C. (2003). The impact of whole-plant instruction on preservice teachers' understanding of plant science principles. *Dissertation Abstracts International*, 65(07). (UMI No. 3139298)
- Jefferson Lab. (2008). *Virginia state standards of learning: Science, math and technology practice tests*. Accessed March 1, 2008 at <http://education.jlab.org/solquiz/index.html>
- Kerley, D. M. (2004). Exploring connections among relational trust, teacher efficacy, and student achievement. *Dissertation Abstracts International*, 65(12). (UMI No. 3158253)
- Keske, K. P. (2002). Elucidating elementary science teachers' conceptions of the nature of science: A view to beliefs about both science and teaching. *Dissertation Abstracts International*, 63(06). (UMI No. 3057150)

- Khalid, T. (1999, March). *The study of preservice teachers' alternative conceptions regarding three ecological issues*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA.
- Knoblauch, D., & Woolfolk-Hoy, A. E. (2008). "Maybe I can teach those kids." The influence of contextual factors on student teachers' efficacy beliefs. *Teaching and Teacher Education*, 24, 166-179.
- Koc, I. (2006). Preservice elementary teachers' alternative conceptions of science and their self-efficacy beliefs about science teaching. *Dissertation Abstracts International*, 68(01). (UMI No. 3248024)
- Krippendorff, K. (1980). *Content analysis: An introduction to its methodology*. Thousand Oaks, CA: Sage.
- Lederman, N. G. (1986). Relating teaching behavior and classroom climate to changes in students' conceptions of the nature of science. *Science Education*, 70, 3-19.
- Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, 29, 331-359.
- Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, 36, 916-929.
- Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39, 497-521.
- Lederman, N. G., & Druger, M. (1985). Classroom factors related to changes in students' conceptions of the nature of science. *Journal of Research in Science Teaching*, 22, 649-662.
- Lederman, N. G., Schwartz, R., Abd-El-Khalick, F., & Bell, R. L. (2001). Preservice teachers' understanding and teaching of nature of science: An intervention study. *Canadian Journal of Science, Mathematics, and Technology Education*, 1, 135-160.
- Lederman, N. G., & Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behavior? *Science Education*, 71, 721-734.

- Ledford, D. M. (2002). Teachers' level of efficacy as a predictor of the academic achievement of students with disabilities. *Dissertation Abstracts International*, 63(05). (UMI No. 3052726)
- Lee, C. A., & Houseal, A. (2003). Self-efficacy, standards, and benchmarks as factors in teaching elementary school science. *Journal of Elementary Science Education*, 15, 37-56.
- Leech, N. L., & Onwuegbuzie, A. J. (in press). Guidelines for conducting and reporting mixed methods research in the field of counseling and beyond. *Journal of Counseling and Development*.
- Luera, G. R., Moyer, R. H., & Everett, S. A. (2005). What type and level of science content knowledge of elementary education students affect their ability to construct an inquiry-based science lesson? *Journal of Elementary Science Education*, 17, 12-25.
- Martin, M. O., Mullis, I. U. S., Gonzales, E. J., & Chrostowski, S. J. (2004). *Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.
- Matkins, J., Bell, R., Irving, K., & McNall, R. (2002, January). *Impacts of contextual and explicit instruction on preservice elementary teachers' understandings of the nature of science*. Paper presented at the Annual International Conference of the Association for the Education of Teachers of Science, Charlotte, NC.
- Meichtry, Y. J. (1999). The nature of science and scientific knowledge: Implications for a preservice elementary methods course. *Science and Education*, 8, 273-286.
- Midgley, C., Feldlaufer, H., & Eccles, J. S. (1989). Change in teacher efficacy and student self- and task-related beliefs in mathematics during the transition to junior high school. *Journal of Educational Psychology*, 81, 247-258.
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded Sourcebook* (2<sup>nd</sup> ed.). Thousand Oaks, CA: Sage.
- Monk, D. H. (1994). Subject matter preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review*, 13(2), 125-145.
- Moore, W., & Esselman, M. (1992, April). *Teacher efficacy, power, school climate and achievement: A desegregating district's experience*. Paper presented at the Annual meeting of the American Educational Research Association, San Francisco, CA.

- Morey, M. K. (1990). Status of science education in Illinois elementary schools. *Journal of Research in Science Teaching*, 27, 387-398.
- Morrell, P. D., & Carroll, J. B. (2003). An extended examination of preservice elementary teachers' science teaching self-efficacy. *School Science and Mathematics*, 103, 246-251.
- Morton, B. A., & Dalton, B. (2007). *Changes in Instructional Hours in Four Subjects by Public School Teachers of Grades 1 Through 4*. Washington, DC: National Center for Educational Statistics.
- Mulholland, J., Dorman, J. P., & Odgers, B. M. (2004). Assessment of science teaching efficacy of preservice teachers in an Australian university. *Journal of Science Teacher Education*, 15, 313-331.
- Muijs, D., & Reynolds, D. (2002). Teachers' beliefs and behaviors: What really matters? *Journal of Classroom Interaction*, 37(2), 3-15.
- National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.
- National Science Board. (2004). *Science and Engineering Indicators 2004*. Arlington, VA: National Science Foundation.
- National Science Board. (2008). *Science and Engineering Indicators 2008*. Arlington, VA: National Science Foundation.
- Newsome, D. L. (2003). The efficacy beliefs of preservice science teachers in professional development school and traditional school settings. *Dissertation Abstracts International*, 64(05). (UMI No. 3090076)
- No Child Left Behind Act of 2001, 20 U.S.C.A. § 6301.
- Organization for Economic Co-operation and Development. (2003). *OECD Science, Technology and Industry Scoreboard*. Paris, France: Author.
- Perry, W. G. (1999). *Forms of ethical and intellectual development in the college years: A scheme*. San Francisco: Jossey-Bass.
- Project MOSART. (2007). *Grades 9-12 physics test form 741*. Retrieved November 27, 2007 from <http://www.cfa.harvard.edu/sed/mosart/>

- Ramey-Gassert, L. K. (1993). A qualitative analysis of factors that influence personal science teaching efficacy and outcome expectancy beliefs in elementary teachers. *Dissertation Abstracts International*, 54(08). (UMI No. 9402712)
- Riggs, I. M. (1988). The development of an elementary teachers' science teaching efficacy belief instrument. *Dissertation Abstracts International*, 49(12). (UMI No. 8905728)
- Ross, J. A. (1992). Teacher efficacy and the effect of coaching on student achievement. *Canadian Journal of Education*, 17(1), 51-65.
- Ross, A. T. (1998). Exploring connections among teacher empowerment, teacher efficacy, transformational leadership, and student achievement. *Dissertation Abstracts International*, 59(09). (UMI No. 9906642)
- Schoon, E., & Boone, W. (1998). Self-efficacy and alternative conceptions of science of preservice elementary teachers. *Science Education*, 82, 553-568.
- Schulte, P. L. (2001). Preservice elementary teachers' alternative conceptions in science and attitudes toward teaching science. *Dissertation Abstracts International*, 62(03). (UMI No. 3009273)
- Schwartz, R. S., Lederman, N. G., & Crawford, B. (2000, April). Understanding the nature of science through scientific inquiry: An explicit approach to bridging the gap. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, new Orleans, LA.
- Smith, T. (2001). *The Retention and Graduation Rates of 1993-1999 Entering Science, Mathematics, Engineering, and Technology Majors in 175 Colleges and Universities*. Norman, OK: Center for Institutional Data Exchange and Analysis, University of Oklahoma.
- Staples, K. A. (2002). The effect of a nontraditional undergraduate science course on teacher and student performance in elementary science teaching. *Dissertation Abstracts International*, 63(05). (UMI No. 3051995)
- Stein, M. (2006). Elementary teachers' acquisition of science knowledge: Case-studies and implications for teaching preparation. *Dissertation Abstracts International*, 67(05). (UMI No. 3220554)
- Sterling, D. R., Matkins, J., Frazier, W. M., Logerwell, M. G. (2007). Science camp as a transformative experience for students, parents, and teachers in the urban setting. *School Science and Mathematics*, 107, 134-148.



- Stockton, J. D. (2002). Epistemology and the nature of science: Implications for preservice elementary science programs. *Dissertation Abstracts International*, 64(06). (UMI No. 3094114)
- Tassey, G. (1999). *R&D Trends in the U.S. Economy: Strategies and Policy Implications*. NIST Planning Report 99-2. Gaithersburg, MD: National Institute of Standards and Technology.
- Thompson, R. (2003). The effect of a laboratory-based, in-context, constructivist teaching approach on preservice teachers' science knowledge and teaching efficacy. *Dissertation Abstracts International*, 64(06). (UMI No. 3095382)
- Tschannen-Moran, M., & Woolfolk-Hoy, A. E. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education*, 23, 944-956.
- Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2002). Preservice elementary teachers' conceptions of moon phases before and after instruction. *Journal of Research in Science Teaching*, 39, 633-658.
- Watson, S. (1991). A study of the effects of teacher efficacy on the academic achievement of third-grade students in selected elementary schools in South Carolina. *Dissertation Abstracts International*, 53(06). (UMI No. 9230552)
- Wenglinsky, H. (2000). *How Teaching Matters: Bringing the Classroom Back Into Discussions of Teacher Quality*. Princeton, NJ: Educational Testing Service.
- Wingfield, M. E. (1998). The effect of site based experiences on elementary science teaching self-efficacy beliefs. *Dissertation Abstracts International*, 59(03). (UMI No. 9828336)
- Wolffe, R. J. (1992). Being a science educator: Effects attributed to expertise of scientific knowledge. *Dissertation Abstracts International*, 53(06). (UMI No. 9232328)
- Woolfolk, A. E., & Hoy, W. K. (1990). Prospective teachers' sense of efficacy and beliefs about control. *Journal of Educational Psychology*, 82, 81-91.

## CURRICULUM VITAE

Mollianne George Logerwell was born in Bryn Mawr, PA and graduated from Tri-Valley (now Albert Gallatin) High School in Uniontown, PA. She received a Bachelor of Science in Molecular Genetics from the University of Rochester, NY in 1994 and a Masters of Arts in Education for Secondary Science Education from The College of William and Mary in 1997. Molli has taught chemistry for Fairfax County Public Schools since 1997, worked as a Graduate Research Assistant for the Center for Restructuring Education in Science and Technology at George Mason University since 2003, and served as an adjunct instructor for science methods at George Mason University since 2006.