RELATIONSHIP OF INQUIRY-BASED LEARNING ELEMENTS ON CHANGES IN MIDDLE SCHOOL STUDENTS' SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) BELIEFS AND INTERESTS

A Dissertation

by

HEATHER SHANNON DEGENHART

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2007

Major Subject: Agricultural Education

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Approved by:

Chair of Committee,	Gary J. Wingenbach
Committee Members,	Julie Harlin
	Larry Johnson
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ABSTRACT

Relationship of Inquiry-Based Learning Elements on Changes in Middle School Students' Science, Technology, Engineering, and Mathematics (STEM) Beliefs and Interests. (May 2007)

Heather Shannon Degenhart, B.A., West Texas A&M University; B.S., West Texas A&M University; M.S., West Texas A&M University

Chair of Advisory Committee: Dr. Gary J. Wingenbach

The purpose of this study was to develop a model describing the relationship of inquiry-based teaching elements on middle school students' science, technology, engineering, and mathematics (STEM) interests and belief changes. The study utilized pretest/posttest, correlational, and longitudinal designs. Classroom inquiry data (N = 139) and middle school students' attitudinal data (N = 1779) were collected in middle school classrooms within a 40 mile radius of Texas A&M University during the 2004-2005 and 2005-2006 school years.

Results indicated 24% of the variation in middle school students' change in science, technology, engineering, and mathematics (STEM) interests was explained by the inquiry-learning element *"teacher as listener" was very characteristic of this classroom."* STEM interest change explained 55% of the variation in middle school students' STEM belief change. Analyses indicated NSF Fellows and teachers affected the rate at which middle school students' STEM beliefs and interests changed. Middle

school students' STEM interests and beliefs remained significantly unchanged from pre- to post-NSF Fellow each year of the study. Classroom inquiry levels did significantly increase from beginning of school-year to end of school-year each year of the project. NSF Fellows had a positive relationship with the one inquiry element *"teacher as listener" was very characteristic of the classroom;* which explained middle school students' change in STEM interests. NSF Fellows had negative relationships with the inquiry elements, *lessons involved fundamental concepts of the subject*; *lessons were designed to engage students as members of a learning community*; *lessons promoted strong conceptual understanding*; and *elements of abstraction were encouraged when it was important to do so*. No inquiry elements were associated with middle school students' change in STEM beliefs. Middle school students' change in STEM interests were positively associated with three inquiry elements, *"teacher as listener" was very characteristic of the classroom; students were involved in the communication of their ideas to others using a variety of means and media*; and *student questions and comments often determine the focus and direction of classroom discourse*. The inquiry element, *instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein,* was negatively associated with changes in middle school students' STEM interests.

DEDICATION

This is dedicated to my parents, Howard and Sondra Degenhart, who always told me I could do whatever I set my mind to. My brother, Jeff Degenhart, for influencing me to return to school, one more time. My grandparents, Bill and Wanda Bedwell, for their love and support. And my niece, Amber Degenhart, for just being her.

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CHAPTER I

INTRODUCTION

The United States is facing a crisis. The pool of talent in science, technology, engineering, and mathematics (STEM), which the U. S. relies on for innovation and economic growth is shrinking, while demand for STEM trained professionals rapidly continues to increase (NCTS, 2000; NSF, 2003). The American public's decreasing science literacy, decreasing enrollment and retention in math and science related fields, and projected job demand increases in these fields creates much concern about the United States' future safety and economic stability (McCallister, Lee, & Mason, 2005; Munn, O'Neill Skinner, Conn, Horsma, & Gregory, 1999; NCTS, 2000).

Increasing demand for STEM professionals is expected to far exceed the available supply as retirement numbers and international competition increases (NCTS, 2000). This shortage generates much concern for the economic stability and security of the American economy as STEM fields account for half of America's productivity gains in the last 50 years (Bybee & Fuchs, 2006; NCTS, 2000). STEM's creation of millions of highly-skilled, high-wage jobs has allowed United States citizens to enjoy a high standard of living, and current evidence indicates the shrinking supply of STEM professionals has started to limit economic growth (NCTS, 2000). "The U.S. Department of Labor estimates that 60% of the new jobs being created in our economy today will require technological literacy while only 22% of the young people entering the job market now actually possess those skills" (NSF, 2003, p. 7). These numbers are

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This dissertation follows the style of the *Journal of Agricultural Education*.

particularly disturbing as the technologically advanced global market requires the United States to maintain a workforce of well-trained and well-educated young people in STEM disciplines for continued economic growth and leadership in the world economy (Bybee & Fuchs, 2006; ERS, 2003; Isreal, Beaulieu, & Hartless, 2001; NSF, 2003).

Traditionally the United States relied on domestic and foreign STEM graduates for an innovative, competitive STEM workforce. Increased foreign expansion of advanced STEM education programs and competition for STEM trained professionals combined with decreasing domestic student interest and enrollment in STEM career fields threatens the continued availability of this talent pool. Foreign expansion of advanced STEM educational programs has resulted in declining numbers of foreign graduate students seeking STEM degrees in the United States (NSTC, 2000).

This declining enrollment of foreign graduate students affects the availability of STEM professionals in the United States, as traditionally half of these students chose employment in the U. S. upon completion of their degrees. With fewer foreign students entering and staying in the American STEM talent pool, the United States must focus on increasing its shrinking domestic pool of STEM professionals. If the current negative trend is not reversed, the United States faces two potentialities in order to fill future STEM positions: outsourcing or importing STEM professionals from other countries (NSTC, 2000).

Federal Educational Reform

Recognizing the need to reform education to meet future demand and ensure economic stability and security, the United States has enacted federal legislation to increase the quality of public education; close student achievement gaps; and produce a population that meets "proficiency" levels in all core academic subjects (Reeves, 2003). The No Child Left Behind (NCLB) Act of 2001 built on existing federal education legislation and expanded the federal governments' role in public education. The purpose of the act was to hold schools accountable for the academic achievement, or lack thereof, of students. A system of rewards and sanctions was implemented based on the level of attainment of state-mandated academic achievement goals (Reschovsky & Imazeki, 2003). The NCLB act "required stronger school accountability, more stringent qualifications for teachers, and an emphasis on programs and strategies with demonstrated effectiveness" (Reeves, 2003, p. 1).

The NCLB legislation required states to develop content standards in core academic subjects such as reading, mathematics, and science (Linn, Baker, & Betebenner, 2002). NCLB also required states to develop and meet Adequate Yearly Progress (AYP) student achievement objectives for all students and demographic groups or face progressively strict government sanctions (Linn et al., 2002; Reeves, 2003). AYP would be determined by student scores on state-mandated, standards-base achievement tests. Those schools not meeting AYP on state performance goals would face state interventions (Reeves, 2003; Reschovsky & Imazeki, 2003).

The NCLB act required all teachers in the core academic subjects, such as math and science, be "highly qualified" within five years. A highly qualified teacher was defined as being state licensed and certified with demonstrated subject-matter competency (Reeves, 2003). This was particularly important as not all teachers were certified in their content area and many were teaching outside of their subject area (Achieve, 2002; Reeves, 2003). This lack of certification and out-of-field teaching assignment was of special concern as student achievement has been linked in educational research to teachers' content knowledge, certification status, education level, and standards-based evaluations (Darling-Hammond, 1999; Darling-Hammond, Holtzman, Gatlin, & Heilig, 2005; Humphrey, Stewart, & Linhardt, 1994; McCutchen et al., 2002). Students' classroom experiences are important factors which affect learning. Subject matter and poor teaching have negative affects on students' persistence in select subjects like science and engineering, and students may leave science altogether due to poor teaching (Colbeck, Cabrera, & Terenzini, 2000; Gibson & Chase, 2002).

The NCLB Act called "for research that enables the successful development and implementation of science-based programs and practices in K-12 education" (NSF, 2003, p. 25). The majority of students' learning experiences involve low-level tasks which contribute to poor attitudes towards school and learning and deficiencies in content and process understanding (Blumenfeld et al., 1991). Development of negative attitudes is most noticeable during the middle school years, a time when critical changes have life-long affects (Anderman & Maehr, 1994).

Not only do students' become progressively negative toward mathematics and science at higher grade levels, but the "disconnect" between scientific content and real-world application increases (Morell & Ledermann, 1998; Weinburgh, 2003). The result of this disconnect is many middle school students unaware of connections between science related careers and classroom content (Atwater et al., 1995). The middle school years are “frequently the point [in] which American students fail to learn challenging content” (Achieve, 2002 p. 23). For example, the National Center for Education Statistics (NCES) reported that only 32% of the United States’ eighth grade students scored at or above the proficient level in science, while 39% scored below the basic level (NCES, 2002). This trend must be reversed as low education levels have been associated with persistent poverty, a low-wage economy, and an unstable workforce (ERS, 2003).

Research indicates a relationship between middle school students’ attitudes toward science and science education and their future career plans in science (Atwater et al., 1995). The steady decline in American secondary school students’ STEM interests and increased negativity toward STEM subjects has resulted in decreasing numbers of American young people entering post-secondary training and professional careers in STEM areas (NSTC, 2000).

To reverse the negative trend, the National Council of Teachers of Mathematics (NCTM) looks for new, improved methods to reform education so that meaningful, context-rich learning environments are created for students (Harris, Marcus, McLaren, & Fey, 2001). Davis et al. (2003) stated “There are several distinguishing characteristics of this reform effort. It relies heavily on a constructivist educational philosophy; it promotes inquiry and student-centered instruction; and it aims for excellence for all children” (p. 121). It has been found that students who are involved in problem-based curricula demonstrated increased higher-order thinking skills and more positive attitudes toward the subject matter than those students involved in a traditional curricula approach (Harris et al., 2001).

The National Science Foundation (NSF) funds research into effective GK-12 STEM (Science, Technology, Engineering, and Mathematics) educational programs. It is "the principal federal agency charged with promoting science and engineering education at all levels and in all settings, from pre-kindergarten through career development" (NSF, 2003, p. 3). The mission of NSF is "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes."

The Partnership for Environmental Education and Rural Health (PEER) GK-12 program was an interdisciplinary program developed at Texas A&M University funded by a combination of two NSF grants, "Integrating Environmental Health Science in Rural Schools" and "Environmental and Rural Health Education Partnership." The PEER GK-12 project utilized an interdisciplinary partnership between different STEM colleges and departments within the Texas A&M University system, graduate and undergraduate fellows from diverse STEM disciplines, and public middle school math and science teachers and students within a 40 mile radius of College Station, Texas. PEER placed STEM graduate students (termed NSF Fellows) in middle school science and mathematics classrooms to promote and create authentic inquiry lessons and serve as both teacher content resources and student role models. The goals of the project were to enhance the quality of middle school student educational experiences using inquiry learning and to improve middle school student's attitudes toward the STEM areas.

Research Questions

The following research questions were developed to guide the conduct of this study:

1. Does the prolonged involvement of an NSF Graduate Fellow significantly affect the change in middle school students' STEM beliefs?
2. Does the prolonged involvement of an NSF Graduate Fellow significantly affect the change in middle school students' STEM interests?
3. Does a significant relationship exist between NSF Fellows and classroom inquiry levels?
4. Does a significant relationship exist between classroom inquiry levels and middle school students' changes in STEM interests and beliefs?
5. What is the relationship between inquiry-based teaching constructs and changes in middle school students' STEM beliefs and interests?

Purpose of the Study

The purpose of this study was to develop a model which quantifies middle school students' STEM interest and belief change as a function of the elements of inquiry-learning constructs. Twenty-five individual elements of inquiry-based learning were divided into the four inquiry learning constructs used in the analysis. These elements were identified by the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) at Arizona State University (Sawada et al., 2002) in the Reformed

Observation Teaching Protocol (RTOP). The four constructs are propositional knowledge; procedural knowledge; student/student relationships; and student/teacher relationships. This study determined if NSF Fellows' consistent classroom interaction affects both classroom inquiry levels and middle school students' STEM interests and beliefs.

Research Objectives

To accomplish the purposes of the study, the following objectives were established:

1. Determine if prolonged classroom involvement of the NSF Fellow significantly affected changes in middle school students' STEM beliefs;
2. Determine if prolonged classroom involvement of the NSF Fellow significantly affected changes in middle school students' STEM interests;
3. Determine if a significant relationship existed between NSF Fellow and classroom inquiry levels;
4. Determine if a significant relationship existed between classroom inquiry levels and middle school students' STEM interests and belief changes;
5. Develop a model which describes the relationship of inquiry-based teaching constructs on middle school students' STEM interests and belief changes.

Theoretical Framework

Inquiry-based learning is grounded in constructivist learning theory, incorporating the theories of Dewey (contextual learning), Piaget (cognitive development), Vygotsky (social cognitive learning and scaffolding), Cobern (sociocultural constructivism), Bruner (discovery learning), Bandura (social learning and self efficacy), and Lave and Wenger (situated learning, communities of practice).

Dewey believed all meaningful learning occurred through real-world contexts, and students' ability to use concepts in the creation of more complex models or representations demonstrated a deeper understanding of those concepts than did a traditional knowledge test (Dewey, 1907). Like Dewey, Lave believed that the situation affects the learning; an idea he termed situated learning (Lave, 1988). The situated learning aspect of inquiry-based learning involves students in contextual, real-world problem solving using authentic techniques and procedures which they can apply to similar problems in different situations (Lave, 1988).

The emphasis of students' using debate, active reflection, collaboration, pre-existing knowledge, and development of critical thinking skills draws heavily from the work of Jean Piaget. Piaget proposed that the development of logical reasoning in children occurs in stages, and children either accommodate what they know to incorporate new knowledge, or assimilate new knowledge (Piaget, 1954). Piaget al.so proposed that students' debating ideas with peers was essential in their cognitive development and that knowledge must be "constructed" through students' experiences and active reflection if understanding is to occur. Merely "giving" students information, as in rote learning, will not lead to understanding (Piaget, 1954; Piaget, Inhelder, & Zwart, 1973).

Students' use of collaboration and discourse as a means of constructing knowledge in inquiry-based learning also incorporates the work of Vygotsky. Vygotsky maintained students learn best through social interactions with more knowledgeable peers, teachers, and others, providing a “scaffold” (or support) for the student’s acquisition of more complex knowledge (Vygotsky, 1978).

Cobern, like Piaget, believed that understanding was built on pre-existing knowledge and experiences, and influenced inquiry-based learning. Cobern further recommended that the prior experiences and knowledge students bring with them to the classroom should be valued and incorporated in the lesson design (Cobern, 1991). Therefore, students’ knowledge and experiences are actively solicited and used in the course of the inquiry-based learning activity.

Bruner recommended students be engaged actively in the discovery of principles and the discussion of ideas and concepts with peers and teachers. Students should be reflective learners and should become personally engaged with the material (Bruner, 1971). Bruner recommended students’ questions be encouraged and integrated into the classroom instruction. Bruner believed that the university and intellectual communities should have an active role in education, and proposed that effective learning occurs through conversation and discussion between the more knowledgeable and the less knowledgeable (Bruner). Bruner’s work supports the student-centered, collaborative nature of inquiry, its emphasis on critical thinking, knowledge construction, and aversion to rote learning and reliance on procedures only.

Bandura’s theory of modeling proposed that students’ will observe and imitate the actions and behaviors of those they perceive to be of the same or higher status (Bandura, 1986). Students’ collaboration and dialogue with peers, teachers, and experts on authentic problems allows them to learn, adopt, and demonstrate the skills and behaviors of more competent members of the collaboration.

Wenger's work promoted inquiry-based learning through the belief that learning occurs between everyone in a community of practice (Wenger, McDermott, & Snyder, 2002). Students' collaboration with practitioners allows them to participate in that field's community of practice. "Communities of practice are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger et al., 2002, p. 4). Communities of practice encourage participants to admit knowledge gaps, share ideas, ask difficult questions, and carefully listen to other members of the community (Wenger et al., 2002). When students join a community of practice, they adopt the attributes and language modeled by that community (also Bandura's modeling theory). As students continue to participate in a community of practice, they become more confident and competent moving toward the role of "expert" for others who are just entering that community (Wenger et al., 2002).

Significance of the Study

Research on the positive effects of inquiry-based learning on middle school students' interests and beliefs about STEM subjects is qualitative or incidental. No studies of inquiry-based learning and students' attitudes using quantitative research methodologies have yet been found. Improved attitudes have yet to be quantifiably linked to specific characteristics of inquiry-based learning.

Definitions

1. Basic-denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade (NCES, 2002, p. 1).
2. Proficient-represents solid academic performance for each grade assessed. Students reaching this level have demonstrated competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter (NCES, 2002, p. 1).
3. Advanced-signifies superior performance (NCES, 2002, p. 1).
4. Highly qualified teacher as defined by the No Child Left Behind Act of 2001; Title IX, Section 9101
    a) When the term “highly qualified teacher” is used with respect to any public elementary school or secondary school teacher teaching in a State, it means that
        i. The teacher has obtained full State certification as a teacher (including certification obtained through alternative routes to certification) or passed the State teacher licensing examination, and holds a license to teach in such State, except that when the term is used with respect to any teacher teaching in a public charter school, the term means that the teacher meets the certification or licensing requirements set forth in the State’s

public charter school law (see entry below for the definition of a highly qualified charter school teacher); and

ii. The teacher has not had certification or licensure requirements waived on an emergency, temporary, or provisional basis.

2. When the term “highly qualified teacher” is used with respect to

a. An elementary school teacher who is new to the profession, it means that the teacher has met the requirements of paragraph (A) above, and:

i) Holds at least a bachelor’s degree; and

ii) Has demonstrated, by passing a rigorous State test, subject knowledge and teaching skills in reading, writing, mathematics, and other areas of the basic elementary school curriculum (which may consist of passing a State-required certification or licensing test or tests in reading, writing, mathematics, and other areas of basic elementary school curriculum); or

b. A middle school or secondary teacher who is new to the profession, it means that the teacher has met the requirements of paragraph (A) above, holds at least a bachelor’s degree, and has demonstrated a high level of competency in each of the academic subjects in which the teacher teaches by

i) Passing a rigorous State academic subject test in each of the academic subjects in which the teacher teaches (which may consist of a passing level of performance on a State-required certification or licensing test or tests in each of the academic subjects in which the teacher teaches); or

ii) Successful completion, in each of the academic subjects in which the teacher teaches, of an academic major, a graduate degree, coursework equivalent to an undergraduate academic major, or advanced certification or credentialing.

3. When the term “highly qualified teacher” is used with respect to an elementary, middle, or secondary school teacher who is not new to the profession, it means that the teacher has met the requirements of paragraph (A) above, holds at least a bachelor’s degree, and

a. Has met the applicable standard in the clauses of subparagraph (B), which includes an option for a test; or

b. Demonstrates competence in all the academic subjects in which the teacher teaches based on a high objective uniform State standard of evaluation that-

i) Is set by the State for both grade appropriate academic subject matter knowledge and teaching skills;

ii) Is aligned with challenging State academic content and student academic achievement standards and developed in consultation with core content specialists, teachers, principals, and school administrators;

iii) Provides objective, coherent information about the teacher's attainment of core content knowledge in the academic subjects in which a teacher teaches;

iv) Is applied uniformly to all teachers in the same academic subject and the same grade level throughout the State;

v) Takes into consideration, but not be based primarily on, the time the teacher has been teaching in the academic subject;

vi) Is made available to the public upon request; and

vii) May involve multiple, objective measures of teacher competency (as cited in Texas Education Agency, 2007, p. 1)

Delimitations

The population of this study was delimited to a voluntary population of middle school teachers and their students within a 40-mile radius of College Station, TEXAS during the school years 2004-2005 and 2005-2006. Further, the study was delimited to those students whose completed pre-and post-NSF Fellow interests and beliefs instruments could be positively matched for each year of the study.

Limitations

This study involved a localized, voluntary sample; therefore caution should be exercised in generalizing results from this study to a broader population. As the evaluation team did not personally administer the pre-and post-NSF Fellow beliefs and interests instruments, bias may have been introduced into the data due to differences in teacher and NSF Fellow administration, students' perception of response anonymity, and social acceptability of responses.

CHAPTER II

REVIEW OF LITERATURE

This chapter presents the need for educational classroom reform; the benefits and drawbacks of scientist/teacher collaborations; the benefits of inquiry learning; the negative aspects of inquiry learning; the barriers to implementation of inquiry learning; the issues in measuring the effects of inquiry learning; the PEER program; and recommendations for further research on the affect of the inquiry-based learning approach on student interests and beliefs.

Call to Reform

Knowledge acquisition and use in the traditional school setting is vastly different from acquisition and use in real-world settings (Roth & Bowen, 1995). "The idea that most school activity exists in a culture of its own is central to understanding many of the difficulties of learning in school" (Brown et al., 1989, p. 35.). School science programs rarely provide students with explanations of real-world phenomena using essential scientific ideas coherently nor do they build on students' ideas, help students correct the misconceptions, or fill the essential knowledge gaps which are very resistant to change (Blumenfeld et al., 1991; Kesidou & Roseman, 2002). Further, most classroom instruction has little relation to students' every-day lives, does not interest them, and neglects contextual learners (Kolodner et al., 2003).

Students must be taught "how" to learn, they do not know how to read text critically, know what questions to ask, when to question, and where and how to find answers. "This kind of skill is learned by doing, by exercise, and is taught by guiding the doing" (Schwab & Bradwein, 1962, p. 67) "When instruction is not powerful, students must rely on their background knowledge and general intelligence to solve problems' (Pine et al., 2006).

State and national expectations of student achievement are continually being increased to correct low science literacy and performance scores and counter the persistent negative attitude trend of students. The National Council of Teachers of Mathematics (NCTM) actively seeks educational reforms which create meaningful, context-rich learning environments for students; effectively increasing student performance to reach these new standards in teacher-friendly contexts (Harris et al., 2001). The National Science Foundation's Collaboratives for Excellence in Teacher Preparation (CETP) defined educational reform as predicating

> student's using data to justify opinion, experiencing ambiguity as a result of learning, and learning from one another. Additionally, reform presupposes that teachers do not emphasize lecture, but rather stress a problem-solving approach and foster active learning. (Frantz, Lawrenz, Kushner, & Miller, 1998; as cited in Sawada et al., 2002)

Reformed teaching is constructivist, student-centered, promotes inquiry-based learning, strives for mastery of all students, and enhances students' learning (Davis et al., 2003; Sawada et al., 2002). Teachers should be student-centered, constantly adapting classroom instruction to students' current level of understanding (Ruiz-Primo & Furtak, 2007).

Several educational reform methods such as integrated curriculum, teacher/scientist collaborations, and inquiry learning, long in use in the agricultural classroom, are being implemented in core curriculum classrooms with varying levels of success (Balschweid, 2002; Caton, Brewer, & Brown, 2000; Davis et al., 2003; Evans, Abrams, Rock, & Spencer, 2001; Finson, 2002; Harris et al., 2001; Munn et al., 1999; Parr & Edwards, 2004; Sawada et al., 2002; Tanner, Chatman, & Allen, 2003; Thompson, 1998; Tretter & Jones, 2003; Trexler & Suvedi, 1998; Weinburgh, 2003). Effective methods that support teachers embracing inquiry in the classroom should be investigated as teachers may need help with content, implementing and managing projects, and utilizing new forms of instruction (Blumenfeld et al., 1991; Crawford, 2000).

Scientist/Educator Partnerships

Many teachers have little to no actual experience conducting scientific research, and have only a superficial understanding of the content and processes they teach students (Singer, Marx, Krajcik, & Chambers, 2000). Collaborations between scientists and educators increase students' positive attitudes toward science, student scientific literacy levels, teacher content knowledge, scientific content, educational effectiveness, and inquiry learning (Caton et al., 2000; Davis et al., 2003; Evans, Abrams, Rock, & Spencer, 2001; Finson, 2002; Munn et al., 1999; Tanner, Chatman, & Allen, 2003; Weinburgh, 2003). Scientists' active participation in classrooms increases students' potential to learn about science's real-world applications and wide range of career options, closing the existing gap in student understanding between science content and science careers (Atwater et al., 1995; Caton et al., 2000; Munn et al., 1999; Tanner et al., 2003; Weinburgh, 2003).

Scientists collaborating with educators in the classroom are able to share their excitement and enthusiasm for their field with students, and potentially improve the scientific classroom content (Caton et al., 2000; Munn et al., 1999). Through collaboration with peers and experts, teachers can witness the practical application and benefit of inquiry activities and change their perceptions and practices (Anderson, 2002). Collaboration with scientists allows students and teachers alike the opportunity to acquire the language and behaviors of scientists (Brown, Collins, & Duguid, 1989). Scientists also benefit from these collaborations in that they became more familiar with the principles of science education and effective teaching practices and incorporate this knowledge into their own teaching practices (Caton et al., 2000).

Scientist/educator collaborations are also successful in changing college and high school students' stereotypical images of scientists. Students' negative attitudes toward science are reinforced by the popular stereotypical image of science as a lonely profession and scientists as white males in lab coats with facial hair and glasses working in chemistry labs (Finson, 2002). The degree to which a person holds a stereotype directly affects the likelihood of that individual choosing science courses and pursuing science-related careers (Finson).

This notion may be true especially for females and minorities educated by teachers who subconsciously hold stereotypical images of scientists, and who transfer their images to students either consciously or unconsciously (Finson, 2002). Scientists who do not conform to this preconceived stereotype have the potential to serve as positive role models for students, especially for female and minority students (Finson). Studies indicate that as a result of interaction with scientists, students learned that scientists were “real” people who enjoyed their work and were not the solitary, lonely people so often portrayed as the stereotypical scientist. Research also indicates personal role models and professionals in a field influence the decision to enter a field of study. Scientist classroom participation also increases students’ potential to realize the vast array of STEM career opportunities and increase their opportunities to experience in-depth inquiry with real-world application (Caton et al., 2000; Munn et al., 1999; Tanner et al., 2003; Weinburgh, 2003; Wildman & Torres, 2001).

Barriers to Integrative Educator/Scientist Partnerships

Interdisciplinary barriers have negative affects on communication and integration efforts not only between disciplines at the secondary and collegiate levels, but also between partnerships of secondary educators and university faculty (Carr, 2002; Davis et al., 2003; Caton et al., 2000; Thompson, Collins, Metzgar, Joeston, & Shepherd, 2002). Interdisciplinary barriers are cultural barriers involving status, differences in the way teaching and learning are viewed, and different definitions and connotations for terms between educators and universities, as well as between university departments. These cultural barriers hinder effective collaboration and communication and lead to misunderstandings (Carr, 2002; Davis et al., 2003; Thompson et al., 2002).

To overcome interdisciplinary barriers and keep the core disciplines working together, it is vital to have a common goal. Keeping the disciplines focused on a common objective increases the levels of collaboration, inquiry learning, and allows students to be participants in the scientific community of practice (Brown et al., 1989; Caton et al., 2000; Krajcik et al., 1998; McGehee, 2001; Singer et al., 2000; Toulmin, 1982).

Inquiry

Scientist/educator collaborations increase inquiry-based learning methods which use problem-solving approaches to teach concepts, and provide in-depth student learning (McGehee, 2001). Inquiry's goal is to identify cause and effect and mainly targets older and adolescent children (Kuhn, Black, Keselman, & Kaplan, 2000). Inquiry learning is "hands-on, minds-on." Students are actively engaged in the learning process not only physically, but mentally. The inquiry approach is not merely "hands-on" activities unconnected to essential content (Crawford, 2000).

The concept of inquiry as a teaching technique is derived from the method used in scientific research termed "scientific inquiry" a way of thought guided by specific assumptions and principles (Rutherford, 1964; Schwab & Brandwein, 1962; Welch, Klopper, Aikenhead, & Robinson, 1981). Schwab and Brandwein (1962) believed that concepts guided, not resulted from inquiry. Inquiry confirmed or disproved the concepts under investigation and the important result from inquiry investigations was not learning facts but learning the types of associations and their consequences (Schwab & Brandwein, 1962). Schwab and Brandwein identified two types of inquiry that composed a cycle in the scientific process-fluid and stable inquiry.

Fluid inquiry (or enquiry as spelled by Schwab & Brandwein, 1962) most closely identifies with the modern concept of inquiry. Fluid inquiry was defined by Schwab and Brandwein as: “a mode of investigation which rests on conceptual innovation, proceeds through uncertainty and failure, and eventuates in knowledge which is contingent, dubitable, and hard to come by” (p. 5). In fluid inquiry, understandings (concepts) constantly change as the they are acquired through inquiry, therefore knowledge is constantly building upon itself and is not static (Schwab & Bradwein). Fluid inquiry results in the testing of scientific principles (concepts) and the creation of new principles which guide new scientific investigations. Fluid inquiry is concerned with invention and failure is integral to the process (Schwab & Bradwein).

Unlike fluid inquiry, stable inquiry treats scientific principles as facts to be used in investigation, not to be investigated themselves. Stable inquiry accumulates scientific principles, not questions them, and “usually finds what it is looking for” (Schwab & Bradwein, 1962, p. 16). Schwab and Bradwein indicated stable inquiry was limiting as it will reach a point in which accepted principles will no longer apply, be able to define effective problems to be researched, and will give contradictory data (Schwab & Bradwein).

Rutherford (1964) also described two different types of inquiry: inquiry as content and inquiry as technique. Inquiry as content is similar to Schwab and Bradwein’s (1962) stable inquiry and “acknowledges there is a pattern of inquiry characteristic of a given science, or of a given field within a science, and that such patterns form an integral part of what science ‘is’” (Rutherford, 1964, p. 80). Scientific concepts could only be truly understood through the context of their discovery and the questions they generated (Rutherford). Inquiry as technique is similar to Schwab and Bradwein's (1962) fluid inquiry and is what is commonly referred to by the inquiry method. It is the strategy used to teach a specific scientific concept (Rutherford). Rutherford believed inquiry as content and inquiry as technique were equally important and the type of inquiry implemented would depend on the topic being investigated. Rutherford proposed that understanding inquiry as content did not depend on understanding inquiry as technique.

In order to analyze junior high school science textbooks, Tafoya, Sunai, and Knecht (1980) operationalized inquiry as consisting of five key elements and developed four classifications of inquiry-based activities. The five elements comprising inquiry were 1) no authoritarian answers; 2) students able to empirically verify the knowledge claims of curricula; 3) students actively investigating in different instructional settings using a variety of materials; 4) students involved in "all phases of knowledge generation at their cognitive level . . . and 5) [inquiry] involves the complete inquiry process-assuming, observing, inferring, hypothesizing, testing, and revising ideas and concepts on the basis of new information" (Tafoya et al., 1980, p. 44).

The four levels of inquiry activities were described as either confirmation, structured-inquiry, guided inquiry, or open-inquiry, and reflected different levels of learners' independent inquiry (Tafoya et al., 1980). The four levels of inquiry were defined as

a) *Confirmation.* A concept or principle is presented and the student performs some exercise to confirm it. She/he knows what is supposed to happen and the procedure has been carefully outlined for the student to follow.

b) *Structured inquiry.* The student is presented with a problem but does not know the results beforehand. Procedures are outlined. Selection of activities and materials is structured to enable the student to discover relationships and to generalize from data collected.

c) *Guided inquiry.* In this level of inquiry only the problem to investigate is given the student. The student directs his/her own procedures and methods of collecting data from which concepts or principles are discovered and generalized.

d) *Open inquiry.* The student formulates both the problem and the procedure for solving the problem, interprets the data, and arrives at conclusions (Tafoya et al., 1980, p. 49-47).

Research by Welch et al. (1981) determined three main themes of inquiry: science process skills, nature of scientific inquiry, and general inquiry processes. Science process skills and general inquiry process were intellectual processes. Science process skills involve the normally understood processes associated with scientific investigations: the search and identification of solutions; observation; measurement; data interpretation; generalization; and theory building, testing, and revision (Welch et al., 1981). General inquiry primarily involved strategies for “problem-solving, uses of evidence, logical and analogical reasoning, clarification of values, decision-making, and safeguards and customs of inquiry" (Welch et al., 1981, p. 34). Scientific ethics were included in general inquiry. The nature of scientific inquiry was the philosophical element of inquiry and was concerned with the "social and psychological context" of inquiry (Welch et al., 1981, p. 34).

Welch et al. (1981) stated the characteristics of effective classroom inquiry relied on the curriculum, the classroom, and characteristics of the teacher. Effective inquiry relied heavily on the teacher's personal value of inquiry, efforts to promote and enable inquiry in others. In the inquiry classroom the various instructional methods of "discussion, investigative laboratories, student-initiated inquiries, lectures, debates" (p. 35) should be in use. Welch et al. (1981)….

> Teachers serve as role models in deliberating issues, in examining values, in admitting error, and in confronting areas of their own ignorance. The classroom atmosphere is conducive to inquiry. It is easy for students to ask questions. Risk-taking is encouraged and student formulations of responses are listened to, clarified, and deliberated with high frequency of student-student transactions. Classroom climates stimulate a thorough, thoughtful exploration of objects and events, rather than a need to finish the text. Inquiry transactions are concerned with students developing meaning. Thus, in an inquiry classroom there is a time for doing . . . a time for reflection . . . a time for feeling . . . and a time for assessment. (p. 35)

To standardize inquiry in educational terms and decrease confusion of what constituted inquiry-based learning, the National Research Council (1996) defined inquiry as an activity involving

> Observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. (p. 23)

The National Research Council (2000) reinforced this definition and listed the five essential elements of classroom inquiry applicable to all grade levels:

1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to **evidence**, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions.
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations. (NRC, 2000, p. 25)

A lesson would be considered "full inquiry" if all five of these elements were present in the lesson. The lesson would be considered "partial inquiry" if one or more elements were missing (NRC, 2000). Partial inquiry accompanied by direct instruction was considered the most effective instructional strategy if students had extensive prior knowledge of a phenomena (NRC, 2000). Anderson (2002) identified three closely interrelated distinctions in the literature when discussing inquiry: Scientific inquiry, inquiry learning, and inquiry teaching. Scientific inquiry is the abilities and processes used by scientists. Inquiry learning is the process that students engage in for learning. Inquiry teaching is the process whereby teachers teach.

Student Benefits from Inquiry Learning

The inquiry approach is student-centered whereby students actively construct their knowledge, and teachers serve as facilitators stressing the process as opposed to the outcome of learning (EBC, 2004). Inquiry should be contextual, student-centered, involve ill-defined problems, encourage collaboration, use essential concepts, build on students' pre-existing knowledge, encourage reflection, encourage the generation of products and representations, involve real problems, and have a driving question (Blumenfeld et al., 1991; Brown et al., 1989; Crawford, 2000; Krajcik et al., 1998; Marks, 2000; Roth & Bowen, 1995; Singer et al., 2000; Toulmin, 1982). Students involved in problem-based curricula demonstrate increased higher-order thinking skills and more positive attitudes toward subject matter than students involved in traditional curricula (Harris et al., 2001). Through actually using subject matter content, inquiry-based learning develops students' problem-solving and information-processing skills. Students easily construct in-depth knowledge due to their high interest and engagement in the inquiry project (EBC, 2004). "Learning becomes almost effortless when something fascinates students and reflects their interests and goals" (EBC, 2004, p. 1).

Inquiry, or project learning, encourages students to collaborate with peers, teachers, and the community, and encourages students' use of technological tools (Krajcik et al., 1998). Inquiry increases the emphasis on critical thinking and conceptual learning while decreasing the emphasis of rote and procedural learning (McGehee, 2001). The use of relevant and personally meaningful problems increases student engagement with the subject matter, and engagement has been linked to students' pursuing college educations (Marks, 2000). Inquiry-based approaches improve student learning, participation, classroom scores, attendance, and student attitudes toward subject matter while decreasing antagonistic behavior and disruptions (Lent, Brown, & Hackett, 1994; Moa, Chang, & Barufaldi, 1998; Sawada et al., 2002; Tretter & Jones, 2003). Students are more self-directed and achieve significant gains in study skills and subject content (McGehee, 2001).

Inquiry activities based on National Science Education Standards increase overall student achievement and decrease the achievement gaps of females and students of lower socio-economic status (Von Secker & Lissitz, 1999). Lower socio-economic status, female, Spanish speaking, and low achieving students also make greater gains relative to more privileged students (Lee et al., 2006). Mao, Chang, and Barufaldi (1998) found inquiry-based instructional methods in earth-science yielded a significant improvement in students' understanding of concepts and performance on questions involving higher-order cognitive skills over traditional instructional methods.

During open-inquiry investigations students cover more topics than contained in the regular curricula in greater depth (Roth, 1998). Students trained by inquiry methods ask more and higher-level (questions requiring more investigation to answer) questions than students trained by traditional methods. Their questions have a greater degree of relevancy and inquiry-trained students demonstrate increased willingness to pursue further investigations and will choose more difficult questions for further investigations. Inquiry-trained students indicate greater degrees of motivation and thoroughness and are able to transfer the abilities and skills learned through inquiry-based instruction to other activities (Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005).

Pine et al. (2006) found fifth-grade students performed significantly better in biology on Third International Mathematics and Science Study (TIMSS) items than students taught via text only. Lee et al. (2006) indicated fourth-grade students made greater significant gains and understanding in controlling variables and supporting theories with data than third-grade students after inquiry-based instruction, supporting the effectiveness of inquiry-based instruction for adolescents and older children (Kuhn et al., 2000)

Negative Aspects of Inquiry-Based Instruction

Inquiry may not be effective for student achievement and cognitive development and because of how inquiry is implemented in the classroom. Also, students with poor cognitive skills may find inquiry frustrating and give up on the inquiry process (Kuhn, Black, Keselman & Kaplan, 2000; Pizzini, Shepardson, & Abell, 1991).

Teacher understanding of true inquiry is lacking in many instances. The majority of science activities in textbooks labeled as “inquiry” are confirmation level activities with some structured inquiry level activities. Textbooks contain few to no guided-inquiry or open-inquiry level activities (Pizzini et al., 1991). Therefore the majority of teachers use only confirmation level or "cookbook" inquiry activities in the mistaken belief they are true inquiry activities (Pine et al., 2006). Confirmation level inquiry is termed "cookbook" because students methodically follow the steps of the investigation just as if they were following a recipe (Barrow, 2006).

The majority of textbook inquiry activities do not allow students to generate their own research questions, determine how to control variables, utilize multiple observations, seek alternative interpretations, detect biased data or experimental flaws. The predominate use of confirmation level inquiry does not develop the higher-order thinking and reasoning skills present in authentic science investigations. Therefore, students have unrealistic perceptions of science, superficial observational skills, and beliefs that scientific investigation is unrelated to the "real-world," simplistic, absolute, and step-by-step (Chinn & Malhotra, 2002).

Barriers to Inquiry-Based Instruction

Limited implementation of inquiry-based learning in classrooms may be due to several teacher-related factors. Many teachers focus on procedure rather than the process of creating knowledge, limiting students' inquiry-learning experiences (Ruiz-Primo & Furtak, 2007). Other teacher-related factors which decrease inquiry-based learning are: poor preparation in inquiry-based methods; lack of actual research experience; lack of depth in content knowledge; the inability to facilitate meaningful discussions of the results and implications from students' investigations; uncertainty of assessment criteria; the perception of classroom management difficulties; reliance on the textbook; beliefs that only upper-level students would benefit from inquiry activities; the persistent confusion of what inquiry truly is; the prevailing belief that facts and vocabulary must be taught; and students must be prepared academically for the next grade (Anderson, 2002; Pine et al., 2006; Hofstein et al., 2005; Welch et al., 1981).

Teachers have many issues competing for their instructional time in the classroom such as: "disciplining, 'basics', mainstreaming, integration, and accountability" (Welch et al., 1981). Therefore, the perception of not having enough instructional time may be another barrier to teacher implementation of inquiry-based learning as in true inquiry-based learning, students require more time for the learning process (Barrow, 2006; Chinn & Malhotra, 2002; Hofstein et al., 2005).

Available funding may also be a limiting factor in the implementation of inquiry-based learning in the classroom. Quality hands-on inquiry requires innovative curriculum, scientific equipment, non-text materials and supplies, and competent teachers to implement inquiry-based activities. As teachers become more knowledgeable in both content and inquiry methods they need increased access to materials and equipment, therefore making the quality of inquiry-based learning dependent on the level of support (both financial and administrative) available (Chinn & Malhotra, 2002; Lee, Buxton, Lewis, & LeRoy, 2006; Welch et al., 1981).

Anderson (2002) identified three specific barriers (technical, political, and cultural) to the implementation of inquiry-based instruction. Technical barriers to inquiry-based instruction were assessment, level of dependence on textbooks, class management issues, teachers' lack of appropriate professional development and inexperience with facilitation and constructivist teaching, learner difficulties transitioning to active learning, and the subjective nature of judgments. Political barriers included funding issues, parents' misperceptions of inquiry instruction, and ideological conflicts among teachers. Cultural barriers were the curricular materials in use, perception of assessments' utility, and the need to prepare students for the next educational level (Anderson, 2002).

Other barriers to adoption may be the relative difficulty students' first experience with the inquiry process: the inability to formulate good questions, difficulty defining a problem, inexperience with creating procedures for data collection and interpretation, and neglect to use representations for data interpretation. All of which may require scaffolding by the teacher to correct (Krajcik et al., 1998). The age at which inquiry is implemented may also be a barrier as Kuhn et al. (2000) indicated that early adolescents may not have the necessary cognitive skills for effective inquiry learning.

Issues in Measuring the Effects of Inquiry-Based Learning

Tafoya et al. (1980) developed the Assessment of Inquiry Potential (AIP) instrument to classify the potential for inquiry learning in science curricula based on a model developed in 1973 by Knecht at Michigan State University. Knecht's model was based on the National Science Teachers' Association (NSTA) goals of Science Education statement and provided "the conceptualization and techniques for program analysis in terms of the degree to which students participate in processes of knowledge generation" (Tafoya et al., 1980, p. 44). Curricular materials could be objectively ranked for their potential to contribute to the goals of science education using the AIP instrument. The AIP did not quantify the actual level of inquiry present when materials were presented, only the materials' potential for inquiry instruction.

Sawada et al. (2003) developed and used a highly inductive instrument, the Reformed Teaching Observation Protocol (RTOP), as an evaluation instrument of reformed teaching methods in science and mathematics classrooms. The RTOP was based on science and mathematics standards developed by the National Council for Teachers of Mathematics (NCTM), the National Research Council (NRC), and the American Association for the Advancement of Science (AAAS) (Sawada et al., 2003). The instrument was a criterion referenced, holistic approach which could be used to define classroom inquiry and provide a means of quantifying the level of inquiry-based learning present in science and mathematics classrooms. The RTOP was grounded in student-centered, constructivist learning theory, and contained 25 statements divided into three constructs: (1) lesson design and implementation; (2) content, and (3) classroom culture. The lesson design and implementation construct consisted of inquiry-learning characteristics corresponding to those outlined by the National Research Council (1996, 2000) and Welch et al. (1981) such as: recognizing students' prior knowledge, engaging students in a community of learners, and pursuit of student generated investigations.

Content was subdivided into the two constructs of propositional knowledge which focused on the quality of what was being taught and procedure knowledge which focused on the inquiry process (how material was being taught). Classroom culture was also subdivided into two constructs of student-to-student interactions/relationship. This construct focused on the frequency, quality, and type of discussion and interaction between students. The second classroom culture construct (student-to-teacher relationship/interaction) focused on the frequency, quality, and type of discussion and interaction between the teacher and the students (Sawada et al., 2003). Using the RTOP instrument, Sawada et al. (2003) found students' normalized gain scores increased or decreased similarly to increases or decreases in RTOP scores for the instructor.

Research by Caton et al. (2000) reported a link between scientist/educator collaborations, teachers' increased classroom inquiry use, and more positive student attitudes. Caton et al. did not measure the level of inquiry present in the classroom, quantify the affect of inquiry-based learning constructs on student attitudes, or provide scientists the opportunity to work directly with students. Research providing a quantifiable link between scientist educator partnerships and classroom inquiry levels, and between levels of inquiry learning elements present in the classroom and students' STEM interests and beliefs, has yet to be found.

Many researchers use the results of qualitative studies to illustrate the benefits of scientist/educator partnerships and inquiry-based methods on student learning and attitudes toward math and science (Crawford, 2000; Krajcik, 1998; Roth, 1992; Roth & Bowen, 1995). The need for further examination of the impact of inquiry learning on students' STEM attitudes and career interests (Gibson & Chase, 2002), and potential benefit of inquiry learning in regular classrooms (Krajcik et al., 1998) has been indicated in the literature. Gibson and Chase stated

> Further investigations should be conducted to study the impact of teachers' methodology on students' attitudes towards science, to discover what specific

> characteristics are most important…we need more data regarding factors, circumstances, and environments that help students maintain a high interest in science. (p. 704)

Pine et al. (2006) also posed the question of what effects the decrease in hands-on curriculum as grade level increases have on students' science interest and pursuit of careers in scientific fields.

The Partnership for Environmental Education and Rural Health (PEER)

The Partnership for Environmental Education and Rural Health (PEER) GK-12 project is an interdisciplinary outreach program targeted toward rural middle school teachers and students. The PEER project was developed by Texas A&M University and funded by a three-year grant from the National Science Foundation (NSF). The ultimate goals of the PEER GK-12 program were to illustrate the effectiveness of inquiry teaching, promote its adoption as an important educational tool in the public school system, and increase the number of people, especially minorities and females, entering careers in the STEM areas (PEER, 2004).

The immediate goals of the PEER program were for graduate to fellows provide rural school teachers and students immediate access to enhanced science/math; provide resources for both content and application of science, technology, engineering, and mathematics (STEM) improving content taught; provide [lead] teachers with university contacts; promote challenges and thrill of discovery; interact in public school rooms; and provide STEM resources, lesson plans, hands-on activities, and resource documents (PEER, 2004). The intermediate goals of the PEER project were to increase levels of inquiry in classrooms of participating teachers; improve attitudes of middle school students toward STEM subjects and careers in STEM areas; and improve student retention and understanding of STEM content. The long-term goal of the PEER program was to develop a transportable and engaging rural middle school model. The model would improve middle school students' STEM knowledge, understanding, and interest by providing under-represented, geographically isolated students relevant, enriching educational opportunities through integrated research and education (PEER, 2004).

The PEER project utilized an interdisciplinary partnership between differing colleges and departments in the Texas A&M University system, graduate and undergraduate fellows from diverse STEM disciplines, and volunteer public junior high school math and science teachers in a 40-mile radius of College Station, Texas. The goal of this partnership was to enhance the quality of middle school student educational experiences using inquiry learning and improve middle school students' attitudes toward STEM areas.

Graduate fellows, termed "NSF Fellows," served as middle school student role models, correcting student misconceptions of science and math and scientists and mathematicians. NSF Fellows promoted increased student understanding of the real-world importance of STEM subjects and fostered positive student STEM beliefs and interests. NSF Fellows served as content specialists and resources for the middle school. NSF Fellows collaborated closely with an assigned "lead teacher" in the middle school. The NSF Fellows provided these teachers content-rich, in-depth, inquiry-based learning activities. It was expected that the active participation of NSF Fellows in the classroom would increase teachers' inquiry teaching abilities and comfort levels, and appreciation for teaching by inquiry methods. It was also anticipated that after involvement in this program NSF Fellows would continue to be actively involved in and actively support public school education and encourage their peers to become involved. The NSF Fellows would retain an understanding of the difficulties and rewards in public school education throughout their professional careers.

Goals and Objectives

The purpose of this study was to develop a model which explains middle school students' STEM interest and belief change as a result of inquiry-based learning constructs. The objectives to accomplish this goal were to

1. Determine if prolonged classroom involvement of the NSF Fellow significantly affected changes in middle school students' STEM beliefs;
2. Determine if prolonged classroom involvement of the NSF Fellow significantly affected changes in middle school students' STEM interests;
3. Determine if a significant relationship existed between NSF Fellow and classroom inquiry elements;
4. Determine if a significant relationship existed between classroom inquiry elements and middle school students' STEM interests and belief changes;

5. Develop a model which describes the relationship of inquiry-based teaching elements on middle school students' STEM interests and belief changes.

CHAPTER III

METHODOLOGY

This study was part of a larger project, the GK-12 PEER project at Texas A&M University. It focused on developing a model explaining middle school students' STEM interests and belief changes as a result of inquiry-based learning constructs. Attitudinal data were collected using a pretest/posttest design from a voluntary sample. Classroom inquiry-level data were collected using the Reformed Teaching Observation Protocol (RTOP) instrument. This chapter presents the population and sample, instrumentation, data collection, and data analysis procedures of the study.

Population and Sample

Each year 12 NSF Fellows were assigned to a "lead teacher" in middle school math and science classrooms in a 40-mile radius of College Station, Texas. NSF Fellows served as resource and content specialists, and provided teachers with and/or conducted content-rich, inquiry-based learning activities for students. In the middle school classroom, NSF Fellows served as role models, corrected student misconceptions about scientists and science, increased student awareness of the importance of science and scientific methods in everyday life, and fostered positive attitudes toward math and science. NSF Fellows also helped develop an appreciation for teaching by inquiry methods, and increased teachers' abilities and comfort levels with inquiry teaching methods.

NSF Fellows were expected to spend approximately 10 hours/week interacting with middle school students in the classroom, four hours/week preparing materials and developing inquiry-based activities, and one hour/week attending weekly meetings to discuss program insights and problems. NSF Fellows were expected to serve as resources to other teachers in their schools, and by the last 12 weeks of the school-year, spend approximately 60% of their time in their lead teachers' classrooms, versus 40% time interacting with students in other teachers' classrooms.

Instrumentation

Middle school students' STEM beliefs and interests were collected using pre-and post-NSF Fellow attitudinal surveys containing Likert scaled questions and open-ended responses. Reverse coding of some statements was used to reduce the biasing effect (Tuckman, 1999). The Likert scales measured students' agreement levels (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree) with 12 statements pertaining to STEM beliefs, and eight statements pertaining to STEM interests. The STEM belief and interest statements were drawn from statements originally developed for use in the National Science Foundation's *Mississippi Information Technology Workforce* project. Content validity for these statements were established by 24 Mississippi agriculture and biology teachers and versions of these statements were pilot tested with audiences similar to this study's proposed population (Lindner et al., 2004; Swortzel, Jackson, Taylor, & Deeds, 2003).

Sample statements for students' beliefs about science included: *I enjoy science class*; *Science is difficult for me; Scientists help make our lives better*; and *Being a scientist would be a lonely job*. Samples of the eight statements pertaining to interests in STEM included: *I like to use computers to learn about science*; *Science class activities* *are boring*; *The things we study in science are not useful to me in daily living*; *I don't usually try my best in science class*.

The Reformed Observation Teaching Protocol (RTOP) developed by the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) at Arizona State University was used to quantitatively measure classroom inquiry levels when graduate students (NSF Fellows) were present. The RTOP instrument used a criterion referenced, holistic approach specifying the level and type of inquiry present in the classroom (Sawada et al., 2002). The RTOP was grounded in student-centered, constructivist learning theory.

The RTOP instrument consisted of 25 statements divided into the three constructs: (1) lesson design and implementation; (2) content, and (3) classroom culture. Lesson design and implementation

> …describes a lesson that begins with recognition of students' prior knowledge and preconceptions … attempts to engage students as members of a learning community … values a variety of solutions to problems … often takes its direction from ideas generated by students. (Piburn et al., 2000, p. 8)

Content was divided into two smaller constructs of propositional knowledge (the quality of what is being taught) and procedural knowledge (how it is being taught-the inquiry process). Classroom culture was also divided into two smaller constructs of student-to-student relationships/interactions (frequency, quality, and type of discourse and interaction between students) and student-to-teacher relationships/interactions (frequency, quality, and type of discourse and interaction between teacher and students)

(Piburn et al., 2000). Each of the four constructs described consisted of five statements describing the inquiry-learning attributes of that construct.

Sample statements for the propositional construct were: *The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.* Sample statements for the procedural construct were: *The lesson promoted strongly coherent conceptual understanding. Connections with other content disciplines and/or real world phenomena were explored and valued.* Sample statements for the student-to-student relationships/interactions construct were: *Students were involved in the communication of their ideas to others using a variety of means and media. There was a high proportion of student talk and a significant amount of it occurred between and among students.* Sample statements for the student-to-teacher relationships/interactions construct were: *Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence. The teacher acted as a resource person, working to support and enhance student investigations.*

The summed score of the four constructs yielded an overall measure of the level of inquiry present in the classroom. Each of the four constructs' five items was scored by the observer from zero (never occurred) to four (very descriptive). The summed range for overall classroom inquiry ranged from 0-100 (Sawada et al., 2002).

The constructs of the RTOP instrument were highly reliable and the inter-rater reliability was high among trained observers (Sawada et al., 2002). Reliability of the

RTOP instrument was indicated by best-fit linear regression of paired observations as high with an R^2 of 0.954. Construct reliability indicated high R^2 values for the five subscales: 1.) Lesson Design and Implementation (0.915); 2) Content-Propositional Pedagogic Knowledge (.67); 3) Content-Procedural Pedagogic Knowledge (.946); 4) Classroom Culture-Communicative Interactions (.907); and 5) Classroom Culture-Student/Teacher Relationships (.872) (Piburn et al., 2000).

More specifically, the RTOP instrument had indicated high construct reliability for inquiry orientation as reported by R^2 values from correlation analysis of the five subscales: 1) Lesson Design and Implementation (R^2 = 0.956); 2) Content-Propositional Pedagogic Knowledge (R^2 = 0.769); 3) Content-Procedural Pedagogic Knowledge (R^2 = 0.971); 4) Classroom Culture-Communicative Interactions (R^2 = 0.967); and 5) Classroom Culture-Student/Teacher Relationships (R^2 = 0.941) (Piburn et al., 2000). The RTOP instrument "is largely a uni-factorial instrument that taps a single construct of Inquiry" (Piburn et al., 2000, p. 24).

Data Collection

Middle school students' STEM beliefs and interests were collected at the beginning of the school-year. Participating middle school teachers administered pre-NSF Fellow STEM beliefs and interests instruments prior to the NSF Fellows' classroom involvement. STEM belief and interest scales were summed to determine an overall belief and/or interest for each STEM area. Year one data were collected from middle school students in the classrooms of both lead teachers and other teachers within the school system in whose classrooms NSF Fellows interacted. Year two data were collected from the classrooms of lead teachers only.

Year one instruments were offered in traditional paper format only, while year two instruments were offered both in traditional paper format and a Web-based format. Both years, teachers assigned students individual identification codes to use when completing the instruments. Teachers maintained the master list of codes so that students' used the same teacher generated identification on the post-NSF Fellow instrument as on the pre-NSF Fellow instrument, allowing analysis of matched student responses and student confidentiality by the evaluation team.

The evaluation team was composed of two faculty members and two doctoral students from the Department of Agricultural Leadership, Education, and Communications at Texas A&M University. The evaluation team received formal training in the use of RTOP from Arizona State University in order to achieve the high inter-rater results and instrument reliability associated with this tool. At least two RTOP observations were conducted per NSF Fellow each semester.

Data Analysis

Cronbach's alpha coefficient was used to determine summed scale reliabilities for the pre-and post-NSF Fellow STEM beliefs and interests instruments, the four RTOP constructs, and the cumulative RTOP score. Descriptive statistics were used to describe the population and indicate middle school students' pre-and post-NSF Fellow mean STEM beliefs and interests. Effect sizes of paired t test analyses were measured by Cohen's d. Interpretation of the d statistic will follow Cohen's proposed convention of

.20 = small, .50 = medium, and .80 = large effect size (Cohen, 1977). Effect sizes of correlation and regression analyses were measured by correlation and regression coefficients, as Cohen (1990) stated

> Effect-size measures include mean differences (raw or standardized), correlations and squared correlation of all kinds … whatever conveys the magnitude of the phenomenon of interest appropriate to the research context. (p. 1310)

Eta squared (η^2) was used as an estimate of effect size for the Univariate and Repeated Measures Analysis of Variance analyses (ANOVA).

> Many effects sought in personality, social, and clinical-psychological research are likely to be small effects [as defined by Cohen, 1977], both because of the attenuation in validity of the measures employed and the subtlety of the issues frequently involved. (Cohen, 1977, p. 13)

The Repeated Measures function of the General Linear Model (GLM) was used to determine if significant differences existed in middle school students' pre-and post-NSF Fellow STEM interest and beliefs, and if NSF Fellow affects the rate of change in middle school students' STEM interests and beliefs. The Repeated Measures design was deemed appropriate as subjects served as their own controls and "all sources of variability between subjects are excluded from the experimental error. Only variation within subjects enters the experimental error…" (Neter, Kutner, Nachtsheim, & Wasserman, 1996, p. 1165).

Paired samples *t* tests and Univariate ANOVA were conducted to determine if a significant difference existed between Spring and Fall semesters in mean classroom inquiry levels. Pearson's Product Moment Correlation analyses were conducted to determine if a significant relationship existed between inquiry level and NSF Fellow for each of the 25 RTOP statements.

In order to perform correlations and regression upon inquiry levels and student STEM interest and beliefs changes, inquiry scores were converted to *z*-scores and a mean *z*-score was calculated for each inquiry statement by NSF Fellow. Middle school students' beliefs and interests were also converted to *z*-scores and mean *z*-scores were calculated for each belief and interest statement by NSF Fellow. Converting both data sets to *z*-scores standardized the variables so that variables originally measured in different units may be compared (Field, 2000). Data were arranged by NSF Fellow as RTOP data and STEM interest and belief data were each blocked by NSF Fellow. Due to the unequal size of the data files of the RTOP (N = 139) and STEM interests and beliefs (N = 1779) mean RTOP scores and mean STEM interests and beliefs by NSF Fellow were used to facilitate correlation and regression analysis.

Due to the literature's indication that inquiry learning constructs have positive effects on students' interests and beliefs in STEM subjects, one-way bivariate correlation analyses were performed using Pearson's Product Moment correlation method to indicate existing relationships between inquiry statements and middle school students' STEM beliefs and interests change. One-way bivariate correlations using Pearson's Product Moment correlation method analysis were also performed to indicate existing relationships between inquiry statements and NSF Fellow. Significance was set *a priori* $\alpha = 0.05$. Strength of correlations was interpreted using the conventions for describing *Q* values proposed by Davis (1971) (.00 = no association; .01-.09 = negligible association; .10-.29 = low association; .30-.49 = moderate association; .50-.69 = substantial association; .70 or higher = very strong association).

RTOP statements identified as having a statistically significant association with middle school students' STEM beliefs and interests were included as independent variables in forced entry multiple regression analysis of students' STEM beliefs and interests. Correlation analyses were also conducted on the year data were collected, NSF Fellow, gender of NSF Fellow, student location, subject, grade level, male students, and female students to identify significant relationships between these factors and changes in middle school students' STEM beliefs and interests. Variables indicating statistically significant associations were included in the forced entry multiple regression on changes in middle school students' STEM beliefs and interests.

Forced entry multiple linear regression analyses were conducted to determine the effect of the variables and RTOP statements identified as having statistically significant associations with middle school students' changes in STEM interests and beliefs. The forced entry regression method was deemed appropriate as order entry of variables does not affect the importance of the variable in the regression model (Field, 2000). In the absence of a statistically significant model being identified by forced entry regression analyses, forward stepwise regression analyses, as recommended by Neter et al. (1996) for the building of significant models resulting from the addition or deletion of variables in the regression analyses, were performed. Significance for the regression models and Beta coefficients was set *a priori* $\alpha = 0.05$. Beta coefficients indicating no statistical significance to the model or multicollinearity problems were removed and a second regression analysis for both STEM beliefs and interest change was performed using only those variables with significant Beta coefficients and acceptable multicollinearity values.

Multicollinearity among the predictor variables in the regression models were analyzed using the variance inflation factor (VIF), as it "takes into account all relations among predictors, so it is more complete than simple correlations" (Ott & Longnecker, 2001 p. 709). Multicollinearity among the variables was indicated by VIF values greater than 10 (Neter et al., 1996). Tolerance values were used to indicate the amount of variance in a variable independent of other variables in the regression model. Tolerance values below .10 indicated serious problems of multicollinearity among variables could exist (Cohen, Cohen, West, & Aiken, 2003).

Middle school students' scores on individual interest and beliefs statements were summed to determine an overall belief and interest as interests and beliefs are attitudes and comprised of more than one variable of interest. Cronbach's alpha coefficient (Cronbach, 1951) was used to determine summed scale reliabilities for both pre-and post-NSF Fellow beliefs and interests for years 1 and 2 of the project, overall project, and for standardized beliefs and interests by fellow used in correlation and regression analyses (Table 1).

Table 1
Reliability Coefficients for Pre- and Post-Beliefs and Interests

Scale	Objectives	Year 1	Year 2	Cumulative: Lead Teacher Only	Standardized Data
Pre-Beliefs	12	.79	.81	.80	.86
Post-Beliefs	12	.83	.82	.82	.93
Pre-Interests	8	.40	.58	.49	.54
Post-Interests	8	.65	.56	.62	.83

Overall, the cumulative and standardized pre-NSF Fellow Beliefs (.80 and .86 respectively) and post-NSF Fellow Beliefs (.82 and .93 respectively) scales provided reliable data for analyses and interpretation. Even though reliability coefficients for overall cumulative and standardized pre-NSF Fellow STEM Interests (.49 and .54 respectively) were low, they were included in the analyses as post-NSF-Fellow STEM Interests (.62 and .83 respectively) met the acceptability criterion and as STEM Interests were a measure of attitude, as noted by Tuckman's (1999) statement, "Observational reliabilities should be at .75 or above…and .50 or above for attitude tests" (p. 445). Reliability coefficients for year one pre-NSF Fellow instruments were: Beliefs scale (.79) and Interests scale (.40). Reliability coefficients for the post-NSF Fellow instruments were: Beliefs scale (.83) and Interests scale (.58). Year two reliability coefficients for pre-NSF Fellow instruments were: Beliefs scale (.81) and Interests scale (.58). Reliability coefficients for the year two post-NSF Fellow instruments were: Beliefs scale (.82) and Interests scale (.56).

Even though the year one pre-NSF Fellow Interest scale reliability coefficient was below the acceptable range (Tuckman, 1999), year one post-NSF Fellow reliability coefficient was included in analyses, since it was a measure of attitude (Tuckman). Year-two pre-NSF Fellow Interests also had a low alpha of .58 and a post-NSF Fellow alpha of .56, and were included in the analyses as they were measures of attitude (Tuckman).

Cronbach's alpha coefficient was used to determine summed scale reliabilities for each of the four RTOP constructs and the overall RTOP instrument for each individual year of the PEER project, the cumulative two-year data, and the standardized data used in correlation and regression analyses (Table 2).

Table 2
Reliability Coefficients RTOP Constructs

Scale	Objectives	Year 1	Year 2	Cumulative: Lead Teacher Only	Standardized Data
Lesson Design and Implementation	5	.69	.73	.70	.69
Propositional Knowledge	5	.46	.52	.49	.58
Procedural Knowledge	5	.80	.70	.73	.69
Communicative Interactions	5	.83	.78	.80	.66
Student/Teacher Relationships	5	.87	.84	.85	.88
Summed Scale	25	.92	.91	.91	.90

Year one and cumulative reliability estimates for the RTOP construct, *Propositional Knowledge*, were below the acceptable range (.46 and .49 respectively), but were included in analyses because the reliability estimate of the standardized data (.58) used in correlation and regression analyses met the acceptability criterion as the results were for research purposes. As noted by Ary, Jacobs, and Razavieh (1996)

> The degree of reliability needed in a measure depends to a great extent on the use that is to be made of the results. If the measurement results are to be used for

> making a decision about a group or even for research purposes, a lower reliability coefficient (in the range of .50 to .60) might be acceptable. (p. 287)

Overall the summed RTOP scale provided reliable data for analyses and interpretation for year 1 (.92), year 2 (.91), Cumulative two-year data (.91), and Standardized data (.90). Reliability estimates were reliable for the individual RTOP constructs with the exception of the aforementioned RTOP construct *Propositional Knowledge*, with alpha coefficients ranging from .66 to .92.

Inter-rater reliabilities for the RTOP instrument were analyzed year one and year two using intra-class correlation (ICC) Two-Way Mixed Model for agreement (Shrout & Fleiss, 1979). The ICC indicated acceptable rater reliability years one (.89), two (.85) and cumulative (.87) of the PEER project (Table 3).

Table 3
RTOP Inter-rater Reliabilities: Years One, Two, and Cumulative

Intra-class Correlation	Year 1	Year 2	Cumulative
Average Measures	.89	.85	.87

Note. Correlation coefficients approach 1.0 when there is no variance within items.

CHAPTER IV

RESULTS*

This chapter details the demographic composition of the population under study for both student attitudinal data and RTOP data. This chapter also details the findings of this study by objective. The primary purposes of this study were to develop a model quantifying middle school students' STEM interest and belief change as a function of the elements of inquiry-learning, and determine if NSF Fellows' consistent classroom interaction affected classroom inquiry levels and changes in middle school students' STEM interests and beliefs.

STEM Attitudinal Demographics

Cumulative Two-Year Student Demographics

Cumulative two-year student attitudinal data from the PEER project were collected year one from the classrooms of both the NSF Fellow's assigned lead teacher and all other teachers' classrooms in the school in which the NSF Fellow interacted. Year two data were collected from the classrooms of the lead teachers only. Middle school program and teacher drop-out resulted in pre-survey data being collected from 17 lead teachers and 12 other teachers representing 11 schools in a 40-mile radius of Texas A&M University; a total of 3,759 students responded to this study. Invalid surveys

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* Part of the data reported in this chapter is reprinted with permission from "Graduate fellows in the classroom: middle school students' stem beliefs and interests" by S. H. Degenhart, G. J. Wingenbach, D. L. Mowen, J. R. Lindner, and L. Johnson, 2006, J*ournal of Southern Agricultural Education Research*, *56*.

lowered the overall response rate; only those students who completed both the pre-and post-attitude surveys were included in the data analysis (*N* = 1779).

Data were analyzed from 1,779 matched pre-and post-surveys. One thousand, one hundred and forty-five (64.4%) matched responses were obtained during year one of the project and 634 (35.6%) were obtained in year two. Of the respondents, 809 (45.5%) were male, 899 (50.5%) were female, and 65 (3.7%) did not declare their gender. Six hundred and fifty-nine (37.0%) students were in the 6th grade, 453 (25.5%) were in the 7th grade, 651 (36.6%) were in the 8th grade, 12 (0.7%) were in the 5^{th} grade, and three (0.2%) were in the 9^{th} grade. There were 1,225 (68.9%) students in science classes, 472 (26.5%) were in mathematics classes, and 82 (4.6%) were in technology classes. Lead teachers' classrooms accounted for 1,361 (76.5%) students and 418 (23.5%) were in other teachers' classrooms (Table 4).

Table 4

Cumulative Two-Year Student Frequencies by Factor (N = 1779)

Factor	Sub-factor	*f*	Percent
Year	2004-2005	1145	64.4
	2005-2006	634	35.6
Grade	6th grade	659	37.0
	8th grade	651	36.6
	7th grade	453	25.5
	5th Grade	12	.7
	9th Grade	3	.2
Subject	Science	1225	68.9
	Math	472	26.5
	Technology	82	4.6
Teacher	Lead Teacher	1361	76.5
	Other Teacher	418	23.5
Gender	Female	899	50.5
	Male	809	45.5
	Undeclared	65	3.7
NSF Fellow	12	299	16.8
	1	225	12.6
	2	132	7.4
	3	117	6.6
	22	114	6.4
	5	103	5.8
	11	91	5.1
	10	82	4.6
	17	80	4.5
	16	78	4.4
	23	68	3.8
	7	59	3.3
	18	57	3.2
	19	56	3.1
	26	54	3.0
	15	41	2.3
	28	40	2.2
	13	37	2.1
	25	24	1.3
	21	22	1.2

Year 1: 2004- 2005 Student Demographics

Year one of the PEER project, student attitudinal data were collected in classrooms of both NSF Fellows' assigned lead teacher and the classrooms of all other teachers within which the NSF Fellow interacted. Middle school program and teacher drop-out resulted in pre-NSF Fellow data being collected from 12 lead teachers and 12 other teachers representing 10 schools in a 40-mile radius of Texas A&M University; a total of 2,184 students responded to the study. Invalid instruments lowered the overall response rate; only those students who completed both the pre-and post-NSF Fellow STEM beliefs and interests instruments were included in the data analysis ($N = 1145$).

Data were analyzed from 1,145 matched pre-and post-surveys. Of the respondents, 517 (45.2%) were male, 560 (48.9%) were female, and 65 (5.7%) did not declare their gender. Four hundred and seventy-one students (41.1%) were in the 6th grade, 290 (25.6%) were in the 7th grade, and 371 (32.8%) were in the 8th grade. There were 844 students (73.7%) in science classes, 219 (19.1%) were in mathematics classes, and 82 (7.2%) were in technology classes. Lead teachers' classrooms accounted for 727 students (63.5%) and 418 students were in other teachers' classrooms (Table 5).

Table 5
Year 1: 2004-2005 Student Frequencies by Factor (N = 1145)

Factor	Sub-factor	*f*	Percent
Grade	6th grade	471	41.1
	7th grade	290	25.3
	8th grade	371	32.4
Subject	Science	844	73.7
	Math	219	19.1
	Technology	82	7.2
Teacher	Lead Teacher	727	63.5
	Other Teacher	418	36.5
Gender	Male	517	45.2
	Female	560	48.9
	Undeclared	65	5.7
NSF Fellow	1	225	19.7
	2	132	11.5
	3	117	10.2
	5	103	9.0
	7	59	5.2
	10	82	7.2
	11	91	7.9
	12	299	26.1
	13	37	3.2

Year 2: 2005- 2006 Student Demographics

Year two data were collected from the classrooms of lead teachers only. Middle school program and teacher drop-out resulted in pre-NSF Fellow data being collected from 11 lead teachers representing 9 schools in a 40-mile radius of Texas A&M University; a total of 1,575 students responded to this study. Invalid instruments lowered the overall response rate; only those students who completed both the pre-and post-NSF Fellow STEM interests and beliefs instruments were included in the data analysis (N = 634).

Data were analyzed from 634 matched pre-and post-NSF Fellow instruments. Of the respondents, 293 (46.2%) were male. One hundred and eighty-eight students (29.7%)

were in the 6th grade, 163 (25.7%) were in the 7th grade, and 280 (44.2%) were in the 8th grade. There were 381 students (60.1%) in science classes and 253 (39.9%) were in mathematics classes (Table 6).

Table 6
Year 2: 2005-2006 Student Frequencies by Factor (N = 634)

Factor	Sub-factor	*f*	Percent
Grade	6th grade	188	29.7
	7th grade	163	25.7
	8th grade	280	44.2
Subject	Science	381	60.1
	Math	253	39.9
Teacher	3	80	12.6
	4	41	6.5
	6	114	18.0
	8	24	3.8
	9	78	12.3
	10	56	8.8
	11	57	9.0
	12	22	3.5
	13	40	6.3
	14	54	8.5
	15	68	10.7
Gender	Male	293	46.2
	Female	339	53.5
NSF Fellow	1	80	12.6
	4	22	3.5
	5	78	12.3
	6	56	8.8
	7	24	3.8
	8	114	18.0
	9	41	6.5
	10	57	9.0
	11	68	10.7
	13	54	8.5
	14	40	6.3

Middle School Students' Pre/Post-NSF Fellow Beliefs

Year 1: 2004-2005 Student Beliefs

Year one data indicated middle school students' STEM beliefs were more positive for post- versus pre-NSF Fellow classroom involvement in 2 of 12 science belief statements, 5 of 12 technology belief statements, and 3 of 12 math belief statements. In science, students were more positive about *scientists making their lives better* (M = 4.26 vs. 4.20) and *getting to do experiments in class* (M = 4.32 vs. 4.19). Students remained steady about *wishing to take more science classes* (M = 2.91) and *believing science was difficult for them* (M = 3.43). For all other statements, student beliefs were less positive at the end than at the beginning of the school-year.

Technology indicated the most overall improvement in student beliefs post- versus pre-NSF Fellow classroom involvement. Students held more positive technology beliefs about *the usefulness of technology in everyday life* (M = 4.36 vs. 3.98); *technology making their lives better* (M = 4.35 vs. 4.16); *technology not being difficult for them* (M = 3.51 vs. 3.50); *that being a technologist would not be a lonely job* (M = 3.77 vs. 3.68); and *not believing studying hard in technology is not cool* (M = 3.95 vs. 3.86). Students remained steady in their *desire to take more technology classes* (M = 3.16). For all other statements student beliefs were less positive at the end than at the beginning of the school-year.

Students held more positive mathematics beliefs about *using the math book to study math* (M = 2.87 vs. 2.53); *getting to do experiments in math class* (M = 3.73 vs. 3.00); and *not believing mathematicians have lonely jobs* (M = 3.41 vs. 3.36). Students were less positive in their beliefs for all other statements at the end than they were at the beginning of the school-year. There were no engineering classes at the middle school level. Therefore, there are no results to report for engineering (Table 7).

Table 7

Year 1: 2004-2005 Descriptive Statistics for Middle School Students' STEM Beliefs (N = 1145)

	Science[a] (*n* = 838)		Technology[a] (*n* = 82)		Math[a] (*n* = 219)	
STEM Beliefs Statements	Pre	Post	Pre	Post	Pre	Post
I enjoy ______ class.	3.84	3.74	4.06	4.01	3.73	3.51
I think I could be a good ______.	2.67	2.63	3.16	2.95	2.93	2.57
I like to find answers to questions by doing experiments.	3.77	3.69	4.10	4.06	3.58	3.54
I get to do experiments in my _____ class.	4.19	4.32	4.05	4.01	3.00	3.73
Being a ______ would be exciting.	3.27	3.17	3.50	3.28	2.94	2.69
______ is difficult for me.*	3.43	3.43	3.50	3.51	3.21	3.20
I like to use the ______ book to learn ___.	2.63	2.32	3.04	2.61	2.53	2.87
______ is useful in everyday life.	3.96	3.89	3.98	4.36	4.33	4.20
Studying hard in ______ is not cool.*	3.48	3.43	3.86	3.95	3.55	3.49
______s help make our lives better.	4.20	4.26	4.16	4.35	3.89	3.76
Being a ______ would be a lonely job.*	3.43	3.41	3.68	3.77	3.36	3.41
I want to take more ______ classes.	2.91	2.91	3.16	3.16	2.86	2.68

Note. [a]Means for pre-and post-Fellow experiences. Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither, 4 = Agree, 5 = Strongly Agree.

* Indicates items that were reverse coded.

Year 2: 2005-2006 Student Beliefs

Year two data indicated the majority of middle school students' STEM beliefs were more positive for post- versus pre-NSF Fellow classroom involvement in 9 of 12 science belief statements, and 7 of 12 math belief statements. In science, students were more positive about *thinking they could be good scientists* (M = 2.72 vs. 2.68); *liking to find answers to questions by doing experiments* (M = 4.06 vs. 4.04); *being a Scientist would be exciting* (M = 3.43 vs. 4.08); *science being useful in everyday life* (M = 4.25 vs. 3.34); *not believing that studying hard in school is not cool* (M = 3.77 vs. 4.12); *scientists making our lives better* (M =4.27 vs. 3.75); and *not believing that being a scientist would be a lonely job* (M = 3.72 vs. 4.25). Students' post-NSF Fellow responses were less positive on all other statements (Table 8).

In mathematics, middle school students were more positive in their *enjoyment of math class* (M = 3.69 vs. 3.62); *liking to find answers to questions by doing experiments* (M = 3.75 vs. 3.69); *believing being a mathematician would be exciting* (M = 2.79 vs. 2.73); *math being useful in everyday life* (M = 4.39 vs. 4.22); *not believing that studying hard in school is not cool* (M = 3.72 vs. 3.66); *mathematicians help make our lives better* (M = 3.95 vs. 3.83); and *not believing that being a mathematician would be a lonely job* (M = 3.28 vs. 3.23). There were no engineering or technology classes at the middle school level. Therefore, there are no results to report for engineering or technology year two (Table 8).

Table 8

Year 2: 2005-2006 Descriptive Statistics for Middle School Students' STEM Beliefs (N = 634)

	Science[a] (*n* =381)		Math[a] (*n* =253)	
STEM Beliefs Statements	Pre	Post	Pre	Post
I enjoy ______ class.	3.98	3.91	3.62	3.69
I think I could be a good ______.	2.68	2.72	2.72	2.55
I like to find answers to questions by doing experiments.	4.04	4.06	3.69	3.75
I get to do experiments in my ______ class.	4.08	4.48	3.23	3.68
Being a ______ would be exciting.	3.34	3.43	2.73	2.79
______ is difficult for me.*	3.59	3.50	3.35	3.27
I like to use the ______ book to learn ______.	2.77	2.58	2.92	2.61
______ is useful in everyday life.	4.12	4.25	4.22	4.39
Studying hard in ______ is not cool.*	3.75	3.77	3.66	3.72
______s help make our lives better.	4.25	4.27	3.83	3.95
Being a ______ would be a lonely job.*	3.64	3.72	3.23	3.28
I want to take more ______ classes.	2.88	3.01	2.69	2.63

Note. [a]Means for pre-and post-Fellow experiences. Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither, 4 = Agree, 5 = Strongly Agree.
* Indicates items were reverse coded

Cumulative Two-Year Student Beliefs

Cumulative two-year data indicated middle school students' science beliefs were more positive for post- versus pre-NSF Fellow classroom involvement in 3 of 12 science belief statements, 5 of 12 technology belief statements, and 4 of 12 mathematics belief statements. In science, students were more positive about *getting to do experiments in science class* (M = 4.37 vs. 4.16); *scientists making our lives better* (M = 4.27 vs. 4.22); and *wanting to take more science classes* (M = 2.94 vs. 2.90). Students remained unchanged in their *not believing that being a scientist would be a lonely job* (M = 3.50). Students were less positive post-NSF Fellow on all other statements than pre-NSF Fellow.

Middle school students held more positive technology beliefs about *the usefulness of technology in everyday life* (*M* = 4.36 vs. 3.98); *not believing technology was difficult for them* (*M* = 3.51 vs. 3.50); *not believing that studying hard in technology is not cool* (*M* = 3.95 vs. 3.86); *not believing being a technologist would be a lonely job* (*M* = 3.77 vs. 3.68); and *technology making their lives better* (*M* = 4.35 vs. 4.16). Students remained steady in their desire to *take more technology classes* (*M* = 3.16). For all other statements, student beliefs were less positive at the end than at the beginning of the school-year.

Students held more positive mathematics beliefs about *liking to find answers to questions by doing experiments* (*M* = 3.65 vs. 3.64); *getting to do experiments in math class* (*M* = 3.70 vs. 3.12); *their belief that math is useful in everyday life* (*M* = 4.30 vs. 4.27); and *not believing that being a scientist would be a lonely job* (*M* = 3.34 vs. 3.29). Students indicated no change in their post- versus pre-NSF Fellow classroom involvement mathematics beliefs of *studying hard in math is not cool* (*M* = 3.61) and *mathematicians help make our lives better* (*M* = 3.86). Students were less positive post-NSF Fellow on all other statements than pre-NSF Fellow. There were no engineering classes at the middle school level. Therefore, there are no results to report for engineering (Table 9).

Table 9

Cumulative Two-Year Descriptive Statistics for Middle School Students' STEM Beliefs Two-Year Cumulative Data (N = 1779)

	Science[a] (n = 1225)		Technology[a] (n = 82)		Math[a] (n = 472)	
STEM Beliefs Statements	Pre	Post	Pre	Post	Pre	Post
I enjoy ______ class.	3.88	3.79	4.06	4.01	3.67	3.60
I think I could be a good ______.	2.67	2.66	3.16	2.95	2.82	2.56
I like to find answers to questions by doing experiments.	3.86	3.81	4.10	4.06	3.64	3.65
I get to do experiments in my ______ class.	4.16	4.37	4.05	4.01	3.12	3.70
Being a ______ would be exciting.	3.29	3.25	3.50	3.28	2.82	2.74
______ is difficult for me.*	3.48	3.45	3.50	3.51	3.29	3.24
I like to use the ______ book to learn ______.	2.67	2.40	3.04	2.61	2.74	2.73
______ is useful in everyday life.	4.01	4.00	3.98	4.36	4.27	4.30
Studying hard in ______ is not cool.*	3.56	3.54	3.86	3.95	3.61	3.61
______s help make our lives better.	4.22	4.27	4.16	4.35	3.86	3.86
Being a ______ would be a lonely job.*	3.50	3.50	3.68	3.77	3.29	3.34
I want to take more ______ classes.	2.90	2.94	3.16	3.16	2.77	2.65

Note. [a]Means for pre-and post-Fellow experiences. Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither, 4 = Agree, 5 = Strongly Agree.
* Indicates items were reverse coded.

Middle School Students' Pre/Post-NSF Fellow Interests

Year 1: 2004-2005 Student Interests

Year one data indicated middle school students' STEM interests were more positive for post- versus pre-NSF Fellow classroom involvement in one of eight science interest statements, five of eight technology interest statements, and two of eight math interest statements. Year one data for science indicates students were more positive in their interest in *working in small groups* (*M* = 3.89 vs. 3.66). Students were less positive for all other statements post-NSF Fellow than pre-NSF Fellow.

Students held more positive technology interests for *using technology equipment* (*M* = 4.19 vs. 3.94) and *computers* (*M* = 4.18 vs. 3.67) *to study technology*; *technology not being useful only in school* (*M* = 4.24 vs. 3.84); and *technology being useful in their everyday live*s (*M* = 4.26 vs. 4.06). Students indicated no change post- versus pre-NSF Fellow in their interest in *working in small groups in technology clas*s (*M* = 3.61). For all other statements, student interests were less positive at the end than at the beginning of the school-year.

Students were more positive in their mathematics interest in *using computers to learn about mathematics* (*M* = 3.87 vs. 3.78); and *mathematics not only being important at school* (*M* = 4.08 vs. 3.98). Students indicated no change in their opinion that *things studied in mathematics weren't important in their daily lives* (*M* = 4.04). For all other statements, student interests were less positive at the end than at the beginning of the school-year.

There were no engineering classes at the middle school level. Therefore, there are no results to report for engineering (Table 10).

Table 10

Year 1: 2004-2005 Descriptive Statistics for Middle School Students' STEM Interests (N = 1145)

	Science[a] (*n* = 838)		Technology[a] (*n* = 82)		Math[a] (*n* = 219)	
STEM Interest Statements	Pre	Post	Pre	Post	Pre	Post
I think ___ is important only at school.*	3.89	3.85	3.84	4.24	3.98	4.08
I like to use computers to learn about ___.	3.94	3.75	3.67	4.18	3.78	3.87
______ tests make me nervous.*	2.82	2.77	3.02	3.21	2.86	2.76
I like to use ___ equipment to study ___.	4.31	4.04	3.94	4.19	3.79	3.60
I don't usually try my best in __ class.*	4.03	3.89	4.38	4.13	4.08	3.79
The things we study in ___ are not useful to me in daily living.*	3.79	3.71	4.06	4.26	4.04	4.04
I like to work in a small group in ____ class.	3.66	3.89	3.61	3.61	3.82	3.80
____ class activities are boring.*	4.19	3.83	4.38	3.93	3.86	3.75

Note. [a]Means for pre-and post-Fellow experiences. Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither, 4 = Agree, 5 = Strongly Agree.
* Indicates items that were reverse coded.

Year 2: 2005-2006 Student Interests

Year two data indicated middle school students' STEM interests were more positive for post- versus pre-NSF Fellow classroom involvement in four of eight science interest statements, and four of eight math interest statements. Year two science data indicated students were more positive in *thinking science was not important in school only* (M = 4.01 vs. 3.91); *science tests not making them nervous* (M = 2.86 vs. 2.76); *liking to work in small groups* (M = 3.90 vs. 3.79); and *not finding science class activities boring* (M = 4.17 vs. 4.06). For all other statements, student interests were less positive at the end than at the beginning of the school-year.

Students held more positive mathematics interests in *thinking math was not important only in school* (M =3.98 vs. 3.97); *believing the things studied in math class are useful in everyday life* (M = 4.08 vs. 4.04); *liking to work in small groups* (M = 4.02 vs. 3.96); and *not finding science class activities boring* (M = 3.88 vs. 3.74). For all other statements, student interests were less positive at the end than at the beginning of the school-year.

There were no engineering or technology classes at the middle school level year two, therefore no results are reported for engineering or technology (Table 11).

Table 11
Year 2: 2005-2006 Descriptive Statistics for Middle School Students' STEM Interests (N =634)

	Science[a] (n =381)		Math[a] (n =253)	
STEM Interest Statements	Pre	Post	Pre	Post
I think ______ is important only at school.*	3.91	4.01	3.97	3.98
I like to use computers to learn about ______.	4.12	4.03	4.15	3.88
______ tests make me nervous.*	2.76	2.86	2.91	2.84
I like to use _____ equipment to study _____.	4.24	4.23	3.90	3.80
I don't usually try my best in ______ class.*	4.26	4.03	4.05	4.04
The things we study in ______ are not useful to me in daily living.*	4.06	3.99	4.04	4.08
I like to work in a small group in _____ class.	3.79	3.90	3.96	4.02
______ class activities are boring.*	4.06	4.17	3.74	3.88

Note. [a]Means for pre-and post-Fellow experiences. Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither, 4 = Agree, 5 = Strongly Agree.
* Indicates items that were reverse coded

Cumulative Two-Year Student Interests

Cumulative two-year data indicated middle school students' science interests were more positive for post- versus pre-NSF Fellow classroom involvement in three of eight science interest statements, five of eight technology interest statements, and four of eight mathematics interest statements. Students held more positive science interests in *thinking science was not important only in school* (*M* = 3.90 vs. 3.89); *liking to work in small groups* (*M* = 3.89 vs. 3.70); and *not finding science class activities boring* (*M* = 3.94 vs. 3.70). Students indicated no change in *science tests not making them nervous* (*M* = 2.80). For all other statements, student interests were less positive at the end than at the beginning of the school-year.

Students held more positive technology interests in *using technology equipment* (*M* = 4.19 vs. 3.94) and *computers* (*M* = 4.18 vs. 3.67) *to study technology*; *technology not being important only in school* (*M* = 4.24 vs. 3.84); and *technology being useful in their everyday lives* (*M* = 4.26 vs. 4.06). Students indicated no change in *liking to work in small groups in technology class* (*M* = 3.61). For all other statements student interests were less positive at the end of the year than at the beginning of the school-year.

Students held more positive mathematics interests for *believing the things studied in math class are useful in everyday life* (*M* = 4.06 vs. 4.04); *liking to work in small groups* (*M* = 3.82 vs. 3.79); *not thinking mathematics are only important at school* (*M* = 4.03 vs. 3.97); and *not thinking mathematics class activities are boring (M* = 3.82 vs. 3.79). For all other statements student interests were less positive at the end of the year than at the beginning of the school-year.

There were no engineering classes at the middle school level. Therefore, there are no results to report for engineering (Table 12).

Table 12
Cumulative Two-Year Descriptive Statistics for Middle School Students' STEM Interests (N = 1779)

	Science[a] (*n* = 1225)		Technology[a] (*n* = 82)		Math[a] (*n* = 472)	
STEM Interest Statements	Pre	Post	Pre	Post	Pre	Post
I think ______ is important only at school.*	3.89	3.90	3.84	4.24	3.97	4.03
I like to use computers to learn about _____.	3.99	3.84	3.67	4.18	3.97	3.88
______ tests make me nervous.*	2.80	2.80	3.02	3.21	2.89	2.80
I like to use _____ equipment to study ______.	4.29	4.10	3.94	4.19	3.85	3.70
I don't usually try my best in _____ class.*	4.10	3.93	4.38	4.13	4.06	3.93
The things we study in ______ are not useful to me in daily living.*	3.87	3.80	4.06	4.26	4.04	4.06
I like to work in a small group in ______ class.	3.70	3.89	3.61	3.61	3.89	3.91
______ class activities are boring.*	3.70	3.94	4.38	3.93	3.79	3.82

Note. [a]Means for pre-and post-Fellow experiences. Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither, 4 = Agree, 5 = Strongly Agree.
* Indicates items that were reverse coded.

Summed Student Beliefs and Interests

Year 1: 2004-2005 Summed Student Beliefs and Interests

Year one individual belief and interest statements were summed to determine students' overall STEM beliefs and interests due to attitudes being comprised of multiple factors. The summed scale for STEM beliefs ranged from 0 to 60, with scores below 30 indicating negative attitudes. The summed scale for interest in STEM ranged from 0 to 40, with scores below 20 indicating negative attitudes. Students' overall post-NSF Fellow science beliefs were less positive (M = 40.92) than their pre-NSF Fellow beliefs

(*M* = 41.61). Middle school students' post-NSF Fellow interests in science were less positive (*M* = 29.52) than their pre-NSF Fellow interests (*M* = 29.55). Overall, students held less positive post-Fellow beliefs about technology (*M* = 43.78) than their pre-Fellow beliefs (*M* = 44.11), but students' post-Fellow interests were more positive (*M* = 31.56) than their pre-Fellow interests (*M* = 30.33). Students' overall post-Fellow beliefs about math (*M* = 39.30) were less positive than their pre-Fellow beliefs (*M* = 39.87), but their post-Fellow interest in math (*M* = 29.47) was more positive than their pre-Fellow interest (*M* = 29.30).

There were no engineering classes at the middle school level. Therefore, there are no results to report for engineering (Table 13).

Table 13
Year 1: 2004-2005 Descriptive Statistics for Middle School Students' STEM Beliefs and Interests (N = 1145)

	Science (*n* = 844)		Technology (*n* = 82)		Math (*n* = 219)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Pre-Fellow STEM Beliefs	41.61	7.56	44.11	6.91	39.87	7.89
Post-Fellow STEM Beliefs	40.92	7.84	43.78	7.06	39.30	9.01
Pre-Fellow STEM Interests	29.55	4.73	30.33	4.20	29.30	4.33
Post-Fellow STEM Interests	29.52	4.86	31.56	4.51	29.47	5.20

Note. STEM Beliefs means for each subject ranged from: Science = 14-60; Technology = 26-60; and Math = 12-60. STEM Interests means for each subject ranged from: Science = 3-40; Technology = 20-40; and Math = 12-40.

Year 2: 2005-2006 Summed Student Beliefs and Interests

Year two individual belief and interest statements were summed to determine students' overall STEM beliefs and interests due to attitudes being comprised of multiple factors. The summed scale for STEM beliefs ranged from 0 to 60, with scores below 30 indicating negative attitudes. The summed scale for interest in STEM ranged from 0 to 40, with scores below 20 indicating negative attitudes. Students' overall post-NSF Fellow beliefs were more positive in science and math (M = 43.44 and 39.99, respectively) than their pre-NSF Fellow beliefs (M = 42.74 and 39.47, respectively). Middle school students' overall post-NSF Fellow interests were less positive in science and math (M = 30.99 and 30.30, respectively) than their pre-NSF Fellow interests (M = 31.02 and 30.54, respectively).

There were no engineering or technology classes at the middle school level year two; therefore there are no results to report for engineering or technology (Table14).

Table 14
Year 2: 2005-2006 Descriptive Statistics for Middle School Students' STEM Beliefs and Interests (N = 634)

	Science[a] (n =381)		Math[a] (n =253)	
	M	SD	M	SD
Pre-Fellow STEM Beliefs	42.74	7.19	39.47	8.07
Post-Fellow STEM Beliefs	43.44	7.14	39.99	8.15
Pre-Fellow STEM Interests	31.02	3.97	30.54	4.90
Post-Fellow STEM Interests	30.99	4.09	30.30	4.73

Note. STEM Beliefs means for each subject ranged from: Science = 14-60; STEM Interests means for each subject ranged from: Science = 3-40; Technology = 20-40; and Math = 12-40.

Cumulative Two-Year Summed Student Beliefs and Interests

Cumulative two-year individual belief and interest statements were summed to determine students' overall STEM beliefs and interests due to attitudes being comprised of multiple factors. The summed scale for STEM beliefs ranged from 0 to 60, with scores below 30 indicating negative attitudes. The summed scale for interest in STEM ranged from 0 to 40, with scores below 20 indicating negative attitudes. Middle school students' overall post-NSF Fellow science beliefs were less positive (M = 41.71) than their pre-NSF Fellow beliefs (M = 41.96). Overall, interests in science were less positive post-NSF Fellow (M = 29.98) than pre-NSF-Fellow (M = 30.01). Overall, students held less positive post-Fellow beliefs about technology (M = 43.78) than their pre-NSF Fellow beliefs (M = 44.11), but students' post-NSF Fellow interests in technology were more positive (M = 31.56) than their pre-NSF Fellow interests (M = 30.33). Middle school students' overall post-NSF Fellow beliefs about math (M = 39.67) were more positive than their pre-NSF Fellow beliefs (M = 39.66), but post-NSF Fellow interest in math (M = 29.92) was less positive than pre-NSF Fellow interest (M = 29.96).

There were no engineering classes at the middle school level. Therefore, there are no results to report for engineering (Table 15).

Table 15
Cumulative Two-Year Descriptive Statistics for Middle School Students' STEM Beliefs and Interests (N = 1779)

	Science (n = 1225)		Technology (n = 82)		Math (n = 472)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Pre-Fellow STEM Beliefs	41.96	7.46	44.11	6.91	39.66	7.98
Post-Fellow STEM Beliefs	41.71	7.71	43.78	7.06	39.67	8.56
Pre-Fellow STEM Interests	30.01	4.55	30.33	4.20	29.96	4.68
Post-Fellow STEM Interests	29.98	4.68	31.56	4.51	29.92	4.97

Note. STEM Beliefs means for each subject ranged from: Science = 14-60; Technology = 26-60; and Math = 12-60. STEM Interests means for each subject ranged from: Science = 3-40; Technology = 20-40; and Math = 12-40.

Differences between Students Pre-and Post-NSF Fellow Beliefs and Interests

Paired samples t tests analyses indicated a statistically significant ($\alpha = 0.05$) difference between the means of pre-and post-NSF Fellow middle school students' beliefs for science in years one and two, but not for the cumulative two-years of the PEER project. Cohen's d (Cohen, 1977) indicated very small effect sizes for middle school students' change in beliefs year one (.10) and year two (.10).

Paired samples t test analyses indicated no statistically significant ($\alpha = 0.05$) difference between the means of pre-and post-NSF Fellow middle school students' science interests in years one, year two, or for the cumulative two-year data.

Paired samples t tests analyses indicated no statistically significant ($\alpha = 0.05$) difference between the means of pre-and post-NSF Fellow middle school students' mathematics beliefs or interests in years one, year two, or for the cumulative two-year data.

Paired samples t test analysis indicated a statistically significant ($\alpha = 0.05$) difference between middle school students' pre-and post-NSF Fellow technology interests in year one, the only year for which technology data were gathered. Cohen's *d* indicated a small effect size (.26) for middle school students' change in technology interest. Analyses indicated no statistically significant ($\alpha = 0.05$) difference between the means of pre-and post-NSF Fellow middle school students' technology beliefs in year one of the PEER project.

Paired samples *t* test analyses of middle school students' pre-and post-NSF Fellow data for all subjects and years indicated no statically significant ($\alpha = 0.05$) differences between pre-and post-NSF Fellow STEM beliefs or interests (Table 16).

Table 16

Paired Samples t tests for Science, Math, Technology, and All Subjects by Year and Cumulative Two-Year Data

Science		*df*	*M*[a]	*SD*	*d*[b]	*t*	Sig.
Year 1	Beliefs	842	.69	7.27	.10	2.75*	.01
	Interests	837	.02	4.93	.00	.09	.93
Year 2	Beliefs	380	-.70	6.82	.10	-2.01*	.04
	Interests	380	.02	4.42	.01	.10	.92
Cumulative	Beliefs	1223	.26	7.16	.04	.26	.21
	Interests	1218	.02	4.77	.00	.02	.90
Math							
2004-2005	Beliefs	218	.57	7.32	.08	1.15	.25
	Interests	218	-.17	5.31	.03	-.48	.63
2005-2006	Beliefs	252	-.51	8.41	.06	-.97	.33
	Interests	252	.24	5.32	.05	.71	.48
Cumulative	Beliefs	471	-.01	7.93	.00	-.03	.98
	Interests	471	.05	5.32	.01	.19	.85
Technology							
	Beliefs	81	.33	7.22	.05	.41	.68
	Interests	81	-1.23	4.76	.26	-2.34*	.02
Cumulative							
	Beliefs	1774	.19	7.37	.03	1.08	.28
	Interests	1772	-.03	4.93	.01	-.27	.78

Note. [a]Mean difference = post-response-pre-response. Scale: 1-5, where 1 = strongly disagree and 5 = strongly agree. [b]Cohen's measure of effect size (.20 = small, .50 = medium, .80 = large).

**p* < .05.

Objective One

Changes in STEM Beliefs by NSF Fellow

Changes in students' STEM beliefs from pre- to post-NSF Fellow were analyzed using the GLM repeated measures function of SPSS for NSF Fellow, grade level, gender, teacher, and subject to determine if these factors affected change in students' STEM beliefs and interests. Between subjects analysis indicated statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow differences in middle school students' mean STEM beliefs between NSF Fellows in years one, two, and two-year cumulative data. Within subjects analysis by NSF Fellow indicated no statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school student mean STEM beliefs in years one, year two, or the cumulative two years. Within subjects analysis indicated statistically significant ($\alpha = 0.05$) interaction effects between students' STEM beliefs and NSF Fellows for years one, two and, two-year cumulative data, indicating NSF Fellow had a statistically significant effect on the rate of change in middle school students' STEM beliefs (Table 17).

Table 17

Repeated Measures ANOVA for STEM Beliefs by NSF Fellow

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*N* = 1145)				
Between Subjects				
Intercept	1	32819.38	.97	.00
Fellow	8	22.32	.14	.00
Error(Beliefs)	1135	(84.69)		
Within Subjects				
Beliefs	1	.02	.00	.88
Beliefs*Fellow	8	4.75	.03	.00
Error(Beliefs)	1135	(25.73)		
Year 2: 2005– 2006 (*N = 634)*				
Between Subjects				
Intercept	1	23221.10*	.97	.00
Fellow	10	14.01*	.18	.00
Error(Beliefs)	623	(37.92)		
Within Subjects				
Beliefs	1	2.94	.01	.09
Beliefs*Fellow	10	4.14*	.06	.00
Error(Beliefs)	623	(26.71)		
Cumulative *(N = 1779)*				
Between Subjects				
Intercept	1	52845.87*	.97	.00
Fellow	16	19.88*	.15	.00
Error(Beliefs)	1761	(81.49)		
Within Subjects				
Beliefs	1	.48	.00	.49
Beliefs*Fellow	16	4.28*	.04	.00
Error(Beliefs)	1761	(26.37)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.

**p* < .05.

Changes in STEM Beliefs by Grade Level

Between subjects analyses indicated statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow differences in middle school students' mean beliefs between grade level for years one, two, and two-year cumulative data of the PEER project. Within subjects analyses by grade level indicated no statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school student mean STEM beliefs for years one, two, and two-year cumulative data. Within subjects analyses also indicated no statistically significant ($\alpha = 0.05$) interaction affect between grade level and middle school students' STEM beliefs for years one, two, and two-year cumulative data. Analyses indicated that even though there were significant differences in middle school students' mean STEM beliefs between the grade levels, grade level did not significantly ($\alpha = 0.05$) effect the rate at which middle school students' STEM beliefs changed (Table 18).

Table 18

Repeated Measures ANOVA for STEM Beliefs by Grade Level

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*n* = 1145)				
Between Subjects				
Intercept	1	6972.11*	.86	.00
Grade	3	57.07*	.13	.00
Error(Beliefs)	1139	(84.90)		
Within Subjects				
Beliefs	1	.61	.00	.44
Beliefs*Grade	3	.36	.00	.79
Error(Beliefs)	1139	(26.45)		
Year 2: 2005-2006 *(N = 634)*				
Between Subjects				
Intercept	1	1892.54*	.75	.00
Grade	3	13.06*	.06	.00
Error(Beliefs)	630	(86.48)		
Within Subjects				
Beliefs	1	.00	.00	.97
Beliefs*Grade	3	1.56	.01	.20
Error(Beliefs)	630	(27.96)		
Cumulative (*N* = 1779)				
Between Subjects				
Intercept	1	2396.61*	.57	.00
Grade	4	44.64*	.09	.00
Error(Beliefs)	1772	(86.85)		
Within Subjects				
Beliefs	1	.14	.00	.71
Beliefs*Grade	4	.21	.00	.93
Error(Beliefs)	1772	(27.20)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.
*p < .05.

Changes in STEM Beliefs by STEM Subject

Between subjects analyses indicated statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow differences in middle school students' mean beliefs between STEM subjects for years one, two, and two-year cumulative data of the PEER project. Within subjects analysis by STEM subject revealed no statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school student mean STEM beliefs for years one, two, or for the two-year cumulative data. Within subjects analysis indicated no statistically significant ($\alpha = 0.05$) interaction effect between STEM subjects and middle school students' STEM beliefs for years one, two, and two-year cumulative data. Analyses indicated that even though there were significant differences in middle school students' mean STEM beliefs between the STEM subjects, STEM subject does not significantly ($\alpha = 0.05$) affect the rate at which middle school students' STEM beliefs changed (Table 19).

Table 19

Repeated Measures ANOVA for STEM Beliefs by Subject

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*n* = 1145)				
Between Subjects				
Intercept	1	18189.29*	.94	.00
Subject	2	12.48*	.02	.00
Error(Beliefs)	1141	(95.41)		
Within Subjects				
Beliefs	1	2.66*	.00	.10
Beliefs*Subject	2	.10	.00	.90
Error(Beliefs)	1141	(26.44)		
Year 2: 2005-2006 *(N = 634)*				
Between Subjects				
Intercept	1	24217.42*	.97	.00
Subject	1	39.87*	.06	.00
Error(Beliefs)	632	(86.13)		
Within Subjects				
Beliefs	1	4.01	.01	.05
Beliefs*Subject	1	.10	.00	.76
Error(Beliefs)	632	(28.07)		
Cumulative *(N = 1779)*				
Between Subjects				
Intercept	1	22368.85*	.93	.00
Subject	2	23.51*	.03	.00
Error(Beliefs)	1775	(92.99)		
Within Subjects				
Beliefs	1	.40	.00	.53
Beliefs*Subject	2	.24	.00	.79
Error(Beliefs)	1775	(27.18)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.
*$p < .05$.

Changes in STEM Beliefs by Gender

Between subjects analysis indicated no statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow difference in middle school students' mean beliefs between gender for years one, two, or for the two-year cumulative data. Within subjects analysis by gender indicated no statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school student mean STEM beliefs for years one, two, or for the two-year cumulative data. Within subjects analysis indicated no statistically significant ($\alpha = 0.05$) interaction effect between gender and middle school students' STEM beliefs for years one, two, or the two-year cumulative data. Analyses indicated no significant difference between male and female middle school students' mean STEM beliefs, and that gender does not significantly ($\alpha = 0.05$) affect the rate at which middle school students' STEM beliefs changed (Table 20).

Table 20

Repeated Measures ANOVA for STEM Beliefs by Gender

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*n* = 1145)				
Between Subjects				
Intercept	1	16094.57*	.93	.00
Gender	2	1.13	.00	.32
Error(Beliefs)	1138	(97.29)		
Within Subjects				
Beliefs	1	1.31	.00	.25
Beliefs*Gender	2	.50	.00	.60
Error(Beliefs)	1138	(26.46)		
Year 2: 2005-2006 *(N = 634)*				
Between Subjects				
Intercept	1	23913.99*	.97	.00
Gender	1	.01	.00	.94
Error(Beliefs)	629	(91.61)		
Within Subjects				
Beliefs	1	3.83	.01	.05
Beliefs*Gender	1	1.67	.00	.20
Error(Beliefs)	630	(28.01)		
Cumulative (*N* = 1779)				
Between Subjects				
Intercept	1	17821.45*	.91	.00
Gender	2	1.50	.00	.22
Error(Beliefs)	1770	(95.29)		
Within Subjects				
Beliefs	1	.04	.00	.84
Beliefs*Gender	2	.38	.00	.69
Error(Beliefs)	1770	(27.19)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.
*$p < .05$.

Changes in STEM Beliefs by Teacher

Between subjects analysis indicated a statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow difference in middle school students' mean beliefs between teachers for years one, two, and the two-year cumulative data. Within subjects analysis by teacher indicated a statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school students' mean STEM beliefs in year one, but indicated no statistically significant ($\alpha = 0.05$) difference between students' mean STEM beliefs for either year two for the two-year cumulative data. Within subjects analysis indicated a statistically significant ($\alpha = 0.05$) interaction effect between teacher and middle school students' STEM beliefs for years one, two, and for the two-year data. Analyses indicated significant differences in middle school students' mean STEM beliefs between teachers, and that teachers affected the rate at which middle school student STEM beliefs changed (Table 21).

Table 21

Repeated Measures ANOVA for STEM Beliefs by Teacher

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*n* = 1145)				
Between Subjects				
Intercept	1	36862.08*	.97	.00
Teacher	1	10.04*	.01	.00
Error(Beliefs)	1142	(96.57)		
Within Subjects				
Beliefs	1	13.59*	.01	.00
Beliefs*Teacher	1	8.92	.01	.00
Error(Beliefs)	1142	(26.22)		
Year 2: 2005-2006 *(N = 634)*				
Between Subjects				
Intercept	1	23221.10*	.97	.00
Teacher	10	14.01*	.18	.00
Error(Beliefs)	623	(75.83)		
Within Subjects				
Beliefs	1	2.94	.00	.09
Beliefs*Teacher	10	4.14*	.06	.00
Error(Beliefs)	623	(26.71)		
Cumulative *(N = 1779)*				
Between Subjects				
Intercept	1	26977.22*	.94	.00
Teacher	12	11.11*	.07	.00
Error(Beliefs)	1765	(89.25)		
Within Subjects				
Beliefs	1	1.57	.00	.21
Beliefs*Teacher	12	5.26*	.03	.00
Error(Beliefs)	1765	(26.39)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.
*$p < .05$.

Changes in STEM Beliefs by NSF Fellow and Teacher

Repeated measures analysis indicated NSF Fellows and teachers affected the rate at which middle school students' STEM beliefs changed. Two-way repeated measures ANOVA on the multiple interaction effects of NSF Fellows and teacher were performed on students' STEM beliefs to determine the effect of NSF Fellow when teacher was present in the classroom.

Between subjects analysis indicated statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow difference in middle school students' mean beliefs between NSF Fellows, but not between teachers for the two-year cumulative data. Within subjects analysis by teacher and NSF Fellow indicated no statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school students' mean STEM beliefs for the two-year cumulative data. Within subjects analysis indicated a statistically significant ($\alpha = 0.05$) interaction effect between teacher and middle school students' STEM beliefs for the two-year data. A statistically significant interaction effect was also indicated between NSF Fellows and middle school students' STEM beliefs for the two-year data. When both teacher and NSF Fellow were present in the classroom, both had a significant affect on the rate at which middle school students' STEM beliefs changed (Table 22).

Table 22
Repeated Measures ANOVA for STEM Beliefs by NSF Fellow and Teacher

Source	*df*	*F*	η^2	*P*
Between Subjects				
Intercept	1	34534.20*	.95	.00
Teacher	4	1.44	.00	.22
Fellow	8	17.46*	.07	.00
Teacher*Fellow	4	5.28*	.01	.00
Error(Beliefs)	1753	(80.80)		
Within Subjects				
Beliefs	1	.44	.00	.51
Beliefs*Teacher	4	5.46*	.01	.00
Beliefs*Fellow	8	2.74*	.01	.01
Beliefs*Teacher*Fellow	4	5.56*	.01	.00
Error(Beliefs)	1753	(25.73)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.
**p* < .05.

Objective Two

Changes in STEM Interests by NSF Fellow

Changes in students' STEM interests from pre- to post-NSF Fellow were analyzed using the GLM repeated measures function of SPSS for NSF Fellow, grade level, gender, teacher, and subject to determine if these factors affected change in students' STEM interests. Between subjects analysis indicated statistically significant (α = 0.05) pre-and post-NSF Fellow differences in middle school students' mean STEM interests between NSF Fellows for years one, two, and the two-year cumulative data of the PEER project. Within subjects analysis by NSF Fellow indicated a statistically significant (α = 0.05) difference between pre-and post-NSF Fellow middle school students' mean STEM interests in year one, but not year two, or for the two-year cumulative data. Within subjects analysis indicated a statistically significant (α = 0.05) interaction effect between students' STEM interests and NSF Fellows for year one and for the two-year cumulative data, but not for year two. Overall, NSF Fellow significantly affected the rate of change in middle school students' STEM interests (Table 23)

Table 23
Repeated Measures ANOVA for STEM Interests by NSF Fellow

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*N* = 1145)				
Between Subjects				
Intercept	1	51085.91*	.98	.00
Fellow	8	24.91*	.15	.00
Error(Interests)	1130	(28.36)		
Within Subjects				
Interests	1	4.84*	.00	.03
Interests*Fellow	8	2.35	.02	.02
Error(Interests)	1130	(12.39)		
Year 2: 2005– 2006 *(N = 634)*				
Between Subjects				
Intercept	1	37399.13*	.98	.00
Fellow	10	3.27*	.05	.00
Error(Interests)	623	(25.69)		
Within Subjects				
Interests	1	.37	.00	.54
Interests*Fellow	10	1.52	.02	.13
Error(Interests)	623	(11.41)		
Cumulative *(N = 1779)*				
Between Subjects				
Intercept	1	83940.09*	.98	.00
Fellow	16	16.76*	.13	.00
Error(Interests)	1756	(27.49)		
Within Subjects				
Interests	1	.62*	.00	.43
Interests*Fellow	16	2.14*	.02	.01
Error(Interests)	1756	(12.02)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.
$*p < .05$.

Changes in STEM Interests by Grade Level

Between subjects analysis indicated statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow differences in middle school students' mean interests between grade level for years one, two, and two-year data of the PEER project. Within subjects analysis by grade level indicated no statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school students' mean STEM interests for years one, two, and two-year cumulative data. Within subjects analysis indicated a statistically significant ($\alpha = 0.05$) interaction affect between grade level and middle school students' STEM interests for year one, and the two-year cumulative data, but not for year two. Analyses indicated significant differences in middle school students' STEM interests between the grade levels, and grade level significantly ($\alpha = 0.05$) affected the rate at which middle school students' STEM interests changed (Table 24).

Table 24

Repeated Measures ANOVA for STEM Interests by Grade Level

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*N* = 1145)				
Between Subjects				
Intercept	1	10397.11*	.90	.00
Grade	3	68.51*	.15	.00
Error(Interests)	1134	(28.04)		
Within Subjects				
Interests	1	.00	.00	.97
Interests*Grade	3	5.39*	.01	.00
Error(Interests)	1134	(12.36)		
Year 2: 2004-2005 *(N = 634)*				
Between Subjects				
Intercept	1	3361.73*	.84	.00
Grade	3	3.64*	.02	.00
Error(Interests)	630	(26.28)		
Within Subjects				
Interests	1	.32	.00	.57
Interests*Grade	3	.96	.00	.41
Error(Interests)	630	(11.51)		
Between Subjects				
Intercept	1	1507.76*	.46	.00
Grade	4	18.25*	.04	.00
Error(Interests)	1767	(25.70)		
Within Subjects				
Interests	1	.34	.00	.56
Interests*Grade	4	3.50*	.01	.01
Error(Interests)	1767	(12.08)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.

*$p < .05$.

Changes in STEM Interests by STEM Subject

Between subjects analysis indicated statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow differences in middle school students' mean interests between STEM subjects for year one, and the cumulative two-year data, but not for year two. Within subjects analysis by STEM subject indicated a statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school students' mean STEM interests for year one, but not year two. Analysis of two-year cumulative data indicated a statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow difference in mean STEM interests overall. Within subjects analysis indicated no statistically significant ($\alpha = 0.05$) interaction effect between STEM subjects and middle school students' STEM interests for years one, two, and two-year data. STEM subject does not significantly ($\alpha = 0.05$) affect the rate at which middle school students' STEM interests changed (Table 25).

Table 25

Repeated Measures ANOVA for STEM Interests by STEM Subject

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*N = 1145*)				
Between Subjects				
Intercept	1	27344.61	.96	.00
Subject	2	4.88	.01	.01
Error(Interests)	1136	(32.91)		
Within Subjects				
Interests	1	4.31	.00	.04
Interests*Subject	2	2.35	.00	.10
Error(Interests)	1136	(12.47)		
Year 2: 2004-2005 *(N = 634)*				
Between Subjects				
Intercept	1	43321.83	.99	.00
Subject	1	3.96	.01	.05
Error(Interests)	632	(26.48)		
Within Subjects				
Interests	1	.45	.00	.50
Interests*Subject	1	.30	.00	.58
Error(Interests)	632	(11.52)		
Cumulative *(N = 1779)*				
Between Subjects				
Intercept	1	14043.31	.89	.00
Subject	2	35.24	.04	.00
Error(Interests)	1770	(25.70)		
Within Subjects				
Interests	1	3.71	.00	.05
Interests*Subject	2	2.56	.00	.08
Error(Interests)	1770	(12.12)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.
$*p < .05$.

Changes in STEM Interests by Gender

Between subjects analysis indicated no statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow difference in middle school students' mean interests between genders for years one and two. A statistically significant difference in STEM interests was indicated by gender for the two-year cumulative data. Within subjects analysis by gender indicated a statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school students' mean STEM interests for years one, two, or for the two-year cumulative data. Within subjects analysis indicated no statistically significant ($\alpha = 0.05$) interaction affect between gender and middle school students' STEM interests for years one, two, or the two-year cumulative data. Analyses indicated that even though there were significant differences between male and female middle school students' STEM interests for the cumulative two-year data, gender did not significantly ($\alpha = 0.05$) affect the rate at which middle school students' STEM interests changed (Table 26).

Table 26

Repeated Measures ANOVA for STEM Interests by Gender

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*N = 1145*)				
Between Subjects				
Intercept	1	24583.88*	.96	.00
Gender	2	1.26	.00	.28
Error(Interests)	1133	(33.15)		
Within Subjects				
Interests	1	2.90	.00	.09
Interests*Gender	2	1.67	.00	.19
Error(Interests)	1133	(12.50)		
Year 2: 2004-2005 *(N = 634)*				
Between Subjects				
Intercept	1	44581.59*	.99	.00
Gender	1	.99	.00	.32
Error(Interests)	630	(13.36)		
Within Subjects				
Interests	1	.45	.00	.50
Interests*Gender	1	.07	.00	.79
Error(Interests)	630	(11.52)		
Between Subjects				
Intercept	1	28538.39*	.94	.00
Gender	2	3.33*	.00	.04
Error(Interests)	1765	(31.36)		
Within Subjects				
Interests	1	2.53	.00	.11
Interests*Gender	2	1.90	.00	.15
Error(Interests)	1765	(12.14)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.
$*p < .05$.

Changes in STEM Interests by Teacher

Between subjects analyses indicated a statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow difference in middle school students' mean interests between teachers for years one, two, and the cumulative two-year data. Within subjects analyses by teacher indicated a statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school students' mean STEM interests for years one, two, or for the two-year cumulative data. Within subjects analyses indicated a statistically significant ($\alpha = 0.05$) interaction effect between teacher and middle school students' STEM interests for years one and for the two-year cumulative data, but not year two of the PEER project. Analyses indicated significant differences in middle school students' STEM interests between the grade levels, and teachers affected the rate at which middle school students' STEM interests changed (Table 27).

Table 27

Repeated Measures ANOVA for STEM Interests by Teacher

Source	*df*	*F*	η^2	*P*
Year 1: 2004-2005 (*N = 1145*)				
Between Subjects				
Intercept	1	56427.48*	.98	.00
Teacher	1	22.40*	.02	.00
Error(Interests)	1137	(32.52)		
Within Subjects				
Interests	1	.00*	.00	.97
Interests*Teacher	1	7.92	.01	.00
Error(Interests)	1137	(12.43)		
Year 2: 2004-2005 *(N = 634)*				
Between Subjects				
Intercept	1	37399.13*	.98	.00
Teacher	10	3.27*	.05	.00
Error(Interests)	623	(25.69)		
Within Subjects				
Interests	1	.37	.00	.54
Interests*Teacher	10	1.52	.02	.13
Error(Interests)	623	(11.41)		
Cumulative *(N = 1779)*				
Between Subjects				
Intercept	1	34053.05*	.95	.00
Teacher	12	111.62*	.41	.00
Error(Interests)	1760	(15.82)		
Within Subjects				
Interests	1	.35	.00	.55
Interests*Teacher	12	1.94*	.01	.03
Error(Interests)	1760	(12.07)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.

*$p < .05$.

Changes in STEM Interests by NSF Fellow, Grade Level, and Teacher

Analyses indicated NSF Fellows, grade level, and teachers affected the rate at which middle school students' STEM interests changed. Repeated measures ANOVA on the multiple interaction effects of NSF Fellows, grade level, and teacher were performed on middle school students' STEM interests.

Between subjects analysis indicated a statistically significant ($\alpha = 0.05$) pre-and post-NSF Fellow difference in middle school students' mean interests between NSF Fellows and grade level, but not between teachers for the two-year cumulative data. Within subjects analysis by teacher, grade level, and NSF Fellow indicated no statistically significant ($\alpha = 0.05$) difference between pre-and post-NSF Fellow middle school students' mean STEM interests for the two-year cumulative data. Within subjects analysis indicated a statistically significant ($\alpha = 0.05$) interaction effect by teacher and by NSF Fellow on middle school students' STEM interests for the cumulative two-year data, but not by grade level. When teacher, grade level, and NSF Fellow were present in the classroom, NSF Fellow and teacher affected the rate at which middle school students' STEM interests changed, but not grade level (Table 28).

Table 28
Repeated Measures ANOVA for STEM Interests by NSF Fellow, Grade Level, and Teacher

Source	*df*	*F*	η^2	*P*
Between Subjects				
Intercept	1	8768.79*	.84	.00
Teacher	4	1.05	.00	.38
Fellow	8	2.90*	.01	.01
Grade	4	4.35	.00	.01
Teacher*Grade	0		.00	
Teacher*Fellow	0		.00	
Grade*NSF Fellow	0		.00	
Teacher*Grade*NSF Fellow	0		.00	
Error(Interests)	1732	(26.50)		
Within Subjects				
Interests	1	.01	.00	.91
Interests*Teacher	4	2.60	.01	.03
Interests*Fellow	8	2.65	.01	.01
Interests*Grade	4	.89	.00	.47
Interests*Teacher*Grade	0		.00	
Interests*Teacher*Fellow	0		.00	
Interests*Grade*NSF Fellow	0		.00	
Interests*Teacher*Grade*NSF Fellow	0		.00	
Error(Interests)	1732	(11.94)		

Note. Values enclosed in parenthesis represent mean square errors. Matched pre-/post-NSF Fellow student attitudinal data were not obtained from all NSF Fellows.
*$p < .05$.

Objective Three

Demographics for RTOP Data

Members of the evaluation team observed NSF Fellows in middle school classrooms. Observations were for one class period in length, and occurred multiple times throughout each semester. The evaluator was an observer only and scored the classroom environment after the class period was completed. Two-year RTOP data were collected from 139 RTOP observations conducted on 22 NSF Fellows in math and science classrooms, representing 18 lead teachers, 24 other teachers, and 11 schools.

Fifty (36%) observations were conducted during the 2004-2005 school-year and 89 (64%) were conducted during the 2005-2006 school-year: 78 (56.1%) observations were conducted in science classrooms. Sixty-six (47.5%) observations were conducted during Fall semester and 73 (52.5%) observations were conducted during Spring semester, with 77 (55.4%) occurring as announced RTOP observations.

One-hundred and twelve (80.6%) RTOP observations were conducted in the classrooms of the lead teachers. Fifty-five (39.6%) observations were conducted in 6th grade classrooms, 44 (31.7%) in 7th grade classrooms, 30 (21.6%) in 8th grade classrooms, 2 (1.4%) in combined 6th and 7th grade classrooms, and 8 (5.7%) RTOP observations were conducted in non-junior high school classrooms. Seventy-eight (56.1%) observations were conducted on female NSF Fellows.

Year one data were collected from 14 NSF Fellows in math and science classrooms, representing 15 teachers and 9 schools. Thirteen (26%) observations were collected in Fall 2004 and 37 (74%) observations were collected in Spring 2005. Observations were conducted by four members of the evaluation team with 38 (76%) RTOP observations being announced. Intra-class correlation two-way mixed model for agreement (Shrout & Fleiss, 1979) was used to determine inter-rater reliability (.89) between evaluators.

Forty-three (86%) of the year one observations were conducted in the classrooms of lead teachers. Twenty-three (46%) observations were conducted in 6th grade classrooms, 17 (34%) in 7th grade classrooms, six (12%) in 8th grade classrooms, 2 (4%) in combined 6th and 7th grade classrooms, and 2 were in non-middle school classrooms (4%). Thirty-two (64%) observations were conducted in science classrooms, and 35 (70%) observations were conducted on female NSF Fellows.

Year two data were collected from 89 RTOP observations conducted on 14 NSF Fellows in math and science classrooms, representing 24 teachers and 8 schools. Fifty-three observations (59.6%) were collected in Fall 2005. Observations were conducted by two- of the four-member evaluation team with 50 (56.2%) unannounced RTOP observations. Intra-class correlation two-way mixed model for agreement (Shrout & Fleiss, 1979) was used to determine inter-rater reliability (.85) between evaluators.

Sixty-nine (77.5%) year two observations were conducted in the classrooms of lead teachers. Thirty-two (36%) observations were conducted in 6th grade classrooms, 27 (30.3%) were in 7th grade classrooms, 24 (27%) were in 8th grade classrooms, 6 (6.6%) were in non-middle school classrooms. Forty-six (51.7%) observations were conducted in science classrooms. Fifty-three (59.6%) RTOP observations were conducted in Spring 2005. Forty-six (51.7%) observations were conducted on male NSF Fellows (Table 29).

Table 29
Demographics for RTOP Observations (N=139)

Variables		2004-2005		2005-2006		Cumulative	
		f	Percent	*f*	Percent	*f*	Percent
Year	2004-2005					50	36.0
	2005-2006					89	64.0
Grade	6th & 7th	2	4.0			2	1.4
	3rd			1	1.1	1	.7
	4th			2	2.2	2	1.4
	5th	1	2.0	2	2.2	3	2.2
	6th	23	46.0	32	36.0	55	39.6
	7th	17	34.0	27	30.3	44	31.7
	8th	6	12.0	24	27.0	30	21.6
	9th	1	2.0	1	1.1	2	1.4
Visits	Announced	38	76.0	39	43.8	77	55.4
	Unannounced	12	24.0	50	56.2	62	44.6
Semester	Fall	13	26.0	53	59.6	66	47.5
	Spring	37	74.0	36	40.4	73	52.5
Observers	1	27	54.0	73	82.0	100	71.9
	2	15	30.0	16	18.0	31	22.3
	3	6	12.0	--	--	6	4.3
	4	2	4.0	--	--	2	1.4
Subject	Math	18	36.0	43	48.3	61	43.9
	Science	32	64.0	46	51.7	78	56.1
Teacher	Lead	43	86.0	69	77.5	112	80.6
	Other	7	14.0	20	22.5	27	19.4
School	1	8	16.0	14	15.7	22	15.8
	2	4	8.0	11	12.4	15	10.8
	3	5	10.0	14	15.7	19	13.7
	4	5	10.0			5	3.6
	5	9	18.0	8	9.0	17	12.2
	6	3	6.0	13	14.6	16	11.5
	7	6	12.0	7	7.9	13	9.4
	8	2	4.0	9	10.1	11	7.9
	10	8	16.0			8	5.8
	11			13	14.6	13	9.4

Table 29 (continued)

Variables		2004-2005 *f*	2004-2005 Percent	2005-2006 *f*	2005-2006 Percent	Cumulative *f*	Cumulative Percent
Fellow	1[a]	3	6.0	7	7.9	10	7.2
	2[a]	6	12.0	7	7.9	13	9.4
	3[a]	4	8.0	7	7.9	11	7.9
	4	4	8.0			4	2.9
	5	3	6.0			3	2.2
	6[a]	4	8.0	7	7.9	11	7.9
	7	4	8.0			4	2.9
	8	2	4.0			2	1.4
	9	4	8.0			4	2.9
	10	3	6.0			3	2.2
	11	5	10.0			5	3.6
	12	1	2.0			1	.7
	13[a]	4	8.0	7	7.9	11	7.9
	14[a]	3	6.0	4	4.5	7	5.0
	15			7	7.9	7	5.0
	16			7	7.9	7	5.0
	17			7	7.9	7	5.0
	18			7	7.9	7	5.0
	19			7	7.9	7	5.0
	20			7	7.9	7	5.0
	21			1	1.1	1	.7
	22			7	7.9	7	5.0
Fellow Gender							
	Female	35	70.0	43	48.3	78	56.1
	Male	15	30.0	46	51.7	61	43.9

Note. [a] Indicates NSF Fellows who participated both in 2004-2005 and 2005-2006.

Significant Differences in Mean RTOP Scores by Semester, Teacher, Subject, Observation, and NSF Fellows' Gender

Cumulative Two-Year RTOP Data. Cumulative two-year RTOP data were analyzed from RTOP observations with two or more observations ($N = 137$) during the 2004-2005 and 2005-2006 school years. Independent samples t tests were used to determine if significant differences in mean RTOP scores existed by semester, lead versus other teacher, subject, announced versus unannounced observation, or gender of NSF Fellow. Analysis of cumulative data indicated Spring semester RTOP scores (M = 68.26) were statistically significantly ($\alpha = 0.05$) higher than Fall RTOP scores (M = 59.23). Cohen's d (Cohen, 1977) indicated a medium effect size (d = .50) for RTOP score differences between semesters. Independent t tests analysis indicated no statistically significant difference ($\alpha = 0.05$) in mean RTOP scores between teachers, subjects, type of observation, or NSF Fellow gender (Table 30).

Table 30
Cumulative Two-Year RTOP Data Independent t tests by Semester, Teacher, Subject, Observation, and NSF Fellows' Gender

RTOP Observations		n	M	SD	d^a	t	Sig.
Semester	Fall	65	59.23	17.91	.50	-3.21*	.00
	Spring	72	68.26	14.68			
Teacher	Lead	110	63.38	16.59	.17	-.80	.43
	Other	27	66.41	17.97			
Subject	Math	60	62.92	16.43	.11	-.65	.51
	Science	77	64.81	17.23			
Observation	Announced	75	64.37	16.48	.05	.30	.77
	Unannounced	62	63.50	17.41			
Fellow Gender	Female	76	65.32	15.62	.17	-1.02	.31
	Male	61	62.31	18.26			

Note. [a] Cohen's measure of effect size (.20 = small, .50 = medium, .80 = large).
*p < .05.

Year 1: 2004-2005 RTOP Data. Year one data were analyzed from RTOP observations with two or more observations (N = 49) during the 2004-2005 school-year. Independent samples t tests were used to determine if significant differences in mean RTOP scores existed by semester, lead versus other teacher, subject, announced versus unannounced observation, or gender of NSF Fellow. Analysis indicated Spring semester RTOP scores (*M* = 67.61) were statistically significantly (α = 0.05) higher than Fall RTOP scores (*M* = 50.31). Cohen's *d* (Cohen, 1977) indicated a large effect size (*d* = .90) for year one difference between semester RTOP scores. Independent samples *t* tests indicated no statistically significant difference (α = 0.05) in mean RTOP scores between teachers, subjects, type of observation, or NSF Fellow gender (Table 31).

Table 31
Year 1: 2004-2005 RTOP Data Independent t tests by Semester, Teacher, Subject, Observation, and NSF Fellows' Gender

RTOP Observations		*n*	*M*	*SD*	*d*[a]	*t*	Sig.
Semester	Fall 2004	13	50.31	19.23	.90	-2.90*	.01
	Spring 2005	36	67.61	16.12			
Teacher	Lead	42	62.93	18.65	.03	-.08	.94
	Other	7	63.57	18.83			
Subject	Math	18	62.33	15.76	.05	-.21	.84
	Science	31	63.42	20.13			
Observation	Announced	37	66.00	17.28	.62	1.91	.07
	Unannounced	12	53.83	19.78			
Fellow Gender	Female	34	63.85	16.74	.12	.42	.68
	Male	15	61.13	22.46			

Note. [a] Cohen's measure of effect size (.20 = small, .50 = medium, .80 = large).
*$p < .05$.

Year 2: 2005-2006 RTOP Data. Year two data were analyzed from RTOP observations with two or more observations (*N* = 88) during the 2005-2006 school-year. Independent samples *t* tests were used to determine if significant differences in mean RTOP scores existed by semester, lead versus other teacher, subject, announced versus unannounced observation, or gender of NSF Fellow. Analysis indicated Spring semester

RTOP scores (*M* = 68.92) were statistically significantly (α = 0.05) higher than Fall RTOP scores (*M* = 61.46). Cohen's *d* (Cohen, 1977) indicated only a small effect size (*d* = .44) for year two RTOP score difference by semester. Independent samples *t* tests indicated no statistically significant difference (α = 0.05) in mean RTOP scores between teachers, subject, type of observation, or NSF Fellow gender (Table 32).

Table 32
Year 2: 2005-2006 RTOP Data Independent Samples t tests by Semester, Teacher, Subject, Observation, and NSF Fellows' Gender

RTOP Observations		*n*	*M*	*SD*	d^a	*t*	Sig.
Semester	Fall 2005	52	61.46	17.03	.44	-2.30*	.02
	Spring 2006	36	68.92	13.29			
Teacher	Lead	68	63.66	15.33	.21	-.84	.41
	Other	20	67.40	18.05			
Subject	Math	42	63.17	16.89	.15	-.75	.46
	Science	46	65.74	15.14			
Observation	Announced	38	62.79	15.74	.19	-.88	.38
	Unannounced	50	65.82	16.15			
Fellow Gender	Female	42	66.50	14.74	.22	1.13	.26
	Male	46	62.70	16.95			

Note. [a] Cohen's measure of effect size (.20 = small, .50 = medium, .80 = large).
*$p < .05$.

Significant Differences in Mean RTOP Scores by NSF Fellow, Grade Level, and Location

Cumulative Two-Year RTOP Data. Two-year RTOP data for all NSF Fellows with two or more observations were analyzed using the Univariate GLM to determine if statistically significant differences existed in mean RTOP scores between NSF Fellows, grade level, and location. Analysis indicated a statistically significant difference (α = .05) between mean RTOP scores when compared by NSF Fellow. Bonferroni post-hoc analysis indicated a significant difference (α = .05) between the RTOP means of NSF Fellows 9 and 2, 3, 6, 10, and 13. Bonferroni post-hoc analysis also indicated a significant difference (α = .05) between the RTOP means of NSF Fellows 13 and 7. Analysis indicated no other statistically significant differences (α = .05) between RTOP means of NSF Fellows. Analysis indicated no statistically significant differences (α = 0.05) between RTOP means when compared by grade level, or teacher (Table 33).

Year 1: 2004-2005 RTOP Data. Univariate ANOVA was used to analyze year one RTOP scores for all NSF Fellows with two or more observations by the variables NSF Fellow, grade level, and location. Analyses indicated a statistically significant difference (α = .05) between mean RTOP scores when compared by NSF Fellow. Bonferroni post-hoc analysis indicated a significant difference (α = .05) between the RTOP means of NSF Fellows 9 and 10, 13, and 14. Analyses indicated no other statistically significant differences (α = .05) between RTOP means of NSF Fellows. Analyses indicated no statistically significant differences (α = 0.05) between RTOP means when compared by grade level, or teacher (Table 34).

Table 33

Cumulative One-way ANOVA

RTOP Observations		*n*	*M*	*SD*	η^2	*F*	Sig.
Fellow	1[a]	10	62.20	17.07	.25	2.02*	.01
	2[a]	13	71.85	14.14			
	3[a]	11	68.91	12.06			
	4	4	60.25	23.33			
	5	3	63.67	2.08			
	6[a]	11	68.82	15.72			
	7	4	44.75	9.00			
	8	2	71.00	2.83			
	9	4	33.75	9.03			
	10	3	79.67	5.77			
	11	5	57.80	17.82			
	13[a]	11	73.82	10.57			
	14[a]	7	62.29	22.19			
	15	7	68.00	10.97			
	16	7	61.57	19.80			
	17	7	63.57	13.32			
	18	7	64.00	21.17			
	19	7	59.86	19.04			
	20	7	60.43	14.29			
	22	7	55.43	19.81			
Grade	6th & 7th	2	71.00	2.83	.08	1.50	.17
	3rd	1	63.00	.			
	4th	2	77.00	7.07			
	5th	2	59.00	12.73			
	6th	55	68.73	14.65			
	7th	44	59.50	18.18			
	8th	29	61.17	17.89			
	9th	2	58.00	26.87			
Location	1	22	61.36	16.55	.11	1.77	.08
	2	15	63.87	15.46			
	3	18	74.56	9.54			
	4	5	73.40	16.01			
	5	16	61.13	19.51			
	6	16	58.44	17.32			
	7	13	67.69	14.38			
	8	11	62.64	17.05			
	9	8	53.50	22.48			
	11	13	64.46	17.07			

Note: [a] Indicates NSF Fellows who participated both 2004-2005 and 2005-2006.

$*p < .05$.

Table 34

Year One: 2004-2005 One-way ANOVA

RTOP Observations		*n*	*M*	*SD*	η^2	*F*	*Sig.*
Fellow	1 [a]	3	51.67	24.91	.51	3.16*	.00
	2 [a]	6	67.33	18.76			
	3 [a]	4	72.25	8.58			
	4	4	60.25	23.33			
	5	3	63.67	2.08			
	6 [a]	4	70.50	10.91			
	7	4	44.75	9.00			
	8	2	71.00	2.83			
	9	4	33.75	9.03			
	10	3	79.67	5.77			
	11	5	57.80	17.82			
	13 [a]	4	76.50	8.58			
	14 [a]	3	78.67	18.77			
Grade	6^{th} & 7^{th}	2	71.00	2.83	.09	1.12	.36
	5^{th}	23					
	6^{th}	17	67.35	15.27			
	7^{th}	6	58.65	22.21			
	8^{th}	1	60.17	19.24			
	9^{th}	2	39.00	.			
Location	1	8	60.75	18.74	.21	1.31	.27
	2	4	72.25	8.58			
	3	4	76.50	8.58			
	4	5	73.40	16.01			
	5	9	58.89	19.09			
	6	3	63.67	2.08			
	7	6	67.33	18.76			
	8	2	43.50	28.99			
	9	8	53.50	22.48			

Note: [a] Indicates NSF Fellows who participated both 2004-2005 and 2005-2006.
*$p < .05$.

Year 2: 2005-2006 RTOP Data. Univariate ANOVA was used to analyze year two RTOP for all NSF Fellows with two or more observations scores by NSF Fellow, grade level, and location. Analysis indicated no statistically significant difference (α = .05) between mean RTOP scores when compared by NSF Fellow, grade level, or teacher (Table 35).

Table 35
Year Two: 2005-2006 One-way ANOVA

RTOP Observations		*n*	*M*	*SD*	η^2	*F*	*Sig.*
Fellow	1 [a]	7	66.71	12.28	.15	1.09	.38
	2 [a]	7	75.71	8.30			
	3 [a]	7	67.00	13.93			
	6 [a]	7	67.86	18.69			
	13 [a]	7	72.29	11.91			
	14 [a]	4	50.00	16.75			
	15	7	68.00	10.97			
	16	7	61.57	19.80			
	17	7	63.57	13.32			
	18	7	64.00	21.17			
	19	7	59.86	19.04			
	20	7	60.43	14.29			
	22	7	55.43	19.81			
Grade	3rd	1	63.00		.10	1.46	.20
	4th	2	77.00	7.07			
	5th	2	59.00	12.73			
	6th	32	69.72	14.35			
	7th	27	60.04	15.56			
	8th	23	61.43	17.97			
	9th	1	77.00				
Location	1	14	61.71	15.90	.11	1.35	.24
	2	11	60.82	16.56			
	3	14	74.00	10.02			
	5	7	64.00	21.17			
	6	13	57.23	19.13			
	7	7	68.00	10.97			
	8	9	66.89	12.10			
	11	13	64.46	17.07			

Note: [a] Indicates NSF Fellows who participated both 2004-2005 and 2005-2006.
$*p < .05$.

Correlation Analysis of RTOP Construct One: Lesson Design and Implementation and NSF Fellow

Pearson's product moment correlation analyses were used to determine if associations existed between NSF Fellows and five statements comprising Construct One: *Lesson Design and Implementation* of the RTOP instrument. A one-tailed test of significance was used as the literature indicated NSF Fellows should have a positive influence on classroom inquiry levels. Significance levels were set *a priori* at $\alpha = 0.05$. Analyses revealed no significant associations between NSF Fellows and RTOP Construct One: *Lesson Design and Implementation.* A significant substantial negative association ($r = -.51$) (Davis, 1971) existed between NSF Fellows and *The lesson was designed to engage students as members of a learning community*. NSF Fellows had a negative effect on lessons being designed to engage students as members of a learning community.

Several significant associations were indicated between RTOP statements and Construct One, as well as between individual RTOP statements. These associations were expected as the statements comprise Construct One and are measures of this construct (Table 36).

Table 36

Pearson r Correlations for RTOP Construct One: Lesson Design and Implementation and NSF Fellow

	RTOP Statements					
	1	2	3	4	5	Construct One
NSF Fellow	-.24	-.51*	.28	.02	.20	-.07
1. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.		.31	-.09	.11	.49*	.61*
2. The lesson was designed to engage students as members of a learning community.			.12	.46*	.26	.62*
3. In this lesson, student exploration preceded formal presentation.				.43*	.28	.46*
4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.					.68*	.78*
5. The focus and direction of the lesson was often determined by ideas originating with students						.85*
Construct 1: *Lesson Design and Implementation*						—

*$p < 0.05$ (1-tailed).

Correlation Analysis of RTOP Construct Two: Propositional Knowledge and NSF Fellow

Pearson's product moment correlation analyses were used to determine if relationships existed between NSF Fellows and five statements comprising Construct Two: *Propositional Knowledge* of the RTOP instrument. A one-tailed test of significance was used as the literature indicated NSF Fellows should have a positive influence on classroom inquiry levels. Significance levels were set *a priori* at $\alpha = 0.05$.

Analyses indicated a significant moderate negative association (*r* = -.40) existed between NSF Fellows and RTOP Construct Two: *Propositional Knowledge.*

A significant substantial negative association (Davis, 1971) existed between NSF Fellows and statement six, *The lesson involved fundamental concepts of the subject* (*r* = -.53). A significant moderate negative association existed between NSF Fellows and statements seven, *The lesson promoted strongly conceptual understanding* (*r* = -.44); and statement nine, *Elements of abstraction (i.e. symbolic representations, theory building) were encouraged when it was important to do so* (*r* = -.48). Analyses indicated NSF Fellows had a negative effect on the lesson promoting conceptual understanding, encouraging elements of abstraction, and involving fundamental concepts of the subject.

Several significant associations were indicated between RTOP statements and Construct Two, as well as between individual RTOP statements. These associations were expected as the statements comprise Construct Two and are measures of this construct (Table 37).

Table 37
Pearson r Correlations for RTOP Construct Two: Propositional Knowledge and NSF Fellow

	RTOP Statements					
	6	7	8	9	10	Construct Two
Fellow	-.53*	-.44*	.17	-.48*	.12	-.40*
6. The lesson involved fundamental concepts of the subject.		.41*	.14	.29	-.21	.42*
7. The lesson promoted strongly conceptual understanding.			.16	.74*	.19	.82*
8. The teacher had a solid grasp of the subject matter content inherent in the lesson.				.07	.15	.32
9. Elements of abstraction (i.e. symbolic representations, theory building) were encouraged when it was important to do so.					.25	.86*
10. Connections with other content disciplines and/or real world phenomena were explored and valued.						.54*
Construct 2: *Propositional Knowledge*						—

*$p < 0.05$ (1-tailed).

Correlation Analysis of RTOP Construct Three: Procedural Knowledge and NSF Fellow

Pearson's product moment correlation analyses were used to determine if relationships existed between NSF Fellows and five statements comprising Construct Three: *Procedural Knowledge* of the RTOP instrument. A one-tailed test of significance was used as the literature indicated NSF Fellows should have a positive influence on classroom inquiry levels. Significance levels were set *a priori* at $\alpha = 0.05$. No significant association existed between NSF Fellows and Construct Three: *Procedural Knowledge,* or any of the five statements comprising Construct Three. NSF Fellows had no significant effect on intellectual rigor, or constructive criticism, and the challenging of ideas being valued; middle school students' using a variety of means to represent phenomena; using predictions, estimations and/or hypotheses and devising means for testing them; being actively engaged in thought-provoking activity involving the critical assessment of procedures; or being reflective about their learning.

Several significant associations were indicated between RTOP statements and Construct Three, as well as between individual RTOP statements. These associations were expected as the statements comprise Construct Three and are measures of this construct (Table 38).

Table 38
Pearson r Correlations for RTOP Construct Three: Procedural Knowledge and NSF Fellow

	RTOP Statements					
	11	12	13	14	15	Construct Three
Fellow	-.38	-.14	.15	-.14	.28	-.10
11. Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.		.56*	.20	.06	-.15	.57*
12. Students made predictions, estimations and/or hypotheses and devised means for testing them.			.50*	.32	.15	.80*
13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.				.37	.35	.73*
14. Students were reflective about their learning.					.56*	.66*
15. Intellectual rigor, or constructive criticism, and the challenging of ideas were valued.						.52*
Construct 3: *Procedural Knowledge*						—

*$p < 0.05$ (1-tailed).

Correlation Analysis of RTOP Construct Four: Communicative Interactions and NSF Fellow

Pearson's product moment correlation analyses were used to determine if relationships existed between NSF Fellows and five statements comprising Construct Four: *Communicative Interactions* of the RTOP instrument. A one-tailed test of significance was used as the literature indicated NSF Fellows should have a positive influence on classroom inquiry. Significance levels were set *a priori* at $\alpha = 0.05$. No significant association existed between NSF Fellows and Construct Four: *Communicative Interactions,* or any of the five statements comprising Construct Four. NSF Fellows had no significant effect on involving middle school students in the communication of their ideas to others using a variety of means and media; the teacher's questions triggering divergent modes of thinking; a classroom environment with a high proportion of student talk, especially between and among students; student questions and comments determining the focus and direction of classroom discourse; or fostering a climate of respect for what others have to say.

Several significant associations were indicated between RTOP statements and Construct Four as well as between individual RTOP statements. These associations were expected as the statements comprise Construct Four and are measures of this construct (Table 39).

Table 39

Pearson r Correlations for RTOP Construct Four Communicative Interactions and NSF Fellow

	RTOP Statements					
	16	17	18	19	20	Construct Four
Fellow	.04	-.19	.12	.31	.10	.11
16. Students were involved in the communication of their ideas to others using a variety of means and media.		.20	.71*	.25	.55*	.80*
17. The teacher's questions triggered divergent modes of thinking.			-.10	.62*	.12	.59*
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.				-.15	.25	.48*
19. Student questions and comments often determined the focus and direction of classroom discourse.					.41*	.68*
20. There was a climate of respect for what others had to say.						.72*
Construct 4: *Communicative Interactions*						—

*$p < 0.05$ (1-tailed).

Correlation Analysis of RTOP Construct Five: Student/Teacher Relationships and NSF Fellow

Pearson's product moment correlation analyses were used to determine if relationships existed between NSF Fellows and five statements comprising Construct Five: *Student/Teacher Relationships* of the RTOP instrument. A one-tailed test of significance was used as the literature indicates NSF Fellows should have a positive influence on classroom inquiry levels. Significance levels were set *a priori* at $\alpha = 0.05$. Analyses indicated no significant association existed between NSF Fellows and RTOP Construct Five: *Student/Teacher Relationships.* A significant moderate positive association (Davis, 1971) existed between NSF Fellows and statement 25, *The metaphor "teacher as listener" was very characteristic of this classroom* ($r = .47$).

NSF Fellows had a positive effect on the "teacher as listener" being very characteristic of the classroom. Several significant associations were indicated between RTOP statements and Construct Five as well as between individual RTOP statements. These associations were expected as the statements comprise Construct Five and are measures of this construct (Table 40).

Table 40

Pearson r Correlations for RTOP Construct Five Student/Teacher Relationships and NSF Fellow

	RTOP Statements					Construct Five
	21	22	23	24	25	
Fellow	.22	.20	.15	.24	.47*	.32
21. Active participation of students was encouraged and valued.		.55*	.51*	.74*	.56*	.79*
22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.			.49*	.54*	.62*	.78*
23. In general the teacher was patient with students.				.69*	.69*	.82*
24. The teacher acted as a resource person, working to support and enhance student investigations.					.70*	.88*
25. The metaphor "teacher as listener" was very characteristic of this classroom.						.87*
Construct 5: *Student/Teacher Relationships*						—

*$p < 0.05$ (1-tailed).

Correlations for RTOP Constructs, Cumulative Scores, and NSF Fellows

Pearson's product moment correlation analyses indicated a significant moderate negative association ($r = -.40$) (Davis, 1971) between NSF Fellow and Construct Two: *Propositional Knowledge*. No significant association between NSF Fellow and any of the remaining five constructs or cumulative RTOP scores were indicated.

Analyses indicated very strong positive associations between cumulative RTOP scores and four of the RTOP Constructs: *Lesson Design and Implementation* ($r = .77$);

Procedural Knowledge (r = .74); *Communicative Interactions*(r = .91); and *Student/Teacher Relationships* (r = .94). Analyses indicated a significant moderate positive relationship between construct two *Propositional Knowledge* and cumulative RTOP scores (r = .49). Analyses indicated the only construct with a significant association with NSF Fellow also had a negative moderate association (r = -.40) with cumulative RTOP scores. Analyses also indicated several significant associations between the five constructs comprising cumulative RTOP scores, which was expected as these constructs were measures of the same element (Table 41).

Table 41
Pearson r Correlations for RTOP Constructs, Cumulative Scores, and NSF Fellows

	RTOP Constructs					
	1	2	3	4	5	RTOP Cumulative
Fellow	-.07	-.40*	-.10	.11	.32	.00
Construct 1		.12	.51*	.62*	.71*	.77*
Construct 2			.26	.50*	.19	.49*
Construct 3				.66*	.68*	.79*
Construct 4					.87*	.94*
Construct 5						.91*
RTOP Cumulative						—

*p < 0.05 (1-tailed).

Objective Four

Middle School Students' Change in STEM Beliefs and Interests by RTOP Statement

RTOP data and middle school student STEM beliefs and interests data were transformed to *z*-scores by subtracting the mean of the distribution and then dividing by the distributions' standard deviation (Field, 2000). Mean scores in lead teachers' classrooms were then obtained for each variable: summed beliefs and interests, RTOP constructs, and cumulative RTOP scores by NSF Fellow. The transformation to *z*-scores allowed data to be compared that were originally measured in differing units (Field, 2000).

Pearson's product moment correlation analyses were used to determine if relationships existed between changes in middle school students' STEM beliefs and interests and the cumulative RTOP scores, the five RTOP constructs, and the 25 individual RTOP statements. A one-tailed test of significance was used as the literature indicated elements of inquiry-based learning should have a positive influence on middle school students' changes in STEM beliefs and interests. Significance levels were set *a priori* at $\alpha = 0.05$.

Pearson's product moment correlation analyses indicated no significant associations between changes in middle school students' STEM beliefs and the 25 statements comprising the RTOP instrument.

Pearson's product moment correlation analyses indicated significant moderate positive association (Davis, 1971) between changes in middle school students' STEM interests and statement 25, *The metaphor "teacher as listener" was very characteristic* *of this classroom* (*r* = .49); statement 16, *Students were involved in the communication of their ideas to others using a variety of means and media* (*r* = .41); and statement 19, *Student questions and comments often determined the focus and direction of classroom discourse* (*r* = .38).

Analyses indicated a moderate negative association between middle school students' STEM interest change and RTOP statement one, *The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein* (*r* = -.43). Analyses indicated that the increase in "teacher as listener" in the classroom; increases in middle school students' involvement in communicating their ideas to others using a variety of means and media and their questions; and students' comments directing the focus of classroom discussion increased the STEM interest of middle school students. Analyses also indicated middle school students' STEM interests decreased as instructional strategies and activities which respected students' prior knowledge and preconceptions increased (Table 42).

Table 42
Pearson r Correlations for Middle School Students' Change in STEM Beliefs and Interests by RTOP Statement

RTOP Statements	Change Belief	Change Interest
1. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	-.33	-.43*
2. The lesson was designed to engage students as members of a learning community.	.01	-.13
3. In this lesson, student exploration preceded formal presentation.	-.05	.14
4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	-.08	.03
5. The focus and direction of the lesson was often determined by ideas originating with students	-.11	.05

Table 42 (continued)

RTOP Statements	Change Belief	Change Interest
6. The lesson involved fundamental concepts of the subject.	.09	.11
7. The lesson promoted strongly conceptual understanding.	.10	.09
8. The teacher had a solid grasp of the subject matter content inherent in the lesson.	.20	.36
9. Elements of abstraction (i.e. symbolic representations, theory building) were encouraged when it was important to do so.	.07	-.10
10. Connections with other content disciplines and/or real world phenomena were explored and valued.	.37	.29
11. Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	.12	-.02
12. Students made predictions, estimations and/or hypotheses and devised means for testing them.	.35	.15
13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	.35	.24
14. Students were reflective about their learning.	-.33	-.07
15. Intellectual rigor, or constructive criticism, and the challenging of ideas were valued.	-.12	.15
16. Students were involved in the communication of their ideas to others using a variety of means and media.	.34	.41*
17. The teacher's questions triggered divergent modes of thinking.	-.20	-.12
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.	.36	.16
19. Student questions and comments often determined the focus and direction of classroom discourse.	.26	.38*
20. There was a climate of respect for what others had to say.	.22	.35
21. Active participation of students was encouraged and valued.	.21	.03
22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	.19	.24
23. In general the teacher was patient with students.	.08	.10
24. The teacher acted as a resource person, working to support and enhance student investigations.	.19	.05
25. The metaphor "teacher as listener" was very characteristic of this classroom.	.36	.49*

*$p < 0.05$ (1-tailed).

Objective Five

Correlations for Middle School Students' Change in STEM Beliefs and Interests by Other Variables of Interest

Pearson's product moment correlation analyses were used to identify demographic variables significantly associated with middle school students' change in STEM beliefs and interests. Variables identified were included in a linear regression model explaining changes in STEM beliefs and interests due to identified RTOP statements and demographics. A two-tailed test of significance was used in the correlation analysis as the direction of the relationship was unknown. Significance levels were set *a priori* at $\alpha = 0.05$.

A significant very strong positive association (Davis, 1971) was indicated between middle school students' change in STEM beliefs and change in STEM interests ($r = .74$). Analysis indicated no significant associations between middle school students' change in STEM beliefs and year, NSF Fellow, NSF fellow gender, location, subject, grade level, female middle school students, or male middle school students. Therefore, the variable change in STEM interest was the only variable included in the regression model for middle school students' change in STEM beliefs.

Analysis indicated no significant associations between middle school students' change in STEM interests and year, NSF Fellow, NSF Fellow gender, location, grade level, or middle school student gender. Therefore, none of the variables were included in the regression model for STEM interests (Table 43).

Table 43
Pearson r Correlations for Middle School Students' Change in STEM Beliefs and Interests by Other Variables of Interest

Variables	Change Belief	Change Interest
Year	.03	.06
Fellow	.12	.07
Gender of Fellow	.11	.03
Location	.20	.04
Subject	-.03	.12
Grade	.00	-.10
Male Students	.00	-.07
Female Students	-.01	.06
Change in Interest	.74*	—

*$p < 0.05$ (1-tailed).

Middle School Students' Change in STEM Beliefs Regression Analyses

Pearson's product moment correlation analyses indicated STEM interest change, was the only variable with a statistically significant ($\alpha = 0.05$) association with middle school students' STEM belief change. Therefore, this variable was the only one included in the regression model explaining the variability in middle school students' change in STEM beliefs.

Forced entry linear regression was used to determine the variability in middle school students' STEM beliefs change. The R^2 of 0.55 indicated that 55% of the variability in middle school students' STEM beliefs change could be explained by changes in STEM interests. ANOVA indicated the model was statistically significant at the $\alpha = .05$ level. The variation explained by the model was not due to chance (Table 44).

Table 44
ANOVA Table for Regression model of Change in STEM Interest on Middle School Students' Change in STEM Beliefs

Source	*df*	*SS*	M^2	*F*	*p*	R^2
Regression	1	37.20	37.20	22.27*	.00	.55
Residual	18	30.07	1.67			
Total	19	67.27				

Note. Predictors include (Constant), Change in STEM Interest. Dependent variable is change in STEM belief.
*p < .05.

The standardized beta coefficient of *change in STEM interest* (β = .74) indicated middle school students' STEM beliefs changed by .74 standard deviations for each additional one standard deviation change in middle school students' STEM interests. The un-standardized beta coefficient of *STEM interest change* indicated a positive relationship between middle school students' STEM interest change and changes in middle school students' STEM beliefs. The change in middle school students' STEM beliefs increased by 1.77 for each additional one unit increase in middle school students' STEM interests (Table 45).

Table 45
Summary of Forced Entry Regression Analysis for Change in STEM Interests Explaining Change in Belief

Variables	*B*	*SE B*	β	*t*	Sig.
(Constant)	-.03	.29		-.10	.92
Change in STEM Interest	1.77	.37	.74	4.72*	.00

Note. R^2 = .55. Dependent variable is change in belief.
*p < .05.

Middle School Students' Change in STEM Interests Regression Analyses

Variables identified by Pearson's product moment correlation analyses for inclusion in the regression model explaining middle school students' STEM interests change were: RTOP statement one, *The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein*; statement 16, *Students were involved in the communication of their ideas to others using a variety of means and media*; statement 19, *Student questions and comments often determined the focus and direction of classroom discourse*; and statement 25, *The metaphor "teacher as listener" was very characteristic of this classroom*.

Forced entry linear regression was used to determine the variability in middle school students' STEM interests change. Forced entry linear regression analyses indicated that a model with all four identified RTOP statements present was not statistically significant (α = 0.05); variation explained by the model could be due to chance (Table 46).

Table 46
ANOVA Table for Regression model of RTOP Statements One, 16, 19, and 25 on Middle School Students' Change in STEM Interests

Source	*df*	*SS*	M^2	*F*	*p*	R^2
Regression	4	5.16	1.29	2.88	.06	.43
Residual	15	6.72	.45			
Total	19	11.89	1.29			

Note. Predictor RTOP statements one, 16, 19, and 25. Dependent variable is change in interests.
**p* < .05.

Stepwise regression analyses were performed to determine if one or a combination of two or more of the identified RTOP statements would comprise a statistically significant (α = 0.05) model explaining the variability in middle school students' STEM interests change. Analyses indicated a model consisting solely of RTOP statement 25, *The metaphor "teacher as listener" was very characteristic of this classroom* yielded a statistically significant (α = 0.05) model. The variation in middle school students' STEM interests change explained by the model was not due to chance. Analyses indicated RTOP statement 25 explained 24.1% of the variation in middle school students' STEM interests change (Table 47).

Table 47
ANOVA Table for Stepwise Regression Model of RTOP Statement 25 on Middle School Students' Change in STEM Interests

Source	*df*	*SS*	M^2	*F*	*p*	R^2
Regression	1	2.86	2.86	5.70	.03	.241
Residual	18	9.03	.50			
Total	19	11.89	2.86			

Note. Predictor RTOP statement 25. Dependent variable is change in interests.
$*p < .05$.

The standardized beta coefficient of RTOP statement 25, *The metaphor "teacher as listener" was very characteristic of this classroom* (β = .49), indicated middle school students' STEM interests changed by .49 standard deviations for each additional one standard deviation change in RTOP statement 25. The un-standardized beta coefficient of RTOP statement 25 indicated a positive relationship between RTOP statement 25 and changes in middle school students STEM interests. The change in middle school students' STEM interests increased by 0.71 for each additional one unit increase in RTOP statement 25 (Table 48).

Table 48

Summary of Stepwise Regression Analysis for RTOP Statement 25 Explaining Change in STEM Interests

Variables	*B*	*SE B*	β	*t*	Sig.
(Constant)	.11	.16		.68	.50
RTOP Statement 25	.71	.30	.49	2.39	.03

Note. R^2 = .241. Dependent variable is change in interests.

**p* < .05.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The primary purposes of this study were to develop models quantifying middle school students' STEM interest and belief change as a function of the elements of inquiry-learning, and determine if NSF Fellows' consistent classroom interaction affected classroom inquiry levels and changes in middle school students' STEM interests and beliefs. To accomplish the purposes of the study, the following objectives were established:

1. Determine if prolonged classroom involvement of the NSF Fellow significantly affected students' STEM beliefs;
2. Determine if prolonged classroom involvement of the NSF Fellow significantly affected students' STEM interests;
3. Determine if a significant relationship existed between NSF Fellow and classroom inquiry levels;
4. Determine if a significant relationship existed between classroom inquiry levels and middle school students' STEM interests and belief changes;
5. Develop a model which describes the relationship of inquiry-based teaching constructs on middle school students' STEM interests and belief changes.

Summary

Middle School Students' STEM Attitudes

For the majority of individual STEM belief statements from the attitudinal instrument, middle school students' were less positive post-NSF Fellow for year one, but more positive during year two of the PEER project. For the cumulative two-years of the PEER project, the majority of students' individual STEM beliefs were less positive post-NSF Fellow than pre-NSF Fellow.

Middle school students' mean science beliefs were significantly less positive post-NSF Fellow for years one, but more positive in year two of the PEER project than pre-NSF Fellow. Middle school students' pre-and post-NSF Fellow science beliefs were not significantly different for the two-year cumulative data. Middle school students' mean technology beliefs were significantly less positive post-NSF Fellow for year one of the PEER project; the only year technology belief and interests data were collected. No significant differences in middle school students' pre- to post-NSF Fellow mean beliefs were indicated for mathematics from either years one, two, or for the two-year cumulative data. No significant differences were indicated between middle school students' pre- to post-NSF Fellow mean overall STEM beliefs for all subjects and all years of the PEER program.

The decrease in mean science and technology beliefs from year one were expected as the literature indicated students' STEM attitudes decrease as grade level increases (Anderman & Maehr, 1994; Morell & Ledermann, 1998). The increase in post-

NSF Fellow science beliefs in year two was unexpected and indicates a countering effect to the negative trend may have been present in the science classrooms for that year.

For the majority of individual STEM interests statements from the attitudinal instrument, middle school students' were less positive post-NSF Fellow in year one. Year two and cumulative two-year middle school students' individual STEM interests were more positive for half of the interest statements post-NSF Fellow than pre-NSF Fellow.

No significant differences were indicated between middle school students' pre- to post-NSF Fellow mean interests for science, technology, or mathematics for either year one (the only year technology data were collected), year two, or for two-year cumulative data. No significant differences were indicated between middle school students' pre- to post-NSF Fellow mean overall STEM interests for all subjects and all years of the PEER program.

A decrease in STEM interests and beliefs was expected due to the negative grade level effect indicated in the literature (Anderman & Maehr, 1994; Morell & Ledermann, 1998). The lack of change in overall STEM beliefs and interests may indicate an element was present in the classrooms of these students which counters the negative grade level effect.

Objective One

Objective one was to determine if prolonged classroom involvement of the NSF Fellow significantly affected changes in middle school students' STEM beliefs. Significant pre-and post-NSF Fellow differences in middle school students' mean STEM beliefs were indicated for NSF Fellows, grade levels, STEM subjects, and teachers for both years one, two, and the overall PEER project.

Significant differences between pre-and post-NSF Fellow STEM beliefs were indicated for teachers in year one of the PEER project, but not year two, or for the overall project. Significant differences between pre-and post-NSF Fellow STEM beliefs were indicated for STEM subjects for year two of the PEER project, but not for year one or the overall project. No significant differences between pre-and post-NSF Fellow STEM beliefs were indicated for NSF Fellow, grade level, or gender year one, two, or for the overall project.

NSF Fellows and teachers affected the rate at which middle school students' STEM beliefs changed both years of the PEER project and for the overall project. Grade level, subject, and gender did not affect the rate of STEM belief change for either year one, two, or for the overall program. When teacher and NSF Fellow were present in the classroom, both affected the rate of middle school students' STEM belief change. This supports the powerful effect scientists in the classroom may have on student perceptions (Anderson, 2002; Brown et al., 1989; Finson, 2002).

Objective Two

Objective two was to determine if prolonged classroom involvement of NSF Fellows affected the change in middle school students' STEM interests. Significant pre-and post-NSF Fellow differences in middle school students' mean STEM interests were indicated for NSF Fellows, STEM subjects, grade levels, and teachers for both years one, two, and the overall PEER project. A significant pre-and post-NSF Fellow difference in mean STEM interests was indicated between genders for the overall project, but not for either year one or year two of the project.

Significant differences between pre-and post-NSF Fellow STEM interests were indicated for NSF Fellows and subject in year one and for the overall PEER project, but not for year two of the project. No significant differences between pre-and post-NSF Fellow STEM interests were indicated for gender, teacher, or grade level in year one, two, or for the overall PEER project.

NSF Fellows, teachers, and grade level affected the rate at which middle school students' STEM interests changed in year one and for the overall PEER project, but not for year two of the project. Subject and gender did not affect the rate of middle school students' STEM interest change for year one, two, or the overall PEER project. When teacher, grade level, and NSF Fellow were present in the classroom, teacher and NSF Fellow, not grade level, had a significant affect on the rate at which middle school students' STEM interests changed from pre- to post-NSF Fellow during the overall PEER project. This finding is contrary to the negative effect grade level has on students' STEM attitudes and supports the positive effect role models and scientists in the classroom have on students' attitudes towards STEM subjects (Anderson, 2002; Bandura, 1986; Brown et al., 1989; Finson, 2002; Morell & Ledermann, 1998).

Objective Three

Objective three was to determine if significant relationships existed between NSF Fellows and classroom inquiry levels. Overall, classroom inquiry levels increased significantly from the Fall semester to the Spring semester each year of the PEER project and for the PEER project overall. There were significant differences in inquiry levels between NSF Fellows for the overall PEER project and year one, but not for year two. There were no significant differences in inquiry levels between lead and other teachers; math and science; announced and unannounced observations; male and female NSF Fellows; grade level; or location for either year of the PEER project, or for the PEER project overall.

The only RTOP construct with a significant relationship to NSF Fellow was Construct Two, *Propositional Knowledge,* which was negative. Of the five Constructs comprising overall classroom inquiry levels, as measured by the cumulative RTOP score, Construct Two had the weakest positive association with cumulative RTOP scores.

Only five significant associations were indicated between NSF Fellow and the 25 RTOP statements comprising the cumulative RTOP score, or overall classroom inquiry level. Analyses indicated NSF Fellows had a positive relationship with the "teacher as listener" being very characteristic of the classroom, but all other significant relationships between NSF Fellow and RTOP statements were negative. NSF Fellows had a negative association with lessons involving fundamental concepts of the subject. NSF Fellows also had a negative affect on lessons being designed to engage students as members of a learning community; the lesson promoting strong conceptual understanding; and elements of abstraction being encouraged when it was important to do so. These relationships run counter to the positive influence the literature indicated scientists in the classroom have on scientific content and inquiry learning (Caton et al., 2000).

Objective Four

Objective four was to determine if significant relationships existed between classroom inquiry levels and changes in middle school students' STEM beliefs and interests. No significant associations were indicated between middle school students' STEM beliefs change and the RTOP statements.

Significant associations were indicated between middle school students' STEM interests change and four RTOP statements. Three of the associations were positive and only one association was negative. Analyses indicated that increases in "teacher as listener" in the classroom; increases in middle school students' involvement in communicating their ideas to others using a variety of means and media; and increases in students' comments directing the focus of classroom discussion increased the STEM interests of middle school students. Analyses also indicated middle school students' STEM interests decreased as instructional strategies and activities which respected students' prior knowledge and preconceptions increased. Only one of the four inquiry statements, *"Teacher as listener" was very characteristic of this classroom,* associated with change in middle school students' STEM interests was also associated with NSF Fellows (Figure 1).

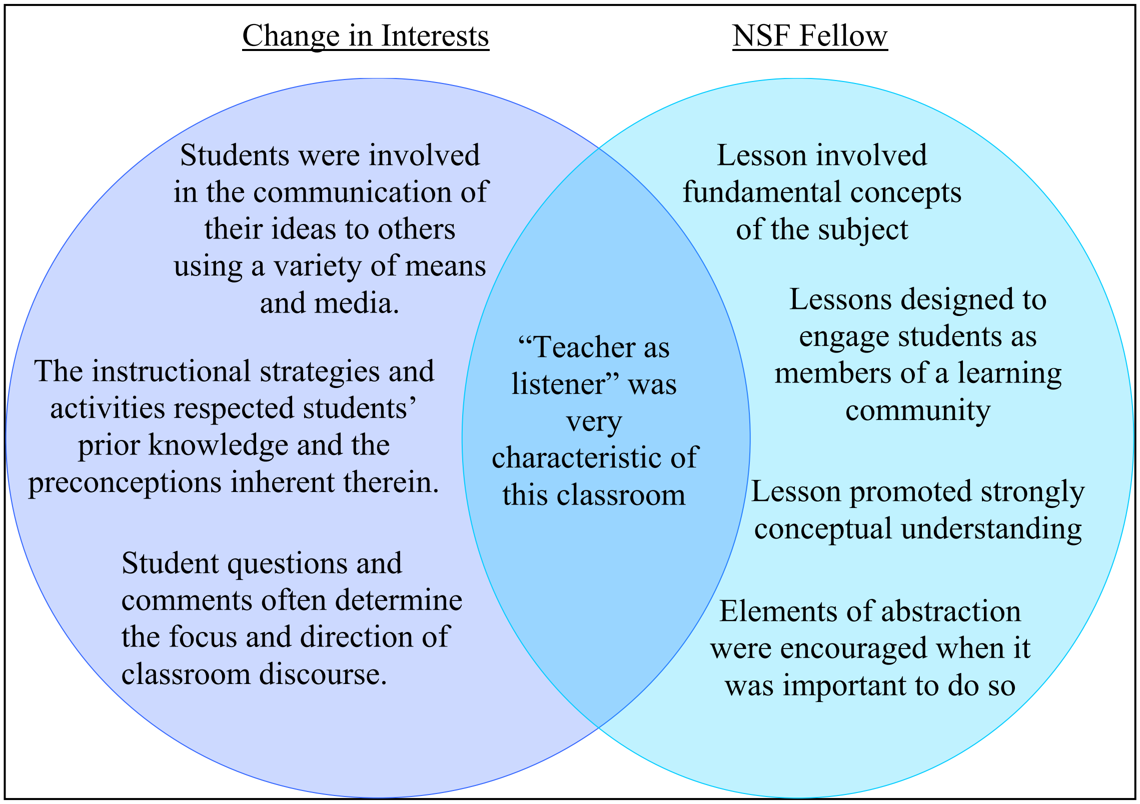

Figure 1. Venn Diagram of Relationship of NSF Fellow to Inquiry Elements Affecting Middle School Students' STEM Interests Change.

Objective Five

Objective five was to develop a model which describes the relationship of the elements of inquiry-based teaching and changes in middle school students' STEM beliefs and interests. Analyses indicated that only one variable and one inquiry statement explained changes in middle school students' STEM attitudes.

Analyses indicated that only STEM interest change explained middle school students' change in STEM beliefs. Analyses indicated that 55% of the change in middle school students' STEM beliefs can be explained by middle school students' STEM interest change (Figure 2). A positive relationship was indicated between middle school students' change in STEM beliefs and their change in STEM interests. As STEM interests increased, students' STEM beliefs increased.

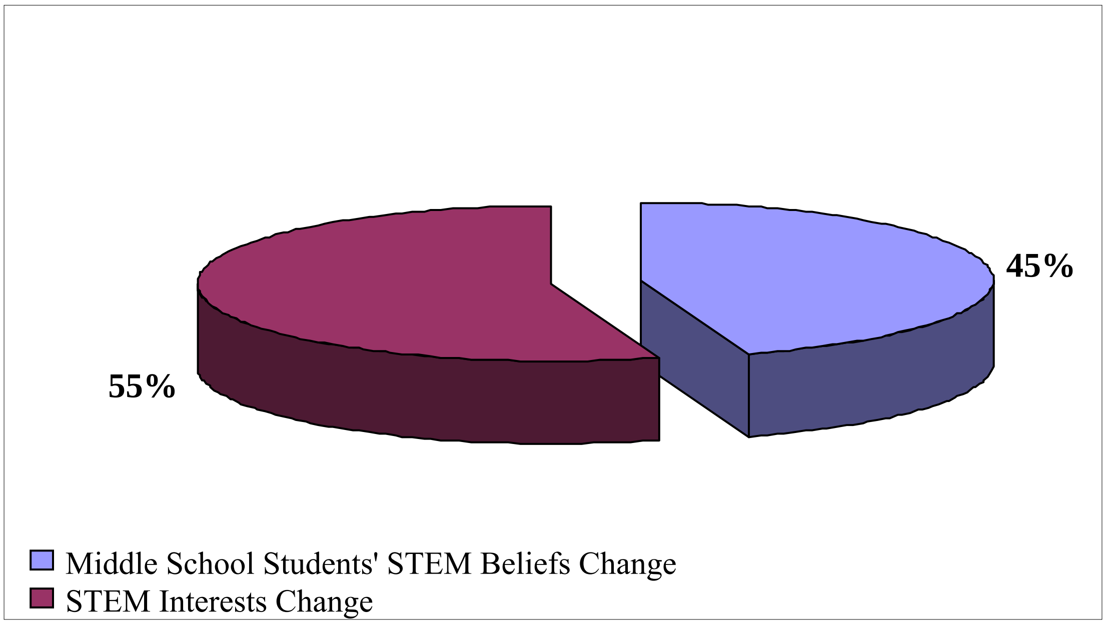

Figure 2. Proportion of Middle School Students' STEM Belief Change as a Function of Middle School Students' STEM Interest Change.

Analyses indicated 24% of middle school students' change in STEM interests were explained by RTOP statement 25, *"Teacher as listener" was very characteristic of this classroom* (Figure 3).

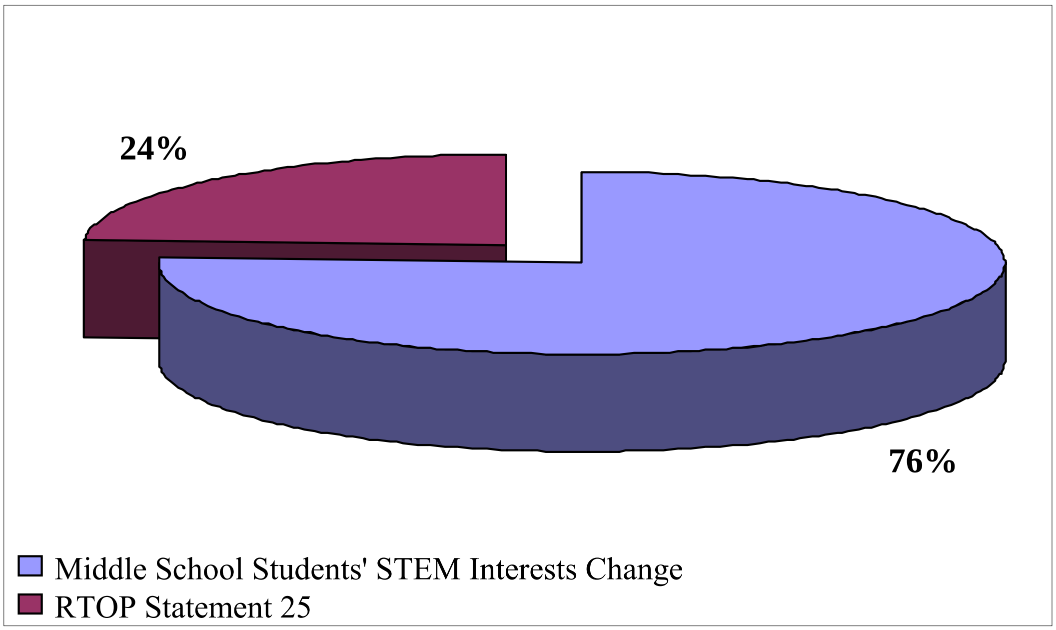

Figure 3. Proportion of Middle School Students' STEM Interests Change as a Function of RTOP Statement 25.

Analyses indicated a positive relationship between the "teacher as listener" in the classroom and middle school students' STEM interests change. Middle school students' STEM interests increased as "teacher as listener" became more characteristic of the classroom. The metaphor "teacher as listener"

> describes a teacher who is often found helping students use what they know to construct further understanding. The teacher may indeed talk a lot, but such talk

> is carefully crafted around understandings reached by actively listening to what students are saying. "Teacher as listener" would be fully in place if "student as listener" was reciprocally engendered. (Piburn et al., 2000, p. 41)

This statement combines elements of the theories of Bruner (1971) *integrate students' comments and questions into the lesson*; Cobern (1991) *build on and use students' pre-existing knowledge in instruction*; Vygotsky (1978) *"scaffold" students' knowledge acquisition*; and Wenger (2002) *engage students in conversation and discussion to share ideas and listen carefully to each othe*r.

Conclusions

This study indicated the PEER program was successful in slowing down the negative grade level effect (Anderman & Maehr, 1994; Morell & Ledermann, 1998) and increasing inquiry levels in middle school classrooms. Further, this study yielded promising results for the involvement of NSF Fellows (STEM experts) in middle school classrooms. The middle school years are a time of dynamic change in students' STEM attitudes, and historically the changes have been predominately negative (Anderman & Maehr, 1994; Morell & Ledermann, 1998). Therefore, the lack of significant improvement in middle school students' STEM interests and beliefs from pre- to post-NSF Fellow for both years of the PEER program was not unexpected.

The lack of significant change of those attitudes over the course of both school years of the PEER program was unexpected (with the exception of the positive change in science beliefs and technology interests in year one). The effect of grade level on middle school students' change in STEM interests was not unexpected. Neither was the effect of teachers on middle school students' STEM interests and beliefs change entirely unexpected (Colbeck, Cabrera, & Terenzini, 2000; Gibson & Chase, 2002). The NSF Fellow was the only new element added to all classrooms, indicating that NSF Fellows may exert a countering influence on the negative attitude trend.

It is important to also note NSF Fellows had a positive relationship to the only inquiry element which explained variation in middle school students' STEM interests change, and no inquiry elements explained variation in middle school students' STEM beliefs change. That NSF Fellows, who only had contact with individual students on average 50 minutes per week, should also have a significant effect on middle school students' changes in STEM beliefs and interests is a profound indication of the effect role models may have in those grades. This finding would seem to support the positive effects of role models claimed by researchers and theorists (Anderson, 2002; Bandura, 1986; Brown et al., 1989; Finson, 2002; Wenger et al., 2002).

Even though the variable NSF Fellows had a negative relationship with four of the five inquiry elements measured by the RTOP instrument, the one element that had a positive relationship was the only inquiry element that explained variation in middle school students' STEM attitude change, as previously mentioned. This inquiry element, *The "teacher as listener" was very characteristic of the classroom,* explained nearly a quarter of the change in middle school students' STEM interests; indicating middle school students' interests increased the more they linked new information to what they already knew and were able to claim "ownership" of a subject. The more middle school students' perceived their ideas and existing knowledge to be valued and integral to the subject they were learning, the more positive they became toward that subject.

NSF Fellows had a substantial affect on changing middle school students' STEM attitudes through their affect on the inquiry element *"Teacher as listener" was very characteristic of the classroom.* This element explained 24% of the variation in middle school students' change in STEM interests, and change in STEM interests explained 55% of the variation in middle school students' change in STEM beliefs. The relationship between STEM interests and STEM beliefs takes on greater importance as STEM attitudes affect career choice (Atwater et al., 1995), and increases in STEM beliefs should increase students' interest and pursuit of STEM careers. This increase in STEM career pursuit should increase the United States' STEM talent pool, ensuring future economic and national security resulting from STEM.

Recommendations

STEM experts should be actively engaged with students in middle school classrooms in order to reverse the negative grade level effect. STEM experts should model the active solicitation and use of students' ideas and knowledge in classroom activities and instruction in order to increase student STEM interests and as a result students' STEM beliefs. To further increase middle school students' STEM interest change, STEM experts and teachers should also increase inquiry activities that involve middle school students in communicating their ideas to others using a variety of means and media, and in which their comments direct the focus of classroom discussion.

In order to provide a more consistent classroom inquiry experience for all middle school students involved in the PEER GK-12 program, PEER should provide teachers, NSF Fellows, and school administrators with inquiry-based professional development opportunities throughout the school year. These professional development opportunities should focus on identification of the potential for inquiry in lessons, identification of types and levels of inquiry, identification of inquiry levels present in the classroom, practice implementing and grading higher level inquiry-level activities, and classroom management issues of higher-level inquiry activities. PEER should also provide administrators of schools involved in the program training opportunities on issues specific to evaluation of inquiry classrooms versus traditional classrooms.

The PEER GK-12 project should implement control classrooms in schools without NSF Fellows. RTOP data and pre-/post-school year attitudinal data should be collected in these schools and analyzed for differences in school-year classroom inquiry level increases and middle school students' STEM beliefs and interests changes between classrooms with NSF Fellows and classrooms without NSF Fellow. PEER should also compare the effects on classroom inquiry levels and student attitude change between NSF Fellows trained in the RTOP instrument and NSF Fellows with no exposure to RTOP training.

The PEER project should also conduct comparison studies of NSF Fellows with high classroom inquiry levels year one placed in different grade levels and with different lead teachers a second year to determine grade level and teacher effect on NSF Fellow inquiry effectiveness. Conversely, NSF Fellows with low classroom inquiry levels year one should be placed in different grade levels and with lead teachers from high inquiry level classrooms year two in order determine what effect grade level and teacher has on NSF Fellow inquiry effectiveness.

Further research should be conducted as to why *"teacher as listener" being very characteristic of a classroom* had such an impact on middle school students' STEM interest change. Did this element fulfill a psychological or emotional need for validation, recognition, or acceptance in adolescent students? The findings suggested such an answer, but other factors may ultimately better explain the impact. This element should also be explored as to its effects on middle school students' role model identification and self-efficacy development. Replication of this study into the effect of role models and self-efficacy on middle school students' STEM beliefs and interests change is recommended.

Questions for further research resulting from the findings of this study are: What are the specific factors or characteristics of NSF Fellows that affect students' STEM attitudinal changes? Is the effect due to the novelty of the NSF Fellows' presence in the classroom? Does the effect result from the perception of the NSF Fellow as a friend/mentor rather than a teacher/authority figure? Do gender and racial/ethnic factors play a role in the NSF Fellows' effect on middle school students' STEM interest change? Do NSF Fellows affect stereotypical preconceptions of middle school students? If so, how and what is the relationship to STEM interest change? Why did NSF Fellows negatively affect the five inquiry elements? Does cognitive level affect the relationship between inquiry elements and middle school students' STEM beliefs and interests change? Additional, long-term research may answer and/or raise new questions related to this topic.

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APPENDIX A

PRE-NSF FELLOW STUDENT INTEREST SURVEY-SCIENCE

Gender: __ Male __ Female

Student Interest Survey: Science

Instructions: The following statements relate to beliefs and interest in science. **Mark the column** that most closely matches how you feel about each statement.

Beliefs about Science	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy science class.					
I think I could be a good scientist.					
I like to find answers to questions by doing experiments.					
I get to do experiments in my science class.					
Being a scientist would be exciting.					
Science is difficult for me.					
I like to use the science book to learn science.					
Science is useful in everyday life.					
Studying hard in science is not cool.					
Scientists help make our lives better.					
Being a scientist would be a lonely job.					
I want to take more science classes.					

Interest in Science	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I think science is important only at school.					
I like to use computers to learn about science.					
Science tests make me nervous.					
I like to use science equipment to study science.					
I don't usually try my best in science class.					
The things we study in science are not useful to me in daily living.					
I like to work in a small group in science class.					
Science class activities are boring.					
Finishing high school is very important to me.					
I get better grades than most of my classmates in school.					
I always give my best effort on my school homework.					
I like being in school.					
My family cares about the grades I get in school.					
I like science more than all other subjects in school.					
My friends and I compete for the highest test scores in science class.					
I will definitely go to college someday.					

Student Interest Survey: Science

Instructions: In your own words answer each of the following questions in the box beside that question.

Open Ended Questions:	Answers:
List 5 words that describe a Scientist.	
What are three things Scientists do when they are doing science?	
Do you think you could become a scientist? Why?	

APPENDIX B

PRE-NSF FELLOW STUDENT INTEREST SURVEY-

TECHNOLOGY

Gender: __ Male __ Female

Student Interest Survey: Technology

Instructions: The following statements relate to beliefs and interest in technology.
Mark the column that most closely matches how you feel about each statement.

Beliefs about Technology	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy technology class.					
I think I could be a good technologist.					
I like to find answers to questions by doing experiments.					
I get to do experiments in my technology class.					
Being a technologist would be exciting.					
Technology is difficult for me.					
I like to use the technology book to learn technology.					
Technology is useful in everyday life.					
Studying hard in technology is not cool.					
Technologists help make our lives better.					
Being a technologist would be a lonely job.					
I want to take more technology classes.					

Interest in Technology	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I think technology is important only at school.					
I like to use computers to learn about technology.					
Technology tests make me nervous.					
I like to use technology equipment to study technology.					
I don’t usually try my best in technology class.					
The things we study in technology are not useful to me in daily living.					
I like to work in a small group in technology class.					
Technology class activities are boring.					
Finishing high school is very important to me.					
I get better grades than most of my classmates in school.					
I always give my best effort on my school homework.					
I like being in school.					
My family cares about the grades I get in school.					
I like technology more than all other subjects in school.					
My friends and I compete for the highest test scores in technology class.					
I will definitely go to college someday.					

Student Interest Survey: Technology

Instructions: In your own words answer each of the following questions in the box beside that question.

Open Ended Questions:	Answers:
List 5 words that describe a Technologist.	
What are three things Technologists do when they are doing technology?	
Do you think you could become a technologist? Why?	

APPENDIX C

PRE-NSF FELLOW STUDENT INTEREST SURVEY-

ENGINEERING

Gender: __ Male __ Female

Student Interest Survey: Engineering

Instructions: The following statements relate to beliefs and interest in engineering. **Mark the column** that most closely matches how you feel about each statement.

Beliefs about Engineering	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy engineering class.					
I think I could be a good engineer.					
I like to find answers to questions by doing experiments.					
I get to do experiments in my engineering class.					
Being a engineer would be exciting.					
Engineering is difficult for me.					
I like to use the engineering book to learn engineering.					
Engineering is useful in everyday life.					
Studying hard in engineering is not cool.					
Engineers help make our lives better.					
Being a engineer would be a lonely job.					
I want to take more engineering classes.					

Interest in Engineering	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I think engineering is important only at school.					
I like to use computers to learn about engineering.					
Engineering tests make me nervous.					
I like to use engineering equipment to study engineering.					
I don't usually try my best in engineering class.					
The things we study in engineering are not useful to me in daily living.					
I like to work in a small group in engineering class.					
Engineering class activities are boring.					
Finishing high school is very important to me.					
I get better grades than most of my classmates in school.					
I always give my best effort on my school homework.					
I like being in school.					
My family cares about the grades I get in school.					
I like engineering more than all other subjects in school.					
My friends and I compete for the highest test scores in engineering class.					
I will definitely go to college someday.					

Student Interest Survey: Engineering

Instructions: In your own words answer each of the following questions in the box beside that question.

Open Ended Questions:	**Answers:**
List 5 words that describe a Engineer.	
What are three things Engineers do when they are doing engineering?	
Do you think you could become a engineer? Why?	

APPENDIX D

PRE-NSF FELLOW STUDENT INTEREST SURVEY-MATH

Gender: __ Male __ Female

Student Interest Survey: Math

Instructions: The following statements relate to beliefs and interest in math. **Mark the column** that most closely matches how you feel about each statement.

Beliefs about Math	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy math class.					
I think I could be a good mathematician.					
I like to find answers to questions by doing experiments.					
I get to do experiments in my math class.					
Being a mathematician would be exciting.					
Math is difficult for me.					
I like to use the math book to learn math.					
Math is useful in everyday life.					
Studying hard in math is not cool.					
Mathematicians help make our lives better.					
Being a mathematician would be lonely.					
I want to take more math classes.					

Interest in Math	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I think math is important only at school.					
I like to use computers to learn about math.					
Math tests make me nervous.					
I like to use math equipment to study math.					
I don't usually try my best in math class.					
The things we study in math are not useful to me in daily living.					
I like to work in a small group in math class.					
Math class activities are boring.					
Finishing high school is very important to me.					
I get better grades than most of my classmates in school.					
I always give my best effort on my school homework.					
I like being in school.					
My family cares about the grades I get in school.					
I like math more than all other subjects in school.					
My friends and I compete for the highest test scores in math class.					
I will definitely go to college someday.					

Student Interest Survey: Math

Instructions: In your own words answer each of the following questions in the box beside that question.

Open Ended Questions:	**Answers:**
List 5 words that describe a Mathematician.	
What are three things Mathematicians do when they are doing math?	
Do you think you could become a mathematician? Why?	

APPENDIX E

POST-NSF FELLOW STUDENT INTEREST SURVEY-SCIENCE

Gender: __ Male __ Female

Student Interest Survey: Science

Instructions: The following statements relate to beliefs and interest in science. **Mark the column** that most closely matches how you feel about each statement.

Beliefs about Science	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy science class.					
I think I could be a good scientist.					
I like to find answers to questions by doing experiments.					
I get to do experiments in my science class.					
Being a scientist would be exciting.					
Science is difficult for me.					
I like to use the science book to learn science.					
Science is useful in everyday life.					
Studying hard in science is not cool.					
Scientists help make our lives better.					
Being a scientist would be a lonely job.					
I want to take more science classes.					

Interest in Science	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I think science is important only at school.					
I like to use computers to learn about science.					
Science tests make me nervous.					
I like to use science equipment to study science.					
I usually don't try my best in science class.					
The things we study in science are not useful to me in daily living.					
I like to work in a small group in science class.					
Science class activities are boring.					
Finishing high school is very important to me.					
I get better grades than most of my classmates in school.					
I always give my best effort on my school homework.					
I like being in school.					
My family cares about the grades I get in school.					
I like science more than all other subjects in school.					
My friends and I compete for the highest test scores in science class.					
I will definitely go to college someday.					

Student Interest Survey: Science

Instructions: In your own words answer each of the following questions in the box beside that question.

Open Ended Questions:	Answers:
List 5 words that describe a Scientist.	
What are three things that scientists do when they are doing science?	
Do you think you could become a scientist like your Resident Scientist? Why?	
What did the Resident Scientist do in your class?	
What was the best thing about having a Resident Scientist work with your class?	
Do you think your Resident Scientist was helpful in increasing your knowledge about science? Why?	

APPENDIX F

POST-NSF FELLOW STUDENT INTEREST SURVEY-

TECHNOLOGY

Gender: __ Male __ Female

Student Interest Survey: Technology

Instructions: The following statements relate to beliefs and interest in technology. **Mark the column** that most closely matches how you feel about each statement.

Beliefs about Technology	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy technology class.					
I think I could be a good technologist.					
I like to find answers to questions by doing experiments.					
I get to do experiments in my technology class.					
Being a technologist would be exciting.					
Technology is difficult for me.					
I like to use the technology book to learn technology.					
Technology is useful in everyday life.					
Studying hard in technology is not cool.					
Technologists help make our lives better.					
Being a technologist would be a lonely job.					
I want to take more technology classes.					

Interest in Technology	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I think technology is important only at school.					
I like to use computers to learn about technology.					
Technology tests make me nervous.					
I like to use technology equipment to study technology.					
I usually don't try my best in technology class.					
The things we study in technology are not useful to me in daily living.					
I like to work in a small group in technology class.					
Technology class activities are boring.					
Finishing high school is very important to me.					
I get better grades than most of my classmates in school.					
I always give my best effort on my school homework.					
I like being in school.					
My family cares about the grades I get in school.					
I like technology more than all other subjects in school.					
My friends and I compete for the highest test scores in technology class.					
I will definitely go to college someday.					

Student Interest Survey: Technology

Instructions: In your own words answer each of the following questions in the box beside that question.

Open Ended Questions:	Answers:
List 5 words that describe a Technologist.	
What are three things that technologists do when they are doing technology?	
Do you think you could become a technologist like your Resident Technologist? Why?	
What did the Resident Technologist do in your class?	
What was the best thing about having a Resident Technologist work with your class?	
Do you think your Resident Technologist was helpful in increasing your knowledge about technology?	

APPENDIX G

POST-NSF FELLOW STUDENT INTEREST SURVEY-

ENGINEERING

Gender: __ Male __ Female

Student Interest Survey: Engineering

Instructions: The following statements relate to beliefs and interest in engineering. **Mark the column** that most closely matches how you feel about each statement.

Beliefs about Engineering	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy engineering class.					
I think I could be a good engineer.					
I like to find answers to questions by doing experiments.					
I get to do experiments in my engineering class.					
Being a engineer would be exciting.					
Engineering is difficult for me.					
I like to use the engineering book to learn engineering.					
Engineering is useful in everyday life.					
Studying hard in engineering is not cool.					
Engineers help make our lives better.					
Being a engineer would be a lonely job.					
I want to take more engineering classes.					

Interest in Engineering	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I think engineering is important only at school.					
I like to use computers to learn about engineering.					
Engineering tests make me nervous.					
I like to use engineering equipment to study engineering.					
I usually don't try my best in engineering class.					
The things we study in engineering are not useful to me in daily living.					
I like to work in a small group in engineering class.					
Engineering class activities are boring.					
Finishing high school is very important to me.					
I get better grades than most of my classmates in school.					
I always give my best effort on my school homework.					
I like being in school.					
My family cares about the grades I get in school.					
I like engineering more than all other subjects in school.					
My friends and I compete for the highest test scores in engineering class.					
I will definitely go to college someday.					

Student Interest Survey: Engineering

Instructions: In your own words answer each of the following questions in the box beside that question.

Open Ended Questions:	Answers:
List 5 words that describe an Engineer.	
What are three things that engineers do when they are doing engineering?	
Do you think you could become an engineer like your Resident Engineer? Why?	
What did the Resident Engineer do in your class?	
What was the best thing about having a Resident Engineer work with your class?	
Do you think your Resident Engineer was helpful in increasing your knowledge about engineering?	

APPENDIX H

POST-NSF FELLOW STUDENT INTEREST SURVEY-MATH

Gender: __ Male __ Female

Student Interest Survey: Math

Instructions: The following statements relate to beliefs and interest in math. **Mark the column** that most closely matches how you feel about each statement.

Beliefs about Math	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy math class.					
I think I could be a good mathematician.					
I like to find answers to questions by doing experiments.					
I get to do experiments in my math class.					
Being a mathematician would be exciting.					
Math is difficult for me.					
I like to use the math book to learn math.					
Math is useful in everyday life.					
Studying hard in math is not cool.					
Mathematicians help make our lives better.					
Being a mathematician would be a lonely job.					
I want to take more math classes.					

Interest in Math	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I think math is important only at school.					
I like to use computers to learn about math.					
Math tests make me nervous.					
I like to use math equipment to study math.					
I usually don’t try my best in math class.					
The things we study in math are not useful to me in daily living.					
I like to work in a small group in math class.					
Math class activities are boring.					
Finishing high school is very important to me.					
I get better grades than most of my classmates in school.					
I always give my best effort on my school homework.					
I like being in school.					
My family cares about the grades I get in school.					
I like math more than all other subjects in school.					
My friends and I compete for the highest test scores in math class.					
I will definitely go to college someday.					

Student Interest Survey: Math

Instructions: In your own words answer each of the following questions in the box beside that question.

Open Ended Questions:	**Answers:**
List 5 words that describe a Mathematician.	
What are three things that mathematicians do when they are doing math?	
Do you think you could become a mathematician like your Resident Mathematician? Why?	
What did the Resident Mathematician do in your class?	
What was the best thing about having a Resident Mathematician work with your class?	
Do you think your Resident Mathematician was helpful in increasing your knowledge about math?	

APPENDIX I*

REFORMED TEACHING OBSERVATION PROTOCOL-

EVALUATION FORM

Reformed Teaching Observation Protocol (RTOP)
Daiyo Sawada, External Evaluator
Michael Piburn, Internal Evaluator
and
Kathleen Falconer, Russell Benford, Eugene Judson, and Irene Bloom
Evaluation Facilitation Group (EFG)
Technical Report No. IN00-1
Arizona Collaborative for Excellence in the Preparation of Teachers
Arizona State University

I. BACKGROUND INFORMATION

Teacher's Name______________________________ Announced Observation?____
(yes/no, explain)

Location of class____
(district, school, room)

Years of Teaching______________________ Teaching Certification______
(K-8 or 7-12)

Subject observed_______________________ Grade level_______________

Observer______________________________ Date of observation________

Start time______________________________ End time_________________

2000 Revision

* Reprinted with permission from *Reformed Teaching Observation Protocol (RTOP): Reference Manual*. Piburn, M., Sawada, D., Turley, J., Falconer, K., Benford, R., Bloom, I., et al. (2000). Arizona Collaborative for Excellence in the Preparation of Teachers. Tempe, AZ: 2000. Arizona Board of Regents.

II. CONTEXTUAL BACKGROUND AND ACTIVITIES

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate.

Record here events which may help in documenting the ratings.

Time	Description of Events

III. LESSON DESIGN AND IMPLEMENTATION

	Never Occurred			Very Descriptive	
1) The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
2) The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3) In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4) This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
5) The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

IV. CONTENT

Propositional knowledge—WHAT is being taught?	Never Occurred			very Descriptiv e	
6) The lesson involved fundamental concepts	0	1	2	3	4
7) The lesson promoted strongly coherent conceptual understanding	0	1	2	3	4
8) The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9) Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10) Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

Procedural Knowledge—HOW is it being taught?					
11) Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
12) Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
13) Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14) Students were reflective about their learning.	0	1	2	3	4
15) Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

V. CLASSROOM CULTURE: Communicative Interactions

Student/Student Relationships—Student to Student Interactions	Never Occurred			Very Descriptive	
16) Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
17) The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18) There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19) Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20) There was a climate of respect for what others had to say.	0	1	2	3	4

Student/Teacher Relationships—Student to Teacher Interactions	**Never Occurred**			**Very Descriptive**	
21) Active participation of students was encouraged and valued.	0	1	2	3	4
22) Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1	2	3	4
23) In general the teacher was patient with students.	0	1	2	3	4
24) The teacher acted as a resource person, working to support and enhance student investigations.	0	1	2	3	4
25) The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

2000 Revision

APPENDIX J*

REFORMED TEACHING OBSERVATION PROTOCOL-TRAINING GUIDE

Reformed Teaching Observation Protocol (RTOP) TRAINING GUIDE

Daiyo Sawada — External Evaluator
Michael Piburn — Internal Evaluator

and

Jeff Turley, Kathleen Falconer, Russell Benford, Irene Bloom, and Eugene Judson

The Evaluation Facilitation Group

Arizona Collaborative for Excellence in the Preparation of Teachers
Arizona State University

ACEPT Technical Report No. IN00-2

The Reformed Teaching Observation Protocol (RTOP) is an observational instrument that can be used to assess the degree to which mathematics or science instruction is "reformed." It embodies the recommendations and standards for the teaching of mathematics and science that have been promulgated by professional societies of mathematicians, scientists and educators.

The RTOP was designed, piloted and validated by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers. Those most involved in that effort were Daiyo Sawada (External Evaluator), Michael Piburn (Internal Evaluator), Bryce Bartley and Russell Benford (Biology), Apple Bloom and Matt Isom (Mathematics), Kathleen Falconer (Physics), Eugene Judson (Beginning Teacher Evaluation), and Jeff Turley (Field Experiences).

The instrument draws on the following sources:

- National Council for the Teaching of Mathematics. *Curriculum and Evaluation Standards* (1989), *Professional Teaching Standards* (1991), and *Assessment Standards* (1995).

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* Reprinted with permission from *Reformed Teaching Observation Protocol (RTOP): Reference Manual*. Piburn, M., Sawada, D., Turley, J., Falconer, K., Benford, R., Bloom, I., et al. (2000). Arizona Collaborative for Excellence in the Preparation of Teachers. Tempe, AZ: 2000. Arizona Board of Regents.

• National Academy of Science, National Research Council. *National Science Education Standards* (1995).
• American Association for the Advancement of Science, Project 2061. *Science for All Americans*(1990), *Benchmarks for Scientific Literacy*(1993).

It also reflects the ideas of all ACEPT Co-Principal Investigators, but especially those of Marilyn Carlson and Anton Lawson, and the principles of reform underlying the ACEPT project. Its structure reflects some elements of the *Local Systemic Change Revised Classroom Observation Protocol* , by Horizon Research (1997-98).

The RTOP is criterion-referenced, and observers' judgments should *not* reflect a comparison with any other instructional setting than the one being evaluated. It can be used at all levels, from primary school through university. The instrument contains twenty-five items, with each rated on a scale from 0 (not observed) to 4 (very descriptive). Possible scores range from 0 to 100 points, with higher scores reflecting a greater degree of reform.

The RTOP was designed to be used by trained observers. This *Training Guide* provides specific information pertinent to the interpretation of individual items in the protocol. It is intended to be used as part of a formal training program in which trainees observe actual classrooms or videotapes of classrooms, and discuss their observations with others. The *Guide*, in its present form, is also designed to solicit trainee thoughts and concerns so that they feel comfortable in using the instrument. For that reason, a space is provided after each item for trainee comments. Such input helps all those being trained to achieve a higher degree of consistency in using the instrument. Please keep this in mind in making comments.

I. BACKGROUND INFORMATION

This section contains space for standard information that should be recorded by all observers. It will serve to identify the classroom, the instructor, the lesson observed, the observer, and the duration of the observation.
comments:

II. CONTEXTUAL BACKGROUND AND ACTIVITIES

Space is provided for a brief description of the lesson observed, the setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity, etc.) and instructor. Try to go beyond a simple description. Capture, if you can, the defining characteristics of this situation that you believe provide the most important context for understanding what you will describe in greater detail in later sections. Use diagrams if they seem appropriate.
comments:

The next three sections contain the items to be rated. Do not feel that you have to complete them during the actual observation period. Space is provided on the facing page of every set of evaluations for you to make notes while observing. Immediately *after the lesson*, draw upon your notes and complete the ratings. For most items, a valid judgment can be rendered only after observing the entire lesson. The whole lesson provides contextual reference for rating each item.

Each of the items is to be rated on a scale ranging from 0 to 4. Choose “0” if in your judgment, the characteristic *never* occurred in the lesson, not even once. If it did occur, even if only once, “1” or higher should be chosen. Choose “4” only if the item was very descriptive of the lesson you observed. Intermediate ratings do not reflect the number of times an item occurred, but rather the degree to which that item was *characteristic* of the lesson observed.

The remainder of this Training Guide attempts provides a clarification of each RTOP item and the subtest (there are five) of which it is a part.

III. LESSON DESIGN AND IMPLEMENTATION

1) The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.

A cornerstone of reformed teaching is taking into consideration the prior knowledge that students bring with them. The term "respected" is pivotal in this item. It suggests an attitude of curiosity on the teacher's part, an active solicitation of student ideas, and an understanding that much of what a student brings to the mathematics or science classroom is strongly shaped and conditioned by their everyday experiences.
comments:

2) The lesson was designed to engage students as members of a learning community.

Much knowledge is socially constructed. The setting within which this occurs has been called a "learning community." The use of the term community in the phrase "the scientific community" (a "self-governing" body) is similar to the way it is intended in this item. Students participate actively, their participation is integral to the actions of the community, and knowledge is negotiated within the community. It is important to remember that a group of learners does not necessarily constitute a "learning community."
comments:

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3) In this lesson, student exploration preceded formal presentation.

Reformed teaching allows students to build complex abstract knowledge from simpler, more concrete experience. This suggests that any formal presentation of content should be preceded by student exploration. This does not imply the converse...that all exploration should be followed by a formal presentation
comments:

4) This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.

Divergent thinking is an important part of mathematical and scientific reasoning. A lesson that meets this criterion would not insist on only one method of experimentation or one approach to solving a problem. A teacher who valued alternative modes of thinking would respect and actively solicit a variety of approaches, and understand that there
comments:

5) The focus and direction of the lesson was often determined by ideas originating with students.

If students are members of a true learning community, and if divergence of thinking is valued, then the direction that a lesson takes can not always be predicted in advance. Thus, planning and executing a lesson may include contingencies for building upon the unexpected. A lesson that met this criterion might not end up where it appeared to be heading at the beginning.
comments:

IV. CONTENT

Knowledge can be thought of as having two forms: knowledge of what is (Propositional Knowledge), and knowledge of how to (Procedural Knowledge). Both are types of content. The RTOP was designed to evaluate mathematics or science lessons in terms of both.

Propositional Knowledge

This section focuses on the level of significance and abstraction of the content, the teacher's understanding of it, andthe connections made with other disciplines and with real life.

6) The lesson involved fundamental concepts of the subject.

The emphasis on "fundamental" concepts indicates that there were some significant scientific or mathematical ideas at the heart of the lesson. For example, a lesson on the multiplication algorithm can be anchored in the distributive property. A lesson on energy could focus on the distinction between heat and temperature.
comments:

7) The lesson promoted strongly coherent conceptual understanding.

The word "coherent" is used to emphasize the strong inter-relatedness of mathematical and/or scientific thinking. Concepts do not stand on their own two feet. They are increasingly more meaningful as they become integrally related to and constitutive of other concepts.
comments:

8) The teacher had a solid grasp of the subject matter content inherent in the lesson.

This indicates that a teacher could sense the potential significance of ideas as they occurred in the lesson, even when articulated vaguely by students. A solid grasp would be indicated by an eagerness to pursue student's thoughts even if seemingly unrelated at the moment. The grade-level at which the lesson was directed should be taken into consideration when evaluating this item.
comments:

9) Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.

Conceptual understanding can be facilitated when relationships or patterns are represented in abstract or symbolic ways. Not moving toward abstraction can leave students overwhelmed with trees when a forest might help them locate themselves.
comments:

10) Connections with other content disciplines and/or real world phenomena were explored and valued.

Connecting mathematical and scientific content across the disciplines and with real world applications tends to generalize it and make it more coherent. A physics lesson on electricity might connect with the role of electricity in biological systems, or with the wiring systems of a house. A mathematics lesson on proportionality might connect with the nature of light, and refer to the relationship between the height of an object and the length of its shadow.
comments:

Procedural Knowledge

This section focuses on the kinds of processes that students are asked to use to manipulate information, arrive at conclusions, and evaluate knowledge claims. It most closely resembles what is often referred to as mathematical thinking or scientific reasoning.

11) Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulatives, etc.) to represent phenomena.

Multiple forms of representation allow students to use a variety of mental processes to articulate their ideas, analyze information and to critique their ideas. A "variety" implies that at least two different means were used. Variety also occurs within a given means. For example, several different kinds of graphs could be used, not just one kind.
comments:

12) Students made predictions, estimations and/or hypotheses and devised means for testing them.

This item does not distinguish among predictions, hypotheses and estimations. All three terms are used so that the RTOP can be descriptive of both mathematical thinking and scientific reasoning. Another word that might be used in this context is "conjectures". The idea is that students explicitly state what they think is going to happen before collecting data.
comments:

13) Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.

This item implies that students were not only actively doing things, but that they were also actively thinking about how what they were doing could clarify the next steps in their investigation.
comments:

14) Students were reflective about their learning.

Active reflection is a meta-cognitive activity that facilitates learning. It is sometimes referred to as "thinking about thinking." Teachers can facilitate reflection by providing time and suggesting strategies for students to evaluate their thoughts throughout a lesson. A review conducted by the teacher may not be reflective if it does not induce students to *re-examine* or *re-assess* their thinking.
comments:

15) Intellectual rigor, constructive criticism, and the challenging of ideas were valued.

At the heart of mathematical and scientific endeavors is rigorous debate. In a lesson, this would be achieved by allowing a variety of ideas to be presented, but insisting that challenge and negotiation also occur. Achieving intellectual rigor by following a narrow, often prescribed path of reasoning, to the exclusion of alternatives, would result in a low score on this item. Accepting a variety of proposals without accompanying evidence and argument would also result in a low score.
comments:

V. CLASSROOM CULTURE

This section addresses a separate aspect of a lesson, and completing these items should be done independently of any judgments on preceding sections. Specifically the design of the lesson or the quality of the content should not influence ratings in this section. Classroom culture has been conceptualized in the RTOP as consisting of: (1) Communicative Interactions, and (2) Student/Teacher Relationships. These are not mutually exclusive categories because all communicative interactions presuppose some kind of relationship among communicants.

Communicative Interactions

Communicative interactions in a classroom are an important window into the culture of that classroom. Lessons where teachers characteristically speak and students listen are not reformed. It is important that students be heard, and often, and that they communicate with one another, as well as with the teacher. The nature of the communication captures the dynamics of knowledge construction in that community. Recall that communication and community have the same root.

16) Students were involved in the communication of their ideas to others using a variety of means and media.

The intent of this item is to reflect the communicative richness of a lesson that encouraged students to contribute to the discourse and to do so in more than a single mode (making presentations, brainstorming, critiquing, listening, making videos, group work, etc.). Notice the difference between this item and item 11. Item 11 refers to representations. This item refers to active communication.
comments:

17) The teacher's questions triggered divergent modes of thinking.

This item suggests that teacher questions should help to open up conceptual space rather than confining it within predetermined boundaries. In its simplest form, teacher questioning triggers divergent modes of thinking by framing problems for which there may be more than one correct answer or framing phenomena that can have more than one valid interpretation.
comments:

18) There was a high proportion of student talk and a significant amount of it occurred between and among students.

A lesson where a teacher does most of the talking is not reformed. This item reflects the need to increase both the amount of student talk and of talk among students. A "high proportion" means that at any point in time it was as likely that a student would be talking as that the teacher would be. A "significant amount" suggests that critical portions of the lesson were developed through discourse among students.
comments:

19) Student questions and comments often determined the focus and direction of classroom discourse.

This item implies not only that the flow of the lesson was often influenced or shaped by student contributions, but that once a direction was in place, students were crucial in sustaining and enhancing the momentum.
comments:

20) There was a climate of respect for what others had to say.

Respecting what others have to say is more than listening politely. Respect also indicates that what others had to say was actually heard and carefully considered. A reformed lesson would encourage and allow every member of the community to present their ideas and express their opinions without fear of censure or ridicule.
comments:

Student/Teacher Relationships

21) Active participation of students was encouraged and valued.
This implies more than just a classroom full of active students. It also connotes their having a voice in how that activity is to occur. Simply following directions in an active manner does not meet the intent of this item. Active participation implies agenda-setting as well as "minds-on" and "hands-on".
comments:

22) Students were encouraged to generate conjectures, alternative solution strategies, and/or different ways of interpreting evidence.

Reformed teaching shifts the balance of responsibility for mathematical of scientific thought from the teacher to the students. A reformed teacher actively encourages this transition. For example, in a mathematics lesson, the teacher might encourage students to find more than one way to solve a problem. This encouragement would be highly rated if the whole lesson was devoted to discussing and critiquing these alternate solution strategies.
comments:

23) In general the teacher was patient with students.
Patience is not the same thing as tolerating unexpected or unwanted student behavior. Rather there is an anticipation that, when given a chance to play itself out, unanticipated behavior can lead to rich learning opportunities. A long "wait time" is a necessary but not sufficient condition for rating highly on this item.
comments:

24) The teacher acted as a resource person, working to support and enhance student investigations.

A reformed teacher is not there to tell students what to do and how to do it. Much of the initiative is to come from students, and because students have different ideas, the teacher's support is carefully crafted to the idiosyncrasies of student thinking. The metaphor, "guide on the side" is in accord with this item.
comments:

25) The metaphor "teacher as listener" was very characteristic of this classroom.

This metaphor describes a teacher who is often found helping students use what they know to construct further understanding. The teacher may indeed talk a lot, but such talk is carefully crafted around understandings reached by actively listening to what students are saying. "Teacher as listener" would be fully in place if "student as listener" was reciprocally engendered.
comments:

VI. SUMMARY

The RTOP provides an operational definition of what is meant by "reformed teaching." The items arise from a rich research-based literature that describes inquiry-oriented standards-based teaching practices in mathematics and science. However, this training guide does not cite research evidence. Rather it describes each item in a more metaphoric way. Our experience has been that these items have richly intuitive meaning to mathematics and science educators .

Further information about the underlying conceptual and theoretical basis of the RTOP, as well as reliability and validity data and norms by grade-level and context, can be found in the *Reformed Teaching Observation ProtocolMANUAL* (Sawada & Piburn, 2000).

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