ABSTRACT

MAHER, TERRENCE PATRICK. A Study of the Influence of a Preservice Science Teacher Education Program over Time. (Under the direction of John Edgar Penick and Leonard Anthony Annetta.)

This dissertation looks at the beliefs and practices of thirteen science teachers across the teaching continuum. Three pre-service teachers, four student teachers, three first year teachers and three teachers with three or more years of experience were participants in this longitudinal study that took place between 2006 and 2009. All participants were graduates of a large university in the southeastern United States. The study found that inquiry-based teaching practices were taught at the university and most participants believe that it is a superior way of teaching science. Using the Reformed Teaching Observation Protocol (RTOP) instrument to measure the amount of inquiry-based teaching, the following findings were made: The highest level of inquiry-based teaching occurs during pre-service education. This was the only group to score within the "reformed-based" teaching range. The total RTOP scores decreased into the traditional teaching practice range during student teaching. The scores continued to decrease during the first and second years of teaching, showing an even stronger prevalence toward traditional teaching. A slight increase in the average total RTOP scores was noted with teachers having three or more years of experience. But even these teachers' scores were well within the traditional teaching method range. When interviewed, the most common reasons cited by these teachers for not using inquiry-based practice in the public classrooms were high stakes testing, crowded class sizes, and lack of equipment/support.

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A Study of the Influence of a Preservice Science Teacher Education Program over Time

by
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DEDICATION

If not for my wife Pam, this dissertation and entire academic endeavor would have been impossible. Her encouragement and patience with this process was a constant source of strength for me. I would also like to thank my niece Katelyn Michelle Whittingham for being the inspiration for my research and participating in my defense of this dissertation.

BIOGRAPHY

After earning A.S. degrees and General Science and Aeronautic/Flight Operations, I attended Oregon State University and received my Bachelor's of Science in Integrated Science Education (1985). I then taught middle school, sixth, seventh, and eighth grade science for one year and coached soccer and track. I went on to teach high school physics, chemistry, aviation and physical science for five years. I also had the privilege of coaching football and wrestling. Together with another instructor, we founded the Key club at the school, and I sponsored the science club and aviation club. During this time, I earned my Master's Degree in Science Education. After my wife survived ovarian cancer, I began my second career. For the next fifteen years, I worked as a pilot, flight instructor, ground instructor, training captain and assistant chief pilot for many companies. During this time, I earned two more Associates of Science degrees, in Aviation Maintenance Technology and Airframe and Powerplant. I was also awarded a Master's degree in Aviation Technology. Then, in 2002 I returned to teaching physics at a community college and rediscovered a love for education. In 2005, I began this doctoral program and became very active in Project IMPPACT. My entire dissertation is based on this five year NSF supported study. It has been an honor and pleasure working with the teachers, professors, students, and fellow graduate students associated with the project and the Friday Institute. For more information on me, please see https://gsoars.acsad.ncsu.edu/index1.php

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A STUDY OF THE INFLUENCE OF A PRESERVICE SCIENCE TEACHER EDUCATION PROGRAM OVER TIME

CHAPTER 1: INTRODUCTION

"Books must follow sciences, and not sciences books."

This quote is found in the Library of Congress, Thomas Jefferson building, 2nd floor of the Great Hall, in the north corridor A. With a little more research, the quote is found to belong to Sir Francis Bacon's, *Proposition Touching Amendment of Laws, 1616.* Almost 400 years later we are still debating this quote and it is the focus of this dissertation (Bacon, 1616)

How Should We Teach Science?

There are two different schools of thought about how science should be taught. Some believe that science is the memorization of facts: the names, dates, and the contributions of scientists (Wallace & Louden, 2002). This group would define a successful science student as one who know course content verbatim and performs well on standardized tests (Solomon & Aikenhead, 1994). This group believes that like reading, writing, and arithmetic, science is just another academic subject and students should learn science the same way they learn other subjects (Bereiter, 1994). These are teachers who teach in traditional ways.

There is a second school of thought about how science should be taught. This group believes that science is more then course content and memorization skills. They believe that science is a process as well as a body of knowledge, very different from

other academic subjects (Schwab, 1969). For these people, science is a way of investigating the physical world around us (Merton & Storer, 1979).This group would define a successful science student as one who thinks like a scientist (Staver, 1998). And, to this end students are taught more like apprentices (Bell, Blair, Crawford, & Lederman, 2003). This camp believes that science teachers should model how to investigate problems, assist students in their own investigations and, through questioning, reshape the way students understand the world (Judson & Lawson, 2006; Penick, 1996).These are teachers who teach in inquiry ways.

Most people in science education feel that science teaching should reflect how science operates and how people learn (R. D. Anderson, 2002; Conle, 1996; Craven & Penick, 2001; Crawford, 2007; Goodman, 1988; Keys & Bryan, 2001). But, science employs many different methods to discern how nature works (L. Cohen, Manion, & Morrison, 2000; Vaishnavi & Kuechler, 2007) and educators disagree about how students learn (Dewey, 1933; Rogers & Freiberg, 1994; Skinner, 2005). Clearly, one scientific method does not work to answer all research questions, nor does one method of instruction allow all students to learn.

Traditional teaching practices are time-proven and effective with many students (D. K. Cohen, 1987). Inquiry-based teaching practices claim to teach higher order thinking skills (Welch, Klopfer, Aikenhead, & Robinson, 1981). In addition, direct comparisons between the effect of inquiry and traditional practices on student learning have shown inquiry to be “at least equally as effective” as traditional

practices (R. D. Anderson, 2002). Furthermore, research has shown that many science teachers "feel better about themselves" when teaching using inquiry-based practices (Blanchard, 2006). Other research has shown that student-centered learning (a key component of inquiry-based instruction) increases student self image (Cornelius-White, 2007). Hence, inquiry is a value plus way of teaching science.

Research shows that traditional teaching practices are pervasive in the science classrooms of today (DeBoer, 2002a). In addition, traditional science teaching methods are favored in the high stakes testing environment of today (M. G. Jones, Jones, & Hargrove, 2003).So, even if inquiry science teaching practices offers a "value plus" benefit, implementing the practice in the school culture of today will be very difficult.

How Should We Prepare Science Teachers?

Some reforms call for more science content background and less of what they call "educational theory" (Clabaugh, 1992; Clark, 1984). These reformers emphasize content rather then process and support science being taught like other academic subjects. The state of Texas licensure has gone to the extreme by restricting the number of "university education" courses allowed for teachers (Clay, Cohen, Ligons, & Roff, 1994; Simms & Miller, 1988). These reformists can be described as "back to basics" proponents who support traditional teaching methods.

Others believe strongly in expanding the preservice programs to include more knowledge of educational psychology, proven learning practices, and enhancing

practical experience prior to full-time teaching (Adams & Krockover, 1998; Cushing, Sabers, & Berliner, 1992; Penick & Yager, 1988). An example of this kind of approach is in the state of North Carolina where more teachers are certified by the National Board for Professional Teaching Standards than any other state (Tell, 2000). Furthermore, North Carolina's standards and assessments for teachers are some of the most demanding in the country (Darling-Hammond, 1992). This group emphasizes cognitive processes rather then fact memorization (Bonnstetter, 1998; Rogers & Freiberg, 1994). These reformists can be described as "constructivists" who support inquiry-based teaching methods.

To compare and contrast traditional vs. inquiry teaching methods, there are two tables below. The first table gives examples of elements of instruction that would be found in typical traditional science teaching. The second table gives examples of elements of instruction that would be found in typical inquiry-based instruction (Bybee, 1989). The reader is cautioned that most of these comparisons are not parallel due to the fact that inquiry-based instruction is not structured the same as traditional instruction. The table is not meant to show opposite comparisons but simply to list elements of each type of teaching method.

Table 1.1 Elements of Traditional Teaching Practice

Traditional
The teacher may begin the class by reviewing yesterday's homework
The diagnostic assessment of homework may influence the days' lesson plan.
The objectives of today's lesson are announced.
Using a chalk board, overhead projector, white board or power point, vocabulary and nomenclature of the topic are taught.
The lecture may involve handouts to assist students in note taking.
A short movie, science documentary, website or worksheet might be used to further the students understanding.
Cook book labs, demonstrations, or very tightly controlled activities allow students to observe the phenomena.
Lab reports or worksheets are completed by the student and submitted for grading.
Graded reports and worksheets are returned to students.
Student work product is reviewed in class and connections to high stakes tests are emphasized.
Content review activities such as Jeopardy games or Concentration are used to prepare students for the test
Little or no time is afforded to student enrichment activities. Off topic discussions are discouraged to avoid possible confusion.
High stakes tests are administered. Usually standardized, these tests have profound affects on student's future opportunities.
No time for reflection or remediation is afforded to students.
Raw scores on standardized test are used to reflect student's conceptual understanding.

The inquiry descriptions in the table 1.2 are those of Rodger Bybee, creator of the 5 E's (Engage, Explore, Explain, Elaborate, and Evaluate) teaching and learning model (Bybee, 1997).

Table 1.2 Elements of Inquiry-based Teaching Practice

Inquiry
Students use their prior knowledge and literacies to develop explanations for their hands-on experiences of scientific phenomena.
Students have opportunities to represent and re-represent their developing understanding while being actively engaged in learning.
Students develop investigation skills and an understanding of the nature of science
Lessons are designed to spark students' interest, stimulate their curiosity, raise questions for inquiry and elicit students' existing beliefs about the topic.
Students writing, drawing and talk provide opportunities for the teacher to assess students' prior knowledge, including any alternative conceptions.
The teacher then takes account of students' existing ideas when planning future learning experiences.
Students explore ideas, collect evidence, discuss their observations and keep records such as science journal entries.
Students discuss and identify patterns and relationships within observations, and develop scientific explanations.
Students consider the current views of scientists and deepen their own understanding.
The students then develop a literacy product to represent their developing understanding.
The representations enable the teacher to monitor developing understanding and provide feedback to learners.
Students plan and conduct an open investigation to apply and extend their new conceptual understanding in a new context.
The teacher can use students' reports of their investigation to assess the extent to which students have achieved the investigating outcomes for the unit.
Students reflect on their learning journey and create a literacy product to re-represent their conceptual understanding.
Teachers can use evidence from this lesson to assess the extent to which students have achieved the conceptual learning outcomes for the unit.

In this dissertation study, the Reformed Teaching Observation Protocol (RTOP) is used to distinguish traditional from inquiry-based teaching practices (Pilburn et al., 2000). A prima-facie examination of the instrument confirms that elements of inquiry-based teaching practices are used to discriminate the two teaching styles (see Appendix 5). This is an important point. High stakes testing may interfere

with inquiry-based teaching practices because such testing usually focuses on basic, low level content. Because there is disagreement within the science education community as to what exactly constitutes inquiry-based teaching, the standard for this dissertation study is that described by Rodger Bybee in the 5E learning model. RTOP reflects many of Bybee's elements. The RTOP instrument will be discussed in much greater detail in chapter 2.

How should we prepare science teachers? If the cognitive skills necessary to learn science are the same as those needed to learn any other academic subject, why do so many students have difficulties (Klein, Hamilton, McCaffrey, & Stecher, 2000)? If the cognitive skills necessary to teach science are the same as those needed to teach any other academic subject, why do so many elementary teachers fear teaching science (Appleton, 1995)? Perhaps, unlike most other academic subjects, a wider range of science knowledge is developed through the process of inquiry (Welch, Klopfer, Alkenhead, & Robenson, 1981). And, therefore, science teaching through inquiry is a natural and logical solution to the problem. Hence, a strong case can be made that science teachers should be prepared in the ways of inquiry (Crawford, 2007).

How Can We Best Prepare Inquiry Teachers?

Because inquiry reflects how science operates, often involves higher order thinking skills, and can bring a class together as a learning community, making inquiry is a value added approach to teaching. Yet, traditional teaching practices are the predominate format used in science classes today (M. G. Jones et al., 2003). Why?

One explanation is that pre-service and new teachers today are graduates of the high stakes testing environment. In order to obtain grade point averages high enough to be accepted to a university and a science teaching program, these individuals must have excelled in an environment that favors traditional teaching methods. Furthermore, most university level introductory science content and general education courses at universities are taught in large auditoriums by professors teaching via lecture. If the only exposure to inquiry-based science teaching is one or two method courses, is it fair to expect new teachers to understand or completely adopt inquiry? With this small exposure to inquiry, are new teachers competent in teaching science through inquiry? These are a few of the questions this study will address.

Inquiry-based teaching practices emphasize the importance of science literacy. The American Association for the Advancement of Science (AAAS) Project 2061: Science for All Americans defines science literacy to include connections between the disciplines of natural and social science, technology, and mathematics (AAAS, 1989). The Project 2061 report stresses the importance of understanding the nature of science including: 1) a scientific world view, 2) scientific methods of inquiry, and 3) the nature of the scientific enterprise. In this paradigm, two salient themes arise. First, science is for all Americans, not just those fortunate few who learn well in traditionally taught classrooms. Second, the best way to become science literate is by actually doing science. If these reforms hope to be realized by 2061, we need to prepare science teachers in the ways of inquiry.

During pre-service education, students should (Penick, 2008): learn about inquiry, have inquiry modeled for them, learn through inquiry, practice inquiry teaching and skills, and develop a disposition to use inquiry. Future science teachers should be made aware of the plethora of scientifically based research showing the effectiveness of inquiry-based instruction. Science education professors should solicit student attitudes about inquiry and address concerns. Inquiry methods should be modeled for each discipline (Physical Science, Biology, Chemistry, Physics, Geology, Meteorology, etc).

An Inquiry-based Pre-service Program

The science education program at the major research university in the southeastern US studied in this dissertation has been recently cited as the number 1 school in the country in faculty research publications (Chronicle, 2007). According to the science education professors at this large land grant university, undergraduate as well as graduate students are schooled in the ways of inquiry. This university is the source of all participants in this dissertation. Many professors had their first day of classes video recorded. This is the day that most professors describe their educational philosophies, explain their course expectations, and distribute their syllabi. Examining this video recording in conjunction with interviews with these professors, an accurate description of the pre-service experience is obtained. Many professors agreed to have an additional class video recorded so that a Reformed Teaching Observation Protocol coding could be performed. The score produced using this instrument describes the

lesson as having elements of traditional teaching or reformed teaching practices. The higher the score, the more reformed teaching the practice is.

Data to determine if inquiry is being taught in this pre-service program will come from the following sources:

- Pre-service program description from the College of Education
- University catalogue description of the course
- Course description found in the syllabus of the class
- Course description as described by the instructor on the first day of class
- Course as described by the instructor who teaches the course
- Course as described by students currently enrolled in the course
- Course as described by recent graduates of the course
- Course as rated using the RTOP instrument

With eight different sources of data, an objective and accurate description of the courses that comprise this pre-service program were obtained. As the research questions will show, the validity of this dissertation is premised on the fact that inquiry-based teaching exists in this pre-service program.

Research Questions

A. To what extent is inquiry taught to graduates of Research University?

B. To what extent do these graduates believe they are using inquiry in their practice?

C. To what extent do these graduates use inquiry in their practice?

D. Does the use of inquiry by these graduates change over time?

E. What changes in classroom practice can be observed over time?

F. What are the perceived barriers to inquiry-based teaching?

Observing for Inquiry

The methods involved in this study were guided by an ethnographic approach that focused on cultural meanings of participants (e.g. what they said, what they did, and what artifacts they produced) (Spradley, 1979). The qualitative research design focused on non-participatory observations (e.g. no interactions with students, teachers or events as they occur) (Marshall & Rossman, 1998). The instrument used to measure inquiry is the Reformed Observation Teaching Protocol (Piburn et al., 2001).

Before an observer is qualified to code using the RTOP instrument, they must not only be a science teacher but they must complete a training session (approximately 4 hours). This class is offered at many conferences for science educators or can be taken on line at: http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/index.htm. Project IMPPACT selected RTOP primarily based on its validity and high inter-rater reliability (r^2=0.94). But in order to achieve this kind of reliability, observers must be standardized. Observers in this project completed at least one training session per year and coding scores were compared. Those observers coding outside the acceptable range (+/-1 point per item), were given additional training until coding was consistent both within and between cites (Tillotson, 2008b).

Observing for inquiry will be visited again in chapters two and three. The literature review (Chapter 2) will focus on common problems associated with any observational research like the Hawthorne Effect and observer bias. The Methods chapter will discuss specifically how these and other problems are minimized or eliminated in this study.

The Focus of this Study

This study describes the education and preparation of science teachers of this big southeastern university. This description will be made from three different perspectives: that of the students, the faculty, and the administration. The methodology is designed to provide a rich and fine grained description that will permit the reader to gain an accurate picture of the preparation of future science teachers at Research University.

The study describes the experiences of these students as they begin teaching in the public schools. Using observations made of these newly inducted science teachers, coding for inquiry-based instruction was completed using RTOP. The total RTOP scores are used to determine the extent to which science inquiry teaching was observed in the classroom. Total RTOP scores and sub-scale scores are compared within and between cohorts to see if cohorts can be characterized by these scores. In addition, RTOP scores are plotted over time for both individuals and cohorts to see what changes, if any, occur in teacher practice with respect to inquiry.

Lastly, the study looked at the teaching method employed (traditional or inquiry) and examine potential reasons why the teachers teach the way that they do. The perceived barriers to inquiry-based science teaching practices are identified using the teacher's own words. Inconsistencies between the observations made of the participant's teaching and the perception of the participant's teaching, based upon their interviews are explored. Insights gain from this study will improve the understanding of challenges facing science teachers today and provide research based evidence for modifying science teacher education programs for tomorrow.

Limitations

The generalizability of this study is limited for three reasons:

A. Small sample size: with only forty five participants, caution must be exercised in overstating the findings of this study.

B. The sample was not randomly selected. All pre-service science education majors were invited to participate in this study. All the volunteers for this study were self selected.

C. The sample is limited to the students and graduates of Research University. The conclusions of this study may not be applicable to other universities that prepare science teachers in different ways and whose graduates teach in settings significantly different from this university.

Implications

This study gives faculty at Research University insight into how their instruction translates into the education of youth at RU. Furthermore, this study provides a baseline for which any future reform efforts can be measured. In addition, this study paints a historic picture of the journey of students from college to school

teacher. Lastly, this study examines two cultures: pre-service and in-service. A deeper understanding of adjustments involved in transitioning from college student to science teacher provides insight into topics such as: teacher attrition, teacher recruitment, professional development, and educational policy.

CHAPTER 2: LITERATURE SEARCH

What is Inquiry?

Science Literacy

The major focus of my research and dissertation is to determine if inquiry is being taught in middle school, high school, and university science classrooms. Inquiry is just one small part of a much larger goal: science literacy for all Americans. Why is science literacy important? "First, an understanding of science offers personal fulfillment and excitement – benefits that should be shared by everyone. Second, Americans are confronted increasingly with questions in their lives that require scientific information and scientific ways of thinking for informed decision making. And the collective judgment of our people will determine how we manage shared resources – such as air, water, and national forests" (AAAS, 1993). An understanding of science will enhance the capability of all students to hold meaningful and productive jobs in the future (Dede, Korte, Nelson, Valdez, & Ward, 2005). The business community needs workers with the ability to learn, reason, think creatively, make decisions, and solve problems (Dede et al., 2005). In addition, concerns regarding economic competitiveness stress the central importance of science and mathematics education that will allow us to keep pace with our global competitors (Schoenfeld, 1999). The National Science Education Standards are designed to guide

our nation toward a scientifically literate society (National Committee on Science Education Standards and Assessment, 1996).

The National Science Education Standards (1996)

The National Resource Council says that inquiry is being taught when "students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills" (National Committee on Science Education Standards and Assessment, 1996).

A Brief History

This is perhaps the best definition of inquiry and is the culmination of decades of research. In 1910, John Dewey's writings laid the groundwork for inquiry in school science. Dewey believed that children learn through activity. Extended, real life experiences in interaction with others were essential to students constructing their knowledge (Dewey, 1910). But, for over 40 years, inquiry as an approach to the learning and teaching of science was little more then a curiosity. Inquiry was spelled with an "E" when Joseph Schwab in 1962 published his book: The Teaching of Science as Enquiry. Schwab explains that science teaching had not kept pace with this new conception of science. Science is taught "as a nearly unmitigated rhetoric of conclusions in which the current and temporary constructions of scientific knowledge are conveyed as empirical, literal, and irrevocable truths" (Schwab & Brandwein,

1962). This description of science education is one hallmark of traditional science teaching practice. George DeBoer explains how this approach might have come about. He states: “In part, this was due to the transfer of control of textbook writing from the scientists themselves to professional educators during the 1920’s, 1930’s, and 1940’s. More attention was paid by these professional educators to the needs of individual, community, and social class then to the subject matter itself” (DeBoer, 1991). If science teaching was to keep pace with advancements in science education, textbooks and curricula would need to be produced by science educators and not scientists according to Schwab. Yet, through the remainder of the 1960s, inquiry was used in few science classrooms.

In 1971, the National Science Teacher Association published a position statement promoting the ideas that science in school should have social relevance, student interest, show connections between science and other areas of the curriculum, the interdependence of science and technology, and the human aspects of the scientific enterprise (Association, 1971). In 1974, Norman Smith, a retired NASA aerospace research scientist defined scientific literacy as “an understanding of the events around us, the ability to verify the truth of claims made by lay persons and the popular media about science, and the ability to evaluate the relevance and importance of scientific developments and projects in relation to the needs of society” (N. Smith, 1974). The movement away from traditional methods of teaching science is shifting in the 1970s toward inquiry.

The momentum for the use of inquiry in the science classroom continued to build when in 1983, *A Nation at Risk* was published. The commission recommended that: “The teaching of *science* in high school should provide graduates with an introduction to: (a) the concepts, laws, and processes of the physical and biological sciences; (b) the methods of scientific inquiry and reasoning; (c) the application of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and technological development” (Gardener, 1983). *A Nation at Risk* called for the reconsideration and reform of the entire U.S. educational system with inquiry as the center piece of science education. The report goes on to further recommend that: “science courses must be revised and updated for both the college-bound and those not intending to go to college”. The commission recognized that one size does not fit all in science education and strongly promoted the tracking of students. Lastly, *A Nation at Risk* cited specific examples of the kinds of inquiry programs the commission endorsed. One program that was singled out as exemplary was the American Chemical Society's "Chemistry in the Community" (Society, 1980).

A Nation at Risk was a call to arms for the science education community. What followed was a series of science educational curricula modeled after the American Chemical Society’s “Chemistry in the Community” program. The Biological Science Curriculum Study (BSCS) developed biological textbooks and support materials with inquiry as the central theme. This company continues its long held commitment to inquiry with textbooks available today with titles like: Biology: An Ecological

Approach, or Biology: A Molecular Approach, or Biology: A Human Approach; recognizing not only the tracked learner but the desire of science teachers to approach the subject from various contexts (BSCS, 2008).

The Educational Development Center is a global nonprofit organization that "develops, delivers, and evaluates innovative programs to solve some of the world's most urgent challenges in education, health, and economic development" (EDC, 2008). During the 1980's EDC developed some of the first science curriculum designed for learning disabled students.

Another key player in this science education reform movement of the 1980's was (and still is) the Lawrence Hall of Science (LHS, 2008). More than just a science, this institution made science a family experience. Their support of science fairs across the country brought many families together in a science endeavor. This was a unique interpretation of a learning community that is one of the hallmarks of inquiry-based instruction.

In 1985, the Smithsonian Institution and the National Academies joined together to form the National Science Resources Center (NSRC). In response to the *Nation at Risk* Report, the NSRC was established "to improve the learning and teaching of science for all students in the United States and throughout the world" (NSRC, 2008). The major goal of the NSRC is to make teachers and administrators aware of the exemplary science teaching practices and provide resources to implement these practices. The NSRC approach is shown in the diagram below.

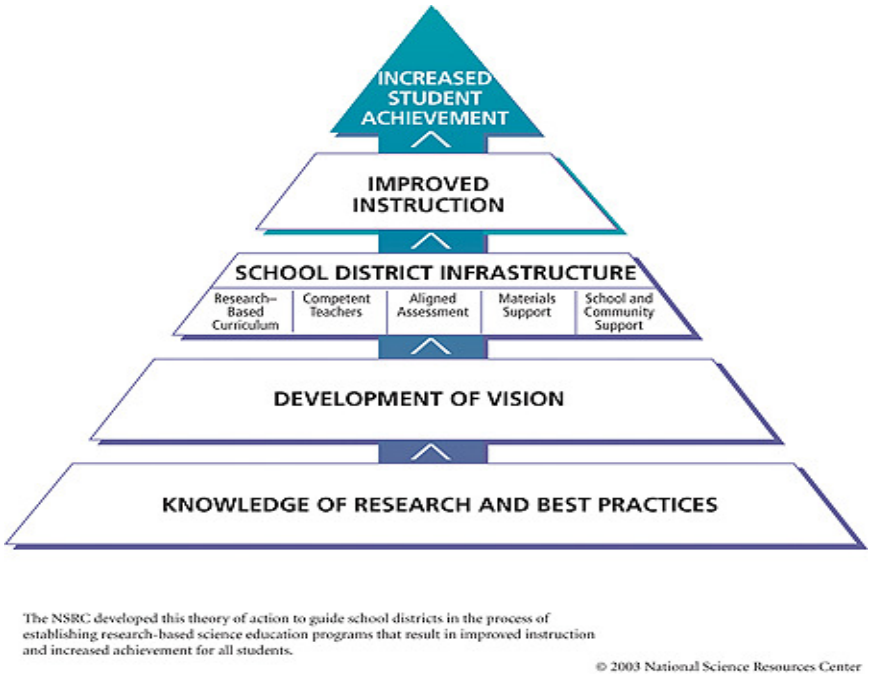


Figure 2.1 Science Education Programs that Result in Improved Instruction

Arguably one of the most influential players in the science education reform movement was (and still is) the Technical Education Resources Center (TERC). This non-profit organization assisted many science teachers in incorporating computers in their teaching during the 1980s (TERC, 2008). This visionary organization was established in 1965, when the nation was still reeling from the Russian success with Sputnik (NASA, 1957). TERC has been providing science educators with the latest in inquiry-based teaching methods as well as technology ever since.

In the 1980s, the American Chemical Society (ACS), the Biological Sciences Curriculum Study, the Education Development Center, the Lawrence Hall of Science, the National Science Resources Center (NSRC), and the Technical Education Resources Center all developed innovative science curricula. These and many other

contributors were changing the way in which science was being taught in K-12. By the end of the decade, there were concerns that too many approaches were "passing" as science (Adams & Krockover, 1993).

The first standards appeared in 1989, when mathematics educators and mathematicians addressed the subject of national standards in mathematics with two publications: *Curriculum and Evaluation Standards for School Mathematics*, by the National Council of Teachers of Mathematics (NCTM, 1989) and *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, by the National Research Council (NRC, 1989). The NCTM experience was important in the development of other educational areas including science. These two publications set the stage for the development of standards for science education in America.

In 1989, the American Association of the Advancement of Science (AAAS), through its Project 2061, published *Science for All Americans*, defining scientific literacy for all high school graduates (AAAS, 1989). The National Standards for Education in Science (1996) closely matched AAAS definitions of science literacy. AAAS acknowledged that students could not achieve these standards of science literacy in most of today's schools. Furthermore, implementation of the Standards will require a sustained, long-term commitment to change as implied by the title the goal is to achieve these changes by the year 2061.

By the early 1990s, science inquiry curricula were proliferating at an astonishing rate. In 1992, the National Science Teachers Association (NSTA), through

its Scope, Sequence & Coordination Project published *The Content Core* (Pearsall, 1992). This book is a collection of research papers and respected philosophical statements on how secondary school students learn science best. Chapters are presented on how spacing content improves learning and how learning is not improved by ability grouping. Science educators could learn the most effective ways of cooperative learning as well as how students' best accommodate scientific concepts. The book is filled with constructivist ideas and how to teach science to girls, learning disabled, and minority students. The book encapsulated inquiry in a teachable way with emphasis on scientific literacy for all Americans.

In 1996, the National Research Counsel published *The National Science Education Standards*. This publication was the culmination of all the books, articles, and reports mentioned in this section. You can hear the echo of each of these publications in the goals stated by NSES:

To educate students who are able to:

- experience the richness and excitement of knowing about and understanding the natural world;
- use appropriate scientific processes and principles in making personal decisions;
- engage intelligently in public discourse and debate about matters of scientific and technological concern; and
- Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers.

"These goals define a scientifically literate society. The standards for content define what the scientifically literate person should know, understand, and be able to do after 13 years of school science. The separate standards for assessment, teaching, program, and system describe the conditions necessary to achieve the goal of scientific literacy for all students that is described in the content standards" (National Committee on Science Education Standards and Assessment, 1996).

The NSES was to do for science teachers what the *Curriculum and Evaluation Standards for School Mathematics* did for math teachers (NCTM, 1989). The *National Science Education Standards* are designed to guide the nation toward a scientifically literate society. "Founded in exemplary practice and research, the *Standards* describe a vision of the scientifically literate person and present criteria for science education that will allow that vision to become reality" (National Committee on Science Education Standards and Assessment, 1996). These exemplary practice and research that the NCSE speaks of was primarily drawn from the works of the National Science Teachers Association (NSTA), in its Scope, Sequence & Coordination Project that produced the data for *The Content Core* book (Pearsall, 1992). But unlike the National Science Teachers Association's book, the *National Science Educational Standards* report presented criteria by which judgments can be made by state and local school personnel and communities, helping them to decide which curriculum, staff development activity, or assessment program is appropriate.

A cornerstone of American education is local control, where boards of education, administration, and teachers make decisions about what students will learn. But with so many different science curricula to choose from, the National Science Education Standards allow everyone to move in the same direction, with the assurance that the risks they (school boards, administrations, and teachers) take in the name of improving science education will be supported by policies and practices throughout the national educational system. The national standards encourage policies that brought coordination, consistency, and coherence to the improvement of science education nationally. This was demonstrated by the Iowa project that studied 20 difference school districts as they implemented the practices suggested by the Scope, Sequence & Coordination Project (Yager, 1999).

The National Science Education Standards embraced teaching science through inquiry. The following two paragraphs from the report clearly illustrate the position of the National Research Council:

> *Some outstanding things happen in science classrooms today, even without national standards. But they happen because extraordinary teachers do what needs to be done despite conventional practice. Many generous teachers spend their own money on science supplies, knowing that students learn best by investigation. These teachers ignore the vocabulary-dense textbooks and encourage student inquiry. They also make their science courses relevant to students' lives, instead of simply being preparation for another school science course.*

> *Schools that implement the* Standards *will have students learning science by actively engaging in inquiries that are interesting and important to them. Students thereby will establish a knowledge base for understanding science. In these schools, teachers will be empowered to make decisions about what students learn, how they learn it, and how resources are allocated. Teachers and students together will be members of a community focused on learning science while being nurtured by a supportive education system* (P.12).

The *Standards* call for more than "science as process," in which students learn such skills as observing, inferring, and experimenting. Inquiry is central to science learning. “When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills”. The report goes on to make a very insightful statement: “the importance of inquiry does not imply that all teachers should pursue a single approach to teaching science. Just as inquiry has many different facets, so teachers need to use many different strategies to develop the understandings and abilities described in the *Standards.”* This last statement clearly shows the wisdom of the authors of the *Standards* by acknowledging that not all quality science teaching has to be inquiry. For example, anatomy is mostly a vocabulary science and inquiry may not be the best approach for teaching it.

The *Standards* not only validated inquiry as an approach for the teaching and learning of science, it elevated inquiry to the level of a national imperative. It not only defined inquiry (as stated in the second paragraph of this section), but provided clear, easy to understand criteria by which to judge if inquiry is being properly employed in the classroom. Perhaps the most significant contribution made by the *National Science Education Standards* is that it gave Americans a clear vision of what science literacy is and a road map of how we can get there.

Inquiry is Learning Science by Doing the Processes of Science

Various Definitions

Part of the problem with the lack of one precise definition of inquiry in the literature is that everyone who writes about inquiry is then required either to describe what they mean by inquiry or leave the reader uncertain or confused. For this study, I will use the basic tenants of the NSES, yet refer to them as the following: *Scientific inquiry*, *inquiry-based learning*, and *inquiry-based science teaching*. Scientific inquiry will refer to the inquiry done by scientists in scientific contexts.

Scientific inquiry "refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (National Committee on Science Education Standards and Assessment, 1996). For example, in this study, science school teachers lectured about remote sensor platforms such as weather satellites and oceanic buoys. The students were tested on their ability to name the various types of remote sensor platforms because that is what appears on the end of course exam.

By using the data produced by these remote sensing devices and available on the internet, students could have hypothesized about future weather events and time would prove them right or wrong, which would have been more consistent with inquiry pedagogy. Inquiry is "something that students do, not something that is done to them" (NRC, 1996, p. 2). Memorizing the names of satellites and oceanic buoys is not science.

In the course of this study, high school students were observed dissecting frogs with the same dissection kits and the same handouts that I used when I was in high school over 30 years ago. I believe that that it is what Dewey had in mind when he wrote: "Science has been taught too much as an accumulation of ready-made material, with which students are to be made familiar, not enough as a method of thinking, an attitude of mind, after the pattern of which mental habits are to be transformed" (Dewey, 1910). The teacher can ask students to find and correctly name the locations where aneurisms occurred during the latex paint injections in the frogs or where circulatory anomalies appear. This would be closer to an inquiry-based approach then the straight memorization of anatomy and the instruments used during the dissection. Almost 100 years after Dewey urged us to teach science as a process, too many teachers still teach science like history, English, or social studies.

Despite decades of effort and financial support, very little inquiry-based science has been documented in classrooms (Frechtling et al., 1995; Keys & Bryan, 2001; Woodbury & Gess-Newsome, 2002). Ron Anderson (2003) and others assert that most teachers don't even know what inquiry is, nor do science educators agree on a definition (Abrams & Southerland, 2003; Moss, 2003; Settlage, 2003). A potential answer for why

teachers are unfamiliar with inquiry: inquiry is not how the teachers *learned* science (Anderson, 2003; Granger & Herrnkind, 1999; Lappert, 1996). This study specifically investigates this potential answer. This longitudinal study followed teachers through pre-service education and into in-service practice. Both interviews and observations will be used to test the validity of this "possible answer".

Another popular criticism of modern day science teaching is that "science teachers should spend more time using inquiry-based instructional strategies in problem-solving contexts, and less time in didactic presentations of facts" (Southerland, Gess-Newsome, & Johnston, 2003). This longitudinal study will help illuminate this as an accurate portrayal of current science practice or as a misconception.

Even if this study should show that inquiry-based science is not being accomplished in every lesson, does this mean that our schools are failing to meet national goals? No. Although inquiry-based science is important, this "does not imply that all teachers should pursue a single approach to teaching science" (NRC, p. 2). The NRC recognizes that an inquiry-based approach may not be developmentally appropriate for students who lack particular skills and may be unsuitable for certain types of content.

Examples of Inquiry-based Practices.

Traditionally, critical thinking has been embedded in the application of various science processes. Schwab (1962), for example, wanted instructional labs to offer opportunities for miniature scientific investigations. To that end, he proposed that teachers present lab problems at three levels for the purpose of developing an orientation to inquiry. At the first level, teachers present problems not discussed in the

text, with descriptions of different ways to approach the solution. At the second level, teachers pose problems without methodological suggestions. At the third level, teachers present phenomena designed to stimulate problem identification. Each level requires more facility in using process skills than the previous level.

What are the Barriers to Inquiry Teaching?

Long before "No Child Left Behind" research has shown that external testing reduces teacher morale and interferes with effective instruction (M. L. Smith, 1991). Professor Smith writes in her article: "From classroom observations it was concluded that testing programs substantially reduce the time available for instruction, narrow curricular offerings and modes of instruction, and potentially reduce the capacities of teachers to teach content and to use methods and materials that are incompatible with standardized testing formats." Clearly research showed that high stakes testing was not a very good idea almost ten years before "No Child Left Behind" (Bush, 2008).

External testing is not the only source of resistance to teachers using inquiry in their classrooms. High workloads are common in many professions, yet it is particularly detrimental in school settings. The leading causes of stress for teachers are large class size, number of classes taught, and percentage of class time spent in areas outside a teacher's certification area (Rees, 2007). In addition, single-cell classrooms (the kind most pervasive in the United States) tend to increase teacher workload through duplicating effort when enacting reforms (Timperley & Robinson, 2000). Stressed teachers are less likely to institute reform measures (Livingstone, 1994). Even

more serious is that high teacher workloads are a leading cause of teacher attrition (McKinney, Berry, Dickerson, & Campbell-Whately, 2007). High teacher workloads are barriers to any reform effort, not just the effort to incorporate science inquiry in the classroom. Furthermore, high teacher workloads are systemic throughout the continuum of teaching, crossing all grades and subjects (Butt & Lance, 2005; Garfield, 2008; Johnstone, 1993; Reyes & Imber, 1992). Clearly, before any reform measure (including teaching science through inquiry) can be successfully implemented, this very serious problem needs to be remedied.

Class size is the main component of teacher workload (Gilbert, 2008). Small student to teacher ratios results in increased academic performance, less disruptive behavior and fewer disciplinary referrals (Education, 2001). The Educational Policy Studies Laboratory goes on to say that student engagement--having both behavioral and affective elements--is essential to learning and that disengagement from learning in both behavioral and affective forms is especially problematic among students at risk. “Small classes, by their nature, promote student engagement in learning and provide the conditions for teachers to encourage student engagement further, if they wish”.



Educational Policy Studies Laboratory

Figure 2.2 Educational Policy Studies Laboratory

Large class sizes also interfere with science laboratory experiences (Report, 1998). Because inquiry-based teaching instruction is heavily reliant on laboratory experiences, large class sizes clearly pose a barrier to inquiry-based classroom instruction.

Discipline problems have a strong correlation to large class sizes (Finn & Achilles, 1990). In a science class, disruptive students can pose even a greater danger to themselves and others in the laboratory setting (Rice, 1999). The correlation between high student to teacher ratios and discipline problems is not just an American problem but has been documented internationally (Akiba, LeTendre, & Scribner, 2007; Desimone, Smith, Ueno, & Baker, 2005; Kang & Hong, 2008). High student to teacher ratios do not always result in discipline problems, but the environment is more conducive to it. Small class sizes promote greater individual accountability and usually produce higher student performance (Luiselli, Putnam, Handler, & Feinberg, 2005). Discipline problems may also be the result of an inappropriate instructional strategy with the student population served (Kohn, 1992). The irony is that many teachers in this study believe that they can't use inquiry in their classroom setting due to the disruptive nature of the students. According to Alfie Kohn, that is the exact time you need to change instructional strategies.

Student ability is another commonly cited reason for not using inquiry in the science classroom. Ample studies have shown that not all middle school and high school students are reading at grade level (Donahue, Voelkl, Campbell, & Mazzeo,

1998; Holt & O'Tuel, 1989). A positive relationship has been shown with students who read at least two grade levels below normal and who have serious emotional disturbances in secondary schools (Wagner, 1995). It is still unclear if poor reading skills causes serious emotionally disturbed students or if the emotion disabilities of these students result in poorer reading test scores (Worling, Humphres, & Tannock, 1999). Teachers in this study have cited disruptive behavior, poor reading ability and emotional disabilities as reasons for not using inquiry.

Administrative demands also present cause for teachers not to employ inquiry in science classrooms according to my research. Large, overcrowded schools produce students with below average reading scores (Fowler & Walberg, 1991). Studies have shown that with respect to education, bigger is not better (with respect to schools) (Dworkin, 1987). In addition, all first year teachers struggle with stress just trying to cope with just the demands of teaching (Schaufeli, Maslach, & Marek, 1997) . Many administrators also require these early induction teachers to be on committees, coach, do hall/lunch monitoring, host clubs, chaperone dances/events, call parents of students with poor attendance and countless other duties (Darling-Hammond & Baransford, 2005). But arguably the must detrimental barriers administrators place in the way of teachers who want to use inquiry in the science classroom are high stakes tests (M. G. Jones et al., 2003). These external tests demand from students the rote memorization of volumes of trivia (Wright & Wright, 2007).

Any educator will tell you that the fastest way to disseminate information is through the lecture process. With the end of course (EOC) tests having more and more material added to them every year, many teachers feel that the only way for them to "teach" the morass of information is through lecture (Felder & Brent, 1996). In the age of the internet where trivia is just a mouse click away, developing minds to memorize facts runs contrary to society's needs and the needs of our nation(Dede et al., 2005). With computers and robotics becoming more capable everyday of managing the tedious, redundant tasks of everyday life, creativity and innovated thought is what is needed in the workplace of today and tomorrow (Schoenfeld, 1999). Creativity and innovative approaches to problems solving is the strength of inquiry-based science instruction (Bybee, 1989; Windschitl, 2002).

Because teachers are acutely aware of the importance of the end of course tests, another interesting, unintended consequence of high stakes testing has occurred: little or no equipment shortages (Bradford, 2005) . For years, teachers would cite lack of equipment as being a compelling reason for not having more laboratory experiences in science (Henriques, 2002). Today, the laboratory experience isn't tested for on EOC tests and consequently has been removed from many science classroom experiences (Veal, Meban, & Randolph, 2006). Many science teachers are actually grateful for this shift because it's one less stressor in their job (Watson, 2006). Virtual labs have become more popular with no set-up or clean up time required by the teachers (Escalada & Zollman, 1998). The technology that today's science teachers are asking

for are not more test tubes, lasers, or electrophoresis panels, but smart boards, computers, and projectors for computers (Wiesenmayer & Koul, 2004).

Perhaps the most menacing barrier to inquiry teaching in the science classroom is the cultural resistance pervasive in many schools today. The "No Child Left Behind" policies of recent years has lead to a high stakes testing environment (Bush, 2008). This environment in turn has caused teachers to focus strictly on the items found on the end of course exam (Shaver, Cuevas, Lee, & Avalos, 2007). Because of the large volume of information the students are responsible for knowing, lecture has become the preferred method of instruction (Gross & Hickman, 2007). As a result, inquiry-based instruction has been relegated to little more then a pre-service educational science exercise for most teachers (Fruge, 2007).

What is High Stakes Testing?

High stakes tests are "any testing program whose results have important consequences for students, teachers, schools, and/or districts. Such stakes may include promotion, certification, graduation, or denial/approval of services and opportunity" (Allen, 2006). This dissertation is concerned specifically with high stakes testing that may result in "retaining a child in grade or withholding a student's high-school diploma solely on the basis of their score on a test, or relying on test scores to determine whether a teacher or school should be sanctioned or rewarded" (K. Jones, 2008).

To the uninformed or less sophisticated, using a test to determine if a student is promoted, or if a teacher retains their job, or if a local school board retains control of a district may seem like an obvious and simple solution. But this solution has two problems: the test and the people taking the test.

In North Carolina, the standardized tests are multiple choice exams. The format of the testing instrument greatly limits what can be tested. For example, students may miss an answer altogether on the multiple choice test, when they might have accurately and eloquently answered had an essay test been used. These standardized tests have been shown to be racially biased (Boger, 2002). "While 87% of White and 85% of Asian students passed both Gateway Exams in 2001, only 62% and 67% of African Americans and Hispanics, respectively, met the same standard. These differential performances among racial/ethnic groups are substantive, especially given the fact that Spring 2001 marked the first year the fifth grade exams were used for promotion decisions" (Horn, 2003). Furthermore, students with disabilities are discriminated against with the use of these types of tests (K. Jones, 2008). Many students have learning, emotional, and mental disabilities severe enough that concentrating for even twenty minutes would be outside the realm of possibility. With imperfect people taking an imperfect exam, is it fair to have such severe consequences determined by the outcome?

Yet, high stakes testing continues to spread in popularity as Americans call for accountability from schools. Amrein and Berliner (2002) gathered comprehensive

evidence from 18 states using high-stakes testing to suggest that in all but one analysis, student learning was indeterminate, remained at the same level as before the policy was implemented, or actually went down after the testing policy was instituted (Amrein & Berliner, 2002). “These high-stakes tests, then, may be increasing risks with no increased benefits to student learning” (Horn, 2003).

Many professional educational organizations have spoken out strongly against the use of a single test score for promotion and/or graduation of students. The American Evaluation Association (AEA) recently released a position paper stating, "High-stakes testing leads to under-serving or miss-serving all students, especially the most needy and vulnerable, thereby violating the principle of `do no harm'" (Mabry et al., 2002). Basing its position on the 1999 Standards for Educational and Psychological Testing, the AERA writes, "Decisions that affect individual students' life chances or educational opportunities should not be made on the basis of the Test scores give us important information, but they do not give us all the information necessary to make critical decisions” (AERA, 2002)

North Carolina

Approved by the state in 1999, the North Carolina Board of Education passed sweeping reforms requiring increased accountability at the student level (Burr, 1999). Although the state already had structures in place to evaluate schools (e.g., The ABCs

of Public Education), these new reforms marked the first time the state implemented high-stakes testing for elementary and middle school students (McMillan, 1999).

How It Works

Students receive a scaled score and a corresponding achievement level ranging from I (student does not have sufficient mastery to be promoted) to IV (student performs beyond what would be expected to be promoted) Students in grades 3 through 8 participate in Gateway Exams, a set of standards-based, end-of-grade multiple-choice tests of reading and mathematics, in order to be promoted from grades 3, 5, and 8. High school students also have to pass an exit exam to graduate from high school. In order to ensure that students are working at grade level in reading, writing, and mathematics before being promoted to the next grade, fifth graders are required to pass reading and math Gateway Exams for promotion. It is important to note, however, that principals have overriding power to make promotion and retention decisions (DPI, 2000).

Below is a table of links with the current high school courses that have EOC tests (NCDPI, 2008).

Table 2.1 Hyperlinks to North Carolina End-of-Course Tests

North Carolina End-of-Course Tests		
Algebra I	**Algebra II**	**Biology**
Chemistry	**Civics & Economics**	**English I**
Geometry	**Physical Science**	**Physics**
U.S. History	**OCS**	

The scores from every EOC course at every school are then posted on the North Carolina Department of Public Instruction Website: http://www.ncreportcards.org/src/.

At small, rural high schools where only one teacher might be teaching a course, local newspapers often print the results of the EOC tests as a service to the community.

"When the state board of education has the power to shut the doors of the school as a result of end-of-grade test scores, there is no local control of education" (Jones et al., 1999). Each state relies on millions of dollars from the federal government provided under title I (Education, 2008). This money is needed to meet the additional educational requirements of students with disabilities. The federal government provides this money because federal law requires states to provide education for all of it citizens (ADA, 1990). If states fail to comply with the accountability requirements of the "No Child Left Behind Act of 2001" (Bush, 2008) gives the U.S. Department of Education the authority to withhold this money if the states fail to meet accountability requirements of the federal government (NEA, 2008).

Consequences of End of Course Testing

Many high-stakes testing policies rest on the belief that attaching consequences to test scores will persuade students of the importance of academics and will motivate them to exert greater effort to achieve at passing levels. In a Massachusetts study, students were asked to make drawings that convey their feelings about the standardized tests. The findings are revealing:

> *Student drawings conveyed a range of opinions about test difficulty, length, and content. A small minority of drawings depicted students as diligent problem-solvers and thinkers. A larger percentage of drawings portrayed students as anxious, angry, bored, pessimistic, or withdrawn from testing* (Wheelock, Bebell, & Haney, 2000).

First do no harm. This is the creed of all professions and is especially true in education. Yet end of course testing shows that this evaluative practice's harm outweighs the benefits. The following criticisms come from the American Evaluation Association (Mabry et al., 2002).

High Stakes tests:

- *are employed without credible independent meta-evaluation*
- *are flawed, both in technical adequacy and in accuracy of scoring and reporting*
- *promulgate undue centralized control of what is taught and how*
- *channel educational offerings to satisfy monolithic, narrow, test-defined state standards rather than address the differential needs of students in local schools*
- *draw schools into narrow conceptions of teaching and education that leave children deprived of the history, cultural perspective, personal experience, and interdisciplinary nature of subject matter*
- *narrow the curriculum to tested subjects, usually reading, writing, and mathematics and marginalize non-tested subjects, which often include the fine arts, physical education, social studies and science*
- *stimulate teachers and principals to manipulate test scoring and standards, change students' answers, send slow learners away on testing day, or otherwise invalidate test scores*
- *consume a disproportionate amount of student and teacher time that takes away from other valued school goals and activities, e.g., spending as much 30% of the school year preparing specifically for tests*
- *assume that all children, including English language learners and special education students, learn in the same ways at the same rate and that they can all demonstrate their achievements on standardized tests*

- *focus attention on particular students, such as those scoring just below the cut-off score and ignoring those who score well above and below the cut off score*
- *encourage, in direct and indirect ways, students who may not pass the test to stay home on testing days or to drop out of school altogether*
- *measure, for the most part, parental income and race, and therefore perpetuate racism, classism and anti-working class sentiment*
- *contribute to an atmosphere of distrust, fear, divisive competition, and hysteria that is antithetical to teaching and learning*
- *contribute to an atmosphere that pits teachers against teachers, students against students, and schools against schools in a bid for financial rewards and to avoid financial retribution are used unjustly to fire and discipline teachers and principals (p. 2-3).*

These are not just hypothetical concerns. A study conducted by Arizona State University found empirical evidence suggesting that the high stakes tests were flawed. The answers to the questions produced unreliable scores. These scores had direct and damaging consequences for students and teachers. "High-stakes testing produces teaching and testing practices that lead to inflated test scores and further disadvantage already disadvantaged students" (M. L. Smith & Fey, 2000).

Perhaps the most extensive report high stakes testing was conducted by the Great Lakes Center for Education Research & Practice. The study concluded that high stakes testing cause's corruption of the educational system. "Educators are trying either to win or not to lose in high-stakes testing environments, by manipulating the indicator for their own benefit. Some do this by pushing the weaker students out, or letting them drop out without helping them stay in school" (Nichols & Berliner, 2005). Thus the test scores of some schools were made to rise artificially. The most distressing finding

was the total abandonment of an ethic of caring. Students became little more then a score.

This behavior demonstrates teachers' and administrators' abandonment of an ethic of caring. For many teachers, this ethic is what brought them to teaching in the first place. Jones (1999) writes "The idealistic intentions that usually bring people into education -- a desire to make some contribution to a better world, to improve the lives of kids, to offer a caring environment to children, and so on -- become perverted by the limited pursuit of higher test scores and the crass exploitation of a few extra dollars for achieving "better" results" (Jones et al., 1999). The ethical dilemma caused by high stakes testing forces many of these fine teachers to leave the profession (Nichols & Berliner, 2005). This 190 page report concludes with the following:

> *The scores we get from high-stakes tests cannot be trusted—they are corrupted and distorted. Moreover, such tests cannot adequately measure the important things we really want to measure. Even worse, to us, is the other issue—the people issue. High stakes testing programs corrupt and distort the people in the educational system and that cannot be good for a profession as vital to our nation as is teaching. We need to stop the wreckage of our public educational system through the use of high-stakes testing as soon as possible (p. 180).*

What does the Literature say with Respect to High Stakes Testing and Inquiry?

One of the most pre-eminent educational philosophers of our times, Howard Gardner, asks us the following questions:

"What does it mean to be educated in a discipline where one learns to think like a scientist, a mathematician, an artist or an historian? What is meant in the

disciplines to pursue the meaning of truth and its equally important opposite, what is false or what is indeterminate? What is beauty and its equally important opposites, ugliness or kitsch (Gardner, 1999)?" Gardner challenges us to think of what it means to deal with what is good and what is evil in this world. After we engage in these exercises, Gardner asks if high stakes tests are designed to measure these things, or are they are likely to miss them completely.

"High-stakes testing holds in high regard a narrow bundle of knowledge and skills. This creates a context in which conversations about the meaning and value of education cannot take place without performance on standardized tests taking center stage. When the default philosophy of education dominates in a school, school district, or state, the possibilities for improving education reform and innovation are limited" (Gunzenhauser, 2003).

A good example of this is found in a research study that uses multiple choice assessments to evaluate an inquiry-based curriculum. "The focus classrooms consisted of three classrooms from urban teachers in high-poverty environments and two classrooms from maverick teachers in middle-class suburban environments. The work presented builds on a multiyear effort to study the implementation and adaptation of *Kids as Global Scientists* (KGS), an inquiry-based, technology-rich middle school learning environment. In all cases, successful classrooms were defined as those where students made significant positive gains on open-ended and multiple-choice assessments" (Songer, Lee, & McDonald, 2003).

In 1997, the relationship between high stakes testing and the teaching of science was investigated through the case studies of two school districts in British Columbia (Canada). Interviews and observation with 80 teachers, their principals over 100 students, and some district personnel in grades 8, 10, and 12. This very extensive study showed that examinations discouraged teaching that promoted inquiry and active student learning (Wideen, O'Shea, Pye, & Ivany, 1997).

Colorado instituted high stakes testing state wide in 2000. The state commissioned an independent study by the Center for Research on Evaluation, Diversity and Excellence University of California, Santa Cruz and Center for the Study of Evaluation National Center for Research on Evaluation, Standards, and Student Testing Graduate School of Education & Information Studies, University of California, Los Angeles. At the time, Colorado was only high stakes testing in reading and math. After interviewing over 1,000 teachers, the report found that instruction was "shifted away from social studies and science" to increase the "time spent on test format practice" (Taylor, Shepard, Kinner, & Rosenthal, 2003). The report goes on to say that the state wide testing "lowered faculty morale".

Another recent study found that when elementary school teachers were faced with standardized testing in science, they had this to say about the reform: "This recognition is not borne out of the importance of science learning for elementary school children, but rather out of fear of failure and the effects of tangible rewards or punishments that accompany high-stakes testing" (Pringle & Martin, 2005). If teachers

are stressed and intimidated by a test, it's likely that this apprehension would be seen in their teaching. Other studies have found that many elementary school teachers were intimidated by science even without high stakes testing (Bryan & Abell, 1999; Craven & Penick, 2001; Fulp, 2002).

Another concern is that states that use standardized tests "may over emphasize social issues rather than scientific ones" (Flick & Lederman, 2006). These authors (Gummer and Champagne) provide specific examples using documents from New York, a state with a long history of standards and high stakes testing. Gummer and Champagne point to "the inconsistency of images in instructional tasks with the nature of scientific inquiry in state standards" (Grummer & Champagne, 2004). Not surprisingly, many authors find inquiry-based science teaching practices at odds with high stakes testing (Bybee, 1997; DeBoer, 2002b; M. L. Smith & Fey, 2000).

"Some scholars have expressed concerns that, as a result of high-stakes testing, teachers could lose their own ability to be creative planners and thinkers (Darling-Hammond, 1991; Madaus, 1991; Monty & Medina, 1989). When teachers teach only what someone else has prescribed and when that prescription involves only one right answer, the teacher becomes what Mary Lee Smith has called an unskilled worker (M. L. Smith, 1991). During an interview, one teacher in this study was asked "What is your role as a teacher?" He responded "a robotron". When asked "How do you decide what to teach and what not to teach, he says "End of Course Test, Standard Course of

Study, and Pacing Guide in that order". In North Carolina, teachers are directed through a pacing guide exactly how a lesson will be taught and how much time will be spent teaching it (Lamb, 2008). These and other concerns lead to questions about what teacher education students carry with them and retain in the classroom, both during the induction years and later, as experienced teachers.

Thus, this dissertation uses data from a large study. The following is a short description of this much larger and deeper research project. Several instruments were used in project IMPPACT, but this dissertation only analyzed data collected from interviews and observations.

This Dissertation is Part of a Larger Study (IMPPACT)

This dissertation is part of a larger, NSF – funded study known as Project IMPPACT (**I**nvestigating the **M**eaningfulness of **P**reservice **P**rograms **A**cross the **C**ontinuum of **T**eaching). The five year longitudinal study receives $2.5 million of support between 2005 and 2010.

- 2005-2006 academic year was the pilot study.
- 2006-2009 academic years, full scale data collection
- 2009-2010 academic year, data analysis and dissemination

Although project IMPPACT used many instruments, collected student work product, teacher lesson plans, transcripts, university instructor's syllabus and administered standardized tests to students, my dissertation only used a small part of

the data collected. A more complete description of Project IMPPACT can be found in Appendix 19. In order to answer the research questions posed in this dissertation, only the following data sources were used from project IMPPACT:

(1) Interviews with university faculty

(2) Portions of the pre-service interview

(3) Portions of the beliefs interview

(4) Observations of university faculty

(5) Observations of teachers

The observations were coded using RTOP. The beliefs interviews were coded using a rubric developed and publish by Julie Luft and Gillian Roehrig. What follows is a detailed discussion of why project IMPPACT decided to use these two coding instruments.

Project IMPPACT Decided to Use RTOP

Developed by the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT), the RTOP took over five years to create (1995-2000) (MacIsaac & Falconer, 2002). With the support of the National Science Foundation, ACEPT brought many entities together: Arizona State University, Northern Arizona University, University of Arizona, Community Colleges and pre-college educational establishments. At ASU, the collaborators came from Biology, Chemistry, Geology, Mathematics, Physics, Liberal Arts and Education (Pilburn et al., 2000). With representatives from all of these different disciplines, general characteristics of

inquiry-based instruction where defined. 37 questions where developed in the original instrument to identify these characteristics during an observation. After field testing and further review, this number was reduced to 25 questions.

Project IMPPACT decision to use RTOP was only made after looking at many different instruments One instrument was developed by David Treagust. Designed to measure the number and types of analogies science teachers use in classroom instruction, it was far too specific for project IMPPACT purposes (Treagust, Duit, Joslin, & Lindauer, 1992). Another instrument that the project could have used was developed by Nancy Brickhouse and measured a wide range of science teacher practices (Brickhouse, 1990). It measured so many factors, that it would have been very difficult to standardize all of the researchers on the project to code reliably. Another strong contender for the project's observational coding instrument was produced in the Netherlands. This instrument measured the pedagogical content knowledge but had a complicated scoring system involving weighting certain scores (van Driel, Verloop, & de Vos, 1998).

The RTOP has several advantages over other instruments that measure teacher *practice*: First, it has excellent psychometrics For example; the reliability using physics and math classes yields an r^2 of 0.945. Construct and validity was determined by using 16 instructors: 6 mathematics, 6 physical science and 4 physics. Each of these 16 instructors used this instrument in several of their classes. This respectable

sample size showed r^2 score in Table 2.2. This offers very strong support for the construct validity of RTOP.

Table 2.2 RTOP Subscale R-Squared Values

Name of Subscale	R-Squared
Subscale 1: Lesson Design and Implementation	0.915
Subscale 2: Content-Propositional Pedagogic Knowledge	0.670
Subscale 3: Content-Procedural Pedagogic Knowledge	0.946
Subscale 4: Classroom Culture – Communicative Interactions	0.907
Subscale 5: Student/Teacher Relationships	0.872

The Predictive validity was determined through comparing RTOP and Normalized Gain scores of six college physical science class (Pilburn et al., 2000). The correlation between RTOP scores and normalized gain scores for six college physical science class was 0.88. Despite small sample size a correlation of this magnitude is significant at the 0.01 level.

Second, it measures only one thing: reformed based teaching practices. Therefore it doesn't muddy the water with other measures. Third, it is easy to use. It asks only 25 questions about an observation and scoring is on a simple five point Likert scale. Lastly, the instrument is easy to score. Simply add up all the points: No formulas to use or adjustments to make.

The RTOP rates participants on a 0 to 100 point scale (Piburn et al., 2001). Zero to 50 indicates a traditional style of instruction. Scores of 51 or greater indicates reformed teaching practice (MacIsaac & Falconer, 2002). By answering 25 questions, (trained) math and science teacher observers can rate other math and science teachers using this instrument with tremendous accuracy ($r>0.89$) (Pilburn et al., 2000).

The 25 items that the RTOP uses to rate observed math and science teachers are categorized as follows. Questions 1-5 address lesson design and implementation. Questions 6-15 address content. This area is broken down into two subsections: Questions 6-10 address propositional knowledge and Questions 11-15 address procedural knowledge. Questions 16- 25 look at the classroom culture and are broken down into two subsections. Questions 16-20 look at communicative interactions and questions 21 – 25 look at student/teacher relationships. So the 25 questions are broken down into five areas of interests with five questions in each area (Table 2.3).

Table 2.3 RTOP Items, Question Numbers, and Scoring

RTOP Items	Question Numbers	Scoring
LESSON DESIGN AND IMPLEMENTATION	1-5	0-4
CONTENT		
PROPOSITIONAL KNOWLEDGE	6-10	0-4
PROCEDURAL KNOWLEDGE.	11-15	0-4
CLASS ROOM CULTURE		
COMMUNICATIVE INTERACTIONS	16-20	0-4
STUDENT/TEACHER RELATIONSHIPS	21-25	0-4

Each item (question) is evaluated on a five point scale (zero through four): zero if the item was never seen during the observation and four if it was observed constantly. By designing the instrument in such a way, the RTOP is very easy to use. It has five categories, and each category has five questions that are rated on a five point scale. The scorer simply adds up all the points for an overall score that rates the math or science teacher from 0 to 100 point scale for reformed teaching *practices*. A researcher can quickly and easily identify in which of the five categories the observed

math or science teacher was strongest and weakest in demonstrating inquiry-based *practices*.

The major drawback of the RTOP is that some of the items are rather ambiguous at first glance (Appendix 1). Take, for example, item 6: "The lesson involved fundamental concepts of the subject." This is clearly a subjective statement. What one person considers fundamental, another may see as in-depth. It depends on the audience. Or item 14: "Students were reflective about their learning." How is an observer to recognize a student's mental process of reflection? In addition, many of the questions on the RTOP are compound questions. Particular attention must be given to "and/or" statements like in question 12: "Students made predictions, estimations and/or hypotheses and devised means for testing them". This item has an "and/or" in the first part and in order for the statement to receive a high mark on the RTOP, the "and" statement in the second part has to be met. It is complicated enough that observers must be trained in how to use RTOP before observing. The best way to get training is to attend a class on RTOP offered at AAPT, NTSA, NARST or ASTE conferences. The classes begin with a room full of math and science teachers who agree on the scoring of very few RTOP items. But with practice and comparing answers to those of experts, within just four hours, the observers are all scoring the RTOP with tremendous agreement to those expert scores. A website exists to provide information on using the instrument: http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/index.htm. Although the

RTOP training class uses much of the material available online, it's amazing to witness the transformation of teachers in an in-person training class. Typically teachers begin the class scoring RTOP forms with a wide variance. But after just a few hours of practice and guidance, teachers are filling out RTOP forms with amazing agreement.

Of the many reasons that project IMPPACT elected to use this instrument, its unparallel inter-rater reliability was the most persuasive. Project IMPPACT was going to be conducting research at three different universities in three different states. It was imperative to find an instrument that could produce scores that were similar with completely independent coders. I picked this instrument for my dissertation because it rating system seemed to be closely aligned with the National Science Education Standards (1996 & 2000). Furthermore, my interest is with investigating the use of inquiry-based instruction in science and RTOP measures exactly that.

Project IMPPACT Decided to Use Guided Interviews

There are many types of interviews that qualitative researchers use: "face to face", "telephone", or "video conference". The advantage of telephone interviews is convenience for both the interviewer and interviewee. The big disadvantage for telephone interviews are that they must be kept relatively short or people feel imposed upon (Valenzuela & Shrivastava, 2008). Questions about individual's beliefs typically don't yield short responses. Video conferencing type interviews were attempted by the

project, but proved to be too technically complicated for most schools techs and librarians. Face to face interviews were selected.

Because project IMPPACT was planning on using several different surveys (questionnaires), the interview questions had to (1) avoid repeating questions that were already being asked in the surveys, and (2) focus on the types of questions that don't have "quick" answers. At first the interviews were designed to be almost informal and conversational. Very broad and rather vague questions were asked during the pilot study interviews. By the first summer meeting of the project, it was clear that at minimum a guided interview would have to be used if any viable information was to be acquired. By the following summer meeting (2007), the interviews became structured. All research associates underwent additional interview training. The questions were reworked and modified. Although all of the questions remained open-ended in the "beliefs" and Nature of Science (NOS) interviews, the interview formats was standardized and became highly structured.

By the summer of 2008, the transcripts revealed that something in the interviews was missing. With all of the research associated concerned about standardization, no one was probing very much. All the researcher associates were sticking very close to the structured interview and important, natural follow-up questions were not being pursued. In addition, the interviews had a strange awkwardness to them. The conversational flow that the year before last interviews had was totally absent. The "beliefs" and "NOS" interviews were once again reworked.

Question sequence was revisited and wording examined. Some new questions were added to smooth the transitions from one area of discussion to another. But the most important change was in the interview training. For the first time, coding rubrics were developed by and for the research associates. The research associates, for the first time had some idea of why we were asking these questions. This shifted the interview training objectives to developing techniques to prevent interview bias. The most effective technique was to make the interviews semi-structured and guided.

Interview and Coding Limitations

The questions for the "beliefs" interview originated with the Teachers' Pedagogical Philosophy Interview (TPPI) (Richardson & Simmons, 1994). The rubric that project IMPPACT used to code the responses was developed by Julie Luft and Gillian Roehrig (Luft & Roehrig, 2007). The coding rubric allows researchers to scale participants as traditional, instructive, transitional, responsive, or reformed with respect to inquiry-based teaching *beliefs*. This five point response scale rubric corresponds very well with the RTOP. By having a semi-structured interview, not only was standardization assured but by allowing follow-up questions where the participants completely explain their positions, accuracy and insight was obtained. Unfortunately, many of the questions on the RTOP, if asked of a participant before an observation, would certainly cue the participant about what the observer is looking for in an observation. This could be overcome, in part, by asking additional questions that

may seem pertinent but are not relevant to the RTOP. This is what was done with the beliefs interview.

Even with the fine grain analysis that interviews can provide, there are drawbacks. Interviews are sometimes difficult to schedule, and technical difficulties with recording equipment arise. In addition, interviews are usually transcribed, which may introduce errors. The transcription process doesn't always capture the tenor, tone or sarcasm that the subject may be using. The loss of voice inflection during the transcription process may lead to erroneous interpretations. This is why transcriptions are considered secondary data sources by qualitative researchers (Marshall & Rossman, 1998).

Specific Research Issues

Using a Camera in the Classroom

Does using a camera in the classroom affect either the objectivity or validity of the data?

The purpose for video recording classroom observations is so that a second educator who had been trained in the use of RTOP could complete a second coding. By having two observers code independently the same lesson, scoring comparisons could be made. Video observations were also traded between sites and scored. These RTOP scores allowed inter-rater reliabilities to be calculated between and within sites. Those observations that produced wide disparities in scoring were examined during the summer leadership meetings and continued training produced consensus scoring.

The primary reason for selecting RTOP was because of RTOP's high reliability. RTOP is dependent on video recorded observation so that other video evaluators can score the observation. If one observer was to use the field notes of another observer to score an RTOP, not just the reliability but the very validity of the RTOP instrument would be questionable.

The presence of a camera does have an effect on most human interactions (Wiemann, 1981). Perhaps the most widely known and cited example is that of the "Hawthorn Effect." The term "Hawthorne effect" refers back to a series of experiments on managing factory workers carried out in the 1920's. The experiments took place in the Hawthorne works of the Western Electric Company in Chicago. Basically, a series of studies on the productivity of some factory workers manipulated various conditions (pay, light levels, rest breaks etc.), but each change resulted on average over time in productivity rising, including eventually a return to the original conditions (Gillespie, 1991). This was true of each of the individual workers as well as of the group mean (Draper, 2008). One interpretation, mainly due to Mayo, was that the important effect here was the feeling of being studied: it is this that is now referred to by "the Hawthorne effect"(Mayo, 1933).

Because of Dr. Mayo's study, all researchers are aware of the fact that being a participant in a study will cause behavioral differences. An almost standardized practice these days is to video record college students preparing to become teachers (Lotter, 2004). So arguably, teachers should be less threatened then the average person

being video taped in their work environment. Yet Dr. Sorrel Penn-Edwards made the following salient observations about video recording teachers:

> *It cannot be denied that the introduction of unannounced and unusual activity into a setting arouses interest, which may occasion disruptive behavior, although researchers seen to be making written comment during similar events have proven more so. The convergence of a camera lens upon a subject being video recorded is often received by that individual with misgivings, if not suspicion, that the editing of resultant images may distort what was believed to have been originally presented to the camera. Whether the recording position is exposed or unobtrusive, the very fact it exists and a process may be in train, affects subjects with respect to their behavior even if they are convinced their behavior patterns are constant and normal. To varying degrees, there is a conscious awareness of a potential audience or video recording's purpose, which influences the way the recorded event is constructed and conducted, the verbal form, dress style and body language. Some teachers, for example, in a classroom situation, are reported as believing that awareness of being video recorded affects their typical performance (p. 274)* (Penn-Edwards, 2004).

To attempt to overcome these disadvantages, video recording equipment is sometimes hidden behind a one-way mirror or hidden, the recording being made only at times agreed between the parties and indicated by a recording light (Davis, Maher, & Martino, 1992). "A more preferable practice (on the principle of familiarity breeds contempt) is to assemble and place the video recording equipment in full view of the subject, and introduce the activity and roles of the crew (particularly to children) so that curiosity is diminished and allow a lapse in time for a return to normal behavior before commencing recording. The lower profile also negates the natural precociousness of some children in front of a camera" (Penn-Edwards, 2004).

How Does Using a Camera as a Recording Device for Interviews Influence the Data?

Many of the same influences mentioned above apply to video-recording interviews. One distinct difference is that subjects should be assured that if at anytime during the interview, they should feel uncomfortable, the camera will be turned off (Bottorff, 1994). This was important because the primary purpose of the interviews in this study was to gain insight into teacher beliefs. The information that we were seeking was both personal and sensitive. Participants had to be assured that everything they said would be held in confidence and that their anonymity was secure. The subtle differences in participant beliefs often required the interviewer to probe deeper into a response and to afford generous wait times as participants carefully reflected on their beliefs (Gillham, 2004). It appeared that many of the younger participants were actually formulating their beliefs for the first time during the interview. Many of these interview questions were designed to solicit much more than factual information. The questions were designed to elicit the personal and private values that define the very self-image of these individuals as teachers.

For this reason, a location that was comfortable and familiar for the participant was imperative (Hammersley & Atkinson, 1995). Most of the interviews were conducted in the teacher's own classroom. In this place, the participant is the authority and it places them in the physical location relevant to the questions we are asking about. Unfortunately, some research assistants elected to conduct interviews in noisy restaurants that not only adversely affected the strength of the responses, but made

transcription difficult (Ritchie & Lewis, 2003). But overall, the interviews were very enlightening and will provide a fine grained resolution to many of the beliefs newly inducted and experience teachers hold true.

What Does The Literature Say About Observing For Inquiry

Drayton asks one simple question to determine if a science classroom is inquiry oriented: Does the classroom reflect a focus on the teacher as broadcaster to student receivers, or is it a work area in which the teacher is supporting students' hard intellectual work? The inquiry-oriented classroom has many tools and instruments around—some in current use, some used a few times during the year, and some used only when need or interest arises (Drayton & Falk, 2001). This article claims that the look of a science classroom is a "tell tale" sign that inquiry is in use.

Other authors are not so sure that simply observing a classroom arrangement is enough evidence to claim that inquiry is being taught. Chinn and Malhotra made these observations, interpretations and state the following conclusions:

> *An important goal of science education is to foster the development of epistemologically authentic scientific reasoning. The ability to reason well about complex models of data is essential not only for scientists but for nonscientists as well. All citizens need to be able to reason well about complex evidence such as evidence relating to health and medical decisions, evidence relating to social policies upon which citizens vote, or evidence relating to the best way to promote employee motivation and satisfaction. Learning an oversimplified version of scientific reasoning will not help on such real-world reasoning tasks. Indeed, when students learn an oversimplified, algorithmic form of scientific reasoning in school, they are likely to reject scientific reasoning as*

> *irrelevant to any real-world decision making (Chinn & Malhotra, 2002).*

But the most definitive literature for observing inquiry is a subsequent publication of the National Science Education Standards (National Committee on Science Education Standards and Assessment, 1996), the "Inquiry and the National Science Education Standards: A Guide for Teaching and Learning"(Council, 1999). Both of these publications are produced by the National Resource Council and give lengthy descriptions of the elements of inquiry-based instruction. Many of those elements were described in the first few pages of this chapter.

What Does the Literature Say about Measuring for Inquiry?

Anderson (O. R. Anderson, 1976) identified four goals when designing a laboratory experience:

> (1) to foster knowledge of the human enterprise of science so as to enhance student intellectual and aesthetic understand;
> (2) to foster science inquiry skills that can transfer to other spheres of problem-solving;
>
> (3) to help the student appreciate and in part emulate the role of the scientist; and
>
> (4) to help the student grow both in appreciation of the orderliness of scientific knowledge and also in understanding the tentative nature of scientific theories and models.

These goals should be measured for in any study for which scientific inquiry is being researched. Not just because on science educator says so, but because these goals agree well with the National Science Education Standards (1996) even though they were written 20 years before the standards. Further evidence for measuring

inquiry in the science classroom can be found in a "Review Of The Literature" in an article written by Avi Hofstein and Vincent Lunetta. They feel that the following factors should be measured for when deciding if inquiry is being used in the classroom (Hofstein & Lunetta, 1982):

> (1) Selection and control of variables – describe the students abilities and attitudes
>
> (2) Group size – most labs are best accomplished with small student numbers
>
> (3) Instrumentation – do students understand the validity of their measurements?
>
> (4) Teacher behavior – are the questions open ended, inductive, deductive, authoritative, sarcastic or demeaning?
>
> (5) Laboratory manual – open ended or more step-by-step

A paper in the 2000 conference proceedings of the International Conference of the Learning Sciences (P. 224) claims that it takes three to five years for teachers to become competent in teaching an inquiry-based science class. Furthermore, professional development summer classes greatly aid in the competency (Holbrook & Kolodner, 2000). Perhaps a measure of not just the number of years a teacher has been teaching, but whether or not they were teaching an inquiry-based science class should be considered when measuring for inquiry.

Another pertinent question to ask is whether the participant has taken a professional development summer school class or workshop in inquiry-based science instruction since graduation. Jonathan Supovitz and Herbert Turner found strong

correlations between the attendance of teachers in professional development classes and improvements in their teaching practices (Supovitz & Turner, 2000).

Although inquiry is considerably more flexible with respect to various teaching approaches than traditional teaching practices, it certainly doesn't mean that qualities that define inquiry-based science teaching practices aren't measurable. Clearly, the arrangement of furniture and the kind of equipment found in a science classroom can be a good indicator (Drayton & Falk, 2001), observing the interactions between student and teacher is the best measure for determining if inquiry is being used in the classroom.

Inquiry-based Teacher Education Programs

The Math, Science, and Technology department at this big southeastern university has a rather modest, one line description of what they provide on their website: "The Department of Mathematics, Science and Technology Education emphasizes exemplary teaching, scholarship and service in the context of a university education" (http://ced.ncsu.edu/mste/). What they mean by exemplary teaching is revealed during interviews conducted by this study with a science education instructor who has taught not only Methods I but "Science and Teaching Methods II (EMS 475). This instructor describes his courses (in part) like this:

> *The way I structured it is . . . We had a different topic every day, that we tried to couch it within a science investigation. So, what I would do, is have . . . do some sort of lab activity . . . some type of inquiry activity. For example, if we are focusing on inquiry one day, instead of talking about inquiry, we will do an inquiry activity. So, I will model that for them. Then, we will do*

> *it as if I were teaching it in a science class. I will say either this is like, "This is a seventh grade lesson on using [unintelligible] and simple circuits." Or, a physics lesson, and . . . you know, I tell them the types of students we're working with. Then, I will go ahead and teach that lesson. But, it's a lesson where we take a look at some specific strategies, some specific learning behaviors, we might be talking about, some modeling we might be doing in that class, and really trying to exemplify what that is. So, if we're talking about inquiry, we'll do inquiry materials. If I'm talking about using graphic organizers, I will teach a sample lesson using graphic organizers, like concept maps or something like that, that would be a part of that lesson I would teach. And so, probably in that class, when I'm teaching, probably half of it is hands-on activities, half is discussing what we did and how we did it, in specific topics [unintelligible] like that* (Park, 2006).

Appendix 13-18 shows the science education program offerings and the associated coursework (http://ced.ncsu.edu/mste/science_programs/index.php). Of the 128 credit hours need to graduate, between 36 and 45 of these credits hours need to be in education. In addition to the science teacher education sequence of courses, students are required to complete studies in teaching to diverse populations, schools and communities, general and adolescent psychology. Many of these EMS courses have field components associated with them so that students are not only given the opportunity to work with "actual" school age children, but these interactions are monitored and evaluated by cooperating teachers and university supervisors.

Inquiry-based teacher education programs must not only teach the most current science education epistemology and pedagogy, but must produce teachers who are very knowledgeable in science content. So an exemplary school is one that not only

requires a high number of science education classes and closely related courses that provide solid scaffolding for professional educators, but also incorporates a large number of science content classes as well.

Closing

This dissertation is focused on the use of inquiry in the science classroom. This literature review opened with defining what inquiry is as it relates to science literacy. It provided a brief history of the evolution of science inquiry in the American that culminated with the National Science Education Standards of 1996 & 2000. Next this chapter discussed the barriers to inquiry teaching. Many researchers talked about what teachers perceive as barriers. Some teachers felt that inquiry-based teaching is more time consuming to plan for and therefore not practical. Other teachers felt that the high number of students in their classrooms was not conducive to inquiry. Equipment shortages and student discipline were also reasons given for not using inquiry in the classroom. But the most popular reason cited by teachers for not using an inquiry-based approach to science education was the school culture.

This common response promoted the literature search of high stakes testing. With all that has been written about the "No Child Left Behind" policies of the Bush administration, it was clear that an exhaustive search of the literature would be impossible. Instead, a somewhat detailed study of the high stakes testing program in the state of North Carolina was completed. This review revealed that North Carolina is

leading the country in the implementation of statewide standardized testing. This state exceeds all of the minimums mandated by the NCLB act of 2001.

Because the data used in this dissertation was collected for use in a much larger study, a description of that larger study was presented next. The conferences that project IMPPACT has already presented at were listed. The instruments and the reason why the project chose those instruments were detailed.

Of all the instruments project IMPPACT used in the study, data from just two sources were used for this dissertation: Observations and Interviews. General problems with using a camera in classroom settings were discussed. Specific problems and limitations with using the RTOP to code the observations were delineated. The literature was searched for problems associated with interviewing in ethnographic studies. Significant findings were presented. An exhaustive search was completed on measuring inquiry using interviews and observations.

Lastly, because this study was conducted completely within the state of North Carolina and studied only graduates of this big southeastern university, a brief description of the science education program was provided.

A STUDY OF THE INFLUENCE OF A PRESERVICE SCIENCE TEACHER EDUCATION PROGRAM OVER TIME

CHAPTER 3: METHODS

Introduction

This dissertation is part of a larger, NSF – funded study known as Project IMPPACT (**I**nvestigating the **M**eaningfulness of **P**reservice **P**rograms **A**cross the **C**ontinuum of **T**eaching). To avoid confusion between these two studies, the following paragraph highlights just a few of the data sources used by Project IMPPACT. The next paragraph will describe those elements of IMPPACT that were used to answer the research questions of this dissertation.

Project IMPPACT collected data at different sites in three different states (Tillotson, 2008a). The IMPPACT study seeks to answer broad questions related to teacher beliefs and practice. Specifically, Project IMPPACT was designed to identify the impact of various interventions from both pre-service education and public school culture that might influence science teaching practice. In order to accomplish this task, Project IMPPACT brought to bear a variety of different investigative tools. First, the study used several different semi-guided interviews with internally developed coding rubrics. In addition, IMPPACT uses video of classroom observations in conjunction with the Reformed Teaching Observation Protocol (RTOP)(Piburn et al., 2001) to determine if inquiry or traditional science teaching practices were observed. Participants answered various surveys, some standardized and others created

specifically for the project. The students of the participants were administered a standardized science test (Iowa Test of Educational Development) (ITED, 2008) and several standardized science attitude questionnaires (Scientific Work Experience Programs for Teachers) (SURVEYS, 2008). The professors of participants in pre-service education were interviewed and their classes were observed. These observations were coded to categorize the degree of inquiry they revealed. Even some cooperating teachers of student teachers were interviewed in an effort to identify additional influences that might affect science teacher practice.

This dissertation uses only a small amount of the data gathered between 2006 and 2009 from Project IMMPACT**. Specifically, this study only employed observations and interviews of Research University students, graduates, and faculty**. Thus, unlike Project IMPPACT, this study seeks to answer research questions related only to the graduates of one major university. But, the research questions carry well beyond this region and university.

Research Questions

A. To what extent is inquiry taught to graduates of Research University?

B. To what extent do these graduates use inquiry in their practice?

C. To what extent do these graduates believe they are using inquiry in their practice?

D. Does the use of inquiry by these graduates change over time?

E. What changes in classroom practice can be observed over time?

F. What are the perceived barriers to inquiry-based teaching?

Although the answer to these questions will not claim to have the national or international significance of the research questions posed by Project IMPPACT, they should provide researched based information to improve teaching and learning practices at Research University and elsewhere. Furthermore, the insights gained through this study will give researchers, administrators, university faculty, pre-service, and induction teachers a clearer idea of the meaningful interventions that promote inquiry-based teaching strategies. Lastly, the study will also identify perceived and real barriers to inquiry-based teaching practices.

Design

The complex nature of the research questions posed [in project IMPPACT's study] required numerous tools to be brought to bear on the problem: observations, interviews, questionnaires, on-line surveys, standardized tests, and student surveys (Tillotson, 2008a). As stated earlier, only interviews and observations were used from the project IMPPACT data to answer the research questions of this dissertation. The methods involved in this dissertation study were guided by an ethnographic approach that focused on cultural meanings of participants (e.g. what they said, what they did, and what artifacts they produced) (Spradley, 1979). This method has been useful in identifying beliefs based on environmental influences (Green, Camilli, & Elmore, 2006). The participants in this study progress from a college environment to a public secondary school environment. The different responses to the same interview

questions may be attributed to the difference between the college culture and public school teaching culture.

The study is categorized as mixed-methods because it entails both qualitative and quantitative components. The qualitative research design focused on non-participatory observations (e.g. no interactions with students, teachers or events as they occur) (Marshall & Rossman, 1998). This methodology has been used in numerous studies and is a time honored research tool in identifying actual practice of teachers (Chuah, 2007; Farrel, 2005; MacLeod-Brudenell, Cortvreind, Hallet, Kay, & Walkup, 2004). In some instances, the instructor video recorded themselves. This method is designed to capture the teachers' actual practice and interaction with students.

These observations are made quantitative with the aid of the Reformed Observation Teaching Protocol (Piburn et al., 2001). This instrument is quickly becoming the industry standard for measuring inquiry teaching practice (Hazari, Key, & Pitre, 2003; MacIsaac & Falconer, 2002; Olsen, 2008; Sawada, Piburn, Judson, & Turley, 2002). So rapidly is this instrument growing in popularity that the NSF supported the first national meeting of RTOP users in San Diego in 2005 (Weber, 2005). The RTOP was described in detail in Chapter 2, but will be concisely described here.

Reformed Teaching Observation Protocol

Before RTOP can be used for research purposes, the investigators must complete a training course. Project IMPPACT conducted initial training using the

RTOP in the summer of 2007. Throughout the course of the study, additional videos from other sites were sent to Research University to be coded using RTOP. Research University sent videos to other sites to be similarly coded using RTOP. Syracuse University compared the coded RTOPs from all sites against the project's reliability index. The acceptable error was +/- 1(on the five point Likert scale) for every RTOP item. All research associates would score the same video observation. Then the project director from Syracuse would compile the scores and list the deviation from the most common score for each item on the RTOP for each research associate. Most differences between the scores were resolved through discussions during conference calls. The associate whose scoring was considerably different then everyone else's were asked to complete additional training. The goal was to assure inter-rater reliability within the study. Additional training was given during the summer of 2008 to all research associates. Inter-rater reliability comparisons and remedial training continued through the 2008/2009 data collection year.

In addition to the training provided by project IMPPACT, I also attended a training class offered through the American Association of Physics Teachers conference in Greensboro (2007). The class was taught by one of the creators of the instrument: Kathleen Falconer. I also had the privilege of training other researchers at the Friday Institute in the use of the instrument. I did this with the help of the official RTOP training website:

http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/index.htm.

With the exception of the first day of class observations made of the faculty, all observations in the study were coded using RTOP. Project IMPPACT required at least two researchers to complete individual RTOPs on every observation. So in addition to the observations made of cohort 1 and 2 and the faculty observations (my area of responsibility), I also observed and coded video recordings of cohorts 3 and 4, as well as numerous observations made at other sites (Iowa and New York). At least two research associates independently coded each observation.

The researcher reviews the video tape made of the classroom observation and scores various elements of the classroom interactions. The total RTOP score is between zero and one hundred. Any total RTOP score over fifty is considered reformed or inquiry-based teaching. Any total RTOP score less then fifty is considered traditional. The total RTOP score is on a continuum which is representative of actual teaching practice. Very few instructors are completely inquiry-based in their practice. The same can be said of teachers using direct instruction. Because RTOP permits a total score to be assigned between zero and one hundred, the score is reflective, on a continuum, of how traditional or reformed the practice is. Analysis of these total scores and subscale scores will give a numerical value to the teaching practice observed. RTOP scores will constitute the quantitative portion of this mixed methods design.

The quantitative component of the study was based on the cohort model (Hulley, Cummings, Browner, Grady, & Newman, 2006) where observations are made

on a group of subjects over time. In this case, there was **not just one cohort but four, all being followed simultaneously over time.** The quantitative component of this study is further defined as prospective or longitudinal because the study begins with a group of subjects and follows them over **three years**. This generated significant numerical data in the form of RTOP scores. The analysis of which will provide great insight into the actual teaching practices of science at this big southeastern university.

The qualitative component of this research takes the form of guided interviews (Maykut & Morehouse, 1994). The focus of the interviews was to understand the beliefs and practices of the participants. The open-ended questions helped to guide the discussions with the college students, teachers, and university faculty members in this study. Occasionally, the discussions would go off topic as many qualitative researchers warn (Kvale, 1996; Marshall & Rossman, 1998; Ritchie & Lewis, 2003), but these excursions often result in fertile future research inquiries and current research question insights. For this reason, Project IMPPACT chose guided interviews rather than formal so as to allow the interviewer the freedom to pursue unexpected responses to the questions.

Over two hundred guided interviews were conducted over three years for this dissertation study. Although Project IMPPACT developed coding rubrics for the analysis of the transcripts, these rubrics were not designed to answer the research questions of this dissertation and hence were not used. Instead grounded qualitative

research methods in the form of quotes from interviews will be used to answer the research questions asked in this dissertation (Marshall & Rossman, 1998).

This mixed methods research design uses guided interviews in the qualitative component and RTOP scores in the quantitative component. The interviews will be used to establish the beliefs of teachers with respect to inquiry-based teaching and the video observations scored using RTOP will be used to determine the practice of teachers with respect to inquiry-based teaching instruction.

Research Components

The Interview Component

Interviews were completed with all participants in the study. In cohorts 1-4, an introductory (Appendix 1) and preservice (Appendix 2) interview was administered. If the participants were In-depth, a Beliefs (Appendix 3) and Nature of Science (Appendix 4) interview were administered as well. Hyperlinks to these guided interviews are provided below:

- Introductory: Current form
- Pre-service: Secondary Teachers
- Beliefs: Preservice Teacher Form
- Nature of Science: In-service Teacher Form

The introductory and pre-service interview was only administered once, but the beliefs and nature of science interviews were administered during each data collection

year. A complete list of when instruments were administered can be found in Appendix 19.

Table 3.1 Interview Administration Schedule

Interview Administration Schedule						
Instrument	Fall 2006	Spring 2007	Fall 2007	Spring 2008	Fall 2008	Spring 2009
Introductory Interview	I,II, III, IV					
Preservice Program Interview	III, IV		II	III, IV	I, II	III, IV
Teacher Beliefs Interview	I,II, III, IV		I,II, III, IV		I,II, III, IV	
Teacher Nature of Science Interview	I,II, III, IV		I,II, III, IV		I,II, III, IV	
I = Cohort One II = Cohort Two III = Cohort Three IV – Cohort Four						

Pre-service Participants

Most pre-service participants were interviewed using the introductory guided interview form. In addition, eight cohort 1 and three cohort 2 participants were administered the pre-service, beliefs, and Nature of Science interviews during the 2006/2007 data collection year.

Interviews were normally done in two sessions. In the first session, the introductory and pre-service interviews were administered. The beliefs and nature of science interviews were given during the second session for In-depth participants. Following all interviews, a thank you e-mail was sent to the participant.

In-service Participants

As cohort 2 participants graduated in the spring of 2007, most went on to become science teachers. Many did not stay with the study. After extensive searches, only eight participants could be considered active. Others would occasionally fill out a survey or respond to an e-mail, but commitments to be observed or interview were not honored. Four of these participants found employment within 50 miles of campus. Two were more than 100 miles from campus and the last two were more than 150 miles.

In 2006/2007, cohort 2 had three in-depth participants, the minimum required number. One of the in-depth participants quit her job in early fall 2007. A non-guided exit interview was administered. Two more participants were administered all of the guided interviews in cohort 2. One participant would be a replacement and the other would be an alternate in the event another in-depth participant is lost the following year. So with only eight cohort 2 participants remaining in the study (2007/2008), half were now in-depths, but at a cost: the study has no year 1 Beliefs or NOS interviews on the new in-depths. This is a significant problem in a longitudinal study with very few participants conducted over only three years. This and other problems will be discussed in detail in the next chapter.

In-service participants were observed every semester and in-depth participants were interviewed in the fall using the Beliefs and NOS guided interviews. The interviews were scheduled at the same time as the observation and usually took place

just before or after the observation in the classroom. Ideally the interview would be scheduled during the lunch and/or prep period because most teachers did not want to have their first or last classes of the day observed.

University Faculty Participants

University faculty participants were interviewed using two different guided interviews (these are links to the actual documents):

Science Faculty (Appendix 10)

Education Faculty (Appendix 11)

These participants were only interviewed once during the entire study. All were interviewed during the first two years of the study and most in the spring semesters. The interviews were scheduled much the same as with all of the other participants of the study: an e-mail with a suggested date and time roughly two weeks before the requested date. This was followed by a reminder the following week and another the weekend before and another the day before. Thank you e-mails were sent immediately after each interview.

As with all participants in this study, the video recording of the interview was downloaded from the camera to the server at the Friday Institute. Then DVDs were made for the file. These DVDs were used for transcription.

Most interviews were conducted in the professors' offices with the exception of two that were conducted at a research building of the College of Education. With the exception of one (a diversity professor), all provided syllabi for their courses.

Three instructors did not have their courses observed because they were not teaching the spring semester that interviews were being conducted. Most of the interviews were conducted in the spring because pre-service and in-service participants scheduling demands were very high in the fall semesters.

Sample Selection

With very few exceptions, all of the participants joined the study during the 2006/2007 school year. Once enrolled, the participants in this study were divided into four cohorts. Participants remained in the same cohort as the longitudinal study progressed. In year two of the study (2007/2008), participants in any given cohort would remain in that cohort. They would **not** be moved to the next cohort. This made for much easier tracking of participants as the study evolved.

Cohort Divisions

Cohort 1: Third year undergraduate science education students (2006/2007)
Cohort 2: Fourth & fifth year undergraduate science education majors (2006/2007)
Cohort 3: First year science teachers (2006/2007)
Cohort 4: Science teacher with 3-10 years of experience (2006/2007)

Solicitation Process

Cohort 1 participants were solicited during their Methods I classes during the fall 2006. With the consent of the university faculty instructor, students were invited to participate in the study and asked to complete an Institutional Review Board approved consent form (Appendix 20) and a self disclosure information sheet (Appendix 21). Students were advised that this study was completely voluntary and participation in the study would in no way affect or influence their grade in Methods I.

Cohort 2 participants were solicited during their Methods II classes during the fall 2006. With the consent of the university faculty instructor, students were invited to participate in the study and asked to complete an Institutional Review Board approved consent form and a self disclosure information sheet. Students were advised that this study was completely voluntary and participation in the study would in no way affect or influence their grade in Methods II.

Using university records, students currently enrolled in the science education undergraduate program but not in attendance during the Methods I or Methods II classroom visit were invited to participate in the study via e-mail. The students who did not respond received phone calls, follow up e-mails, and letters to solicit their participation. A strong effort was made to enroll every student in science education at Research University in the study. Unfortunately, not all students agreed to partake. Four students (two from cohort 1 and two from cohort 2) knew that they would not be going into public school teaching and declined to participate.

Cohort 3 participants were solicited by referencing the university graduation records. The university's Alumni office also assisted the study by providing correct information on graduates. Letters, e-mails, and phone calls were used to elicit participation. But the most effective means for increasing enrollment in this cohort were personal school visits. Comparing the university's science education graduate names against public school faculty, potential subjects were identified. Primarily

through personal contact, these participants agreed to be involved in the study, signed consent forms and completed information sheets.

Cohort 4 participants were solicited by letter using addresses provided by university graduate records, Alumni records, and the North Carolina Department of Public Instruction. In addition, letters were sent to school principals explaining the study and eliciting science teacher participation of those known to have graduated from Research University. The teachers who replied in the affirmative were asked if they knew where any other science teacher graduates of this university were working. Through this kind of networking, cohort 4 was filled.

Maintaining Contact

Contact with cohort 1 and 2 participants was most difficult during the summer months. A second information sheet was e-mailed to participants as a way of verifying e-mail addresses (Appendix 22). Some students in cohort 1 would change majors or drop out of school all together without notifying the study or the science education department. As students graduated from college and accepted their first teaching positions, many failed to keep in contact with the study. Systematic electronic searches of middle and high school teachers by North Carolina County had limited success. The most effective means of re-establishing contact with these missing participants was through e-mail solicitation of fellow cohort members.

Maintaining contact with cohort 3 and 4 teachers was much easier. Most stayed at their schools and maintained professional contact continuously.

In-depth Participant Selection

From the full group of participants, a subset was identified for In-depth study, as follows:

Table 3.2 Number of Participants

Cohort	Number of Participants (2006/2007)	Number of In-depth Participants (subset of the participants)
1	**22**	**2**
2	**21**	**3**
3	**11**	**3**
4	**11**	**2**
Total	**65**	**10**

The number of in-depth participants was decided by the advisory panel to Project IMPPACT. This study was designed so that participants would tell us "what" is going on in both the college and public school classrooms and the in-depths would explain "why" it is happening. The design called for all participants to be observed and video recorded every semester. All participants would be administered an introductory interview and a pre-service interview (see table 3.1). In addition, all participants would complete three surveys:

1) National Survey of Teacher Education Program Graduates (NSTEPG),

2.) Beliefs about Reformed Science Teaching and Learning (BARSTL)

3.) Survey of Enacted Curriculum (SEC)

What sets in-depth participants apart from the regular participants is that in addition to the above mentioned observations, interviews and surveys, the in-depth

participants would receive a Beliefs interview and a Nature of Science interview every year (http://imppact.syr.edu/instruments.html). See assessment section for description.

Project IMPPACT had numerous criteria for the selection of in-depth participants. Diversity was the central theme in the selections. The protocol required representation at both middle school and high school levels and at least one participant from each discipline: earth science, physical science, chemistry, biology, and physics. In addition, the study called for on in-depth participants from rural, suburban, and urban settings. Furthermore, the project wanted in-depth teachers from various economic bases using the school lunch programs as a delineator (Truman, 1946). The project also sought equal numbers of male and female in-depth participants.

Finding it extremely difficult to meet all of these selection criteria with only five in-depth participants in the combined cohorts 3 and 4, the research associate simply had all participants comply with the increased demands of in-depth participants. This in essence, made all participants in-depth.

Because students in cohorts 1 and 2 have no idea where or what they would be teaching, the primary selection criteria involved informally polling the science education faculty to determine which students they felt would be most likely to remain in teaching for at least 3 years. Selections were made based primarily upon these recommendations. Over-sampling was done in cohort 1 to hedge against the known high attrition rates of early induction science teachers (Ingersoll, 2002).

Representative

"A biased sample is a statistical sample of a population in which some members of the population are less likely to be included than others" (Heckman, 1979). If the selection bias is not taken into account, then any conclusions drawn may be wrong.

In this study, every effort was made to include all students enrolled in the science teacher undergraduate education program at Research Universtiy. Each person enrolled in the university's science education was contacted in person or via e-mail and invited to participate in the study. Had everyone agreed, the sample for cohorts one and two would have been the population for the purpose of this study. In actuality, four potential subjects declined because they were not intending to teach.

All potential cohort 3 participants had letters sent to the last known address in the 2005/2006 school year. Most letters came back as "undeliverable, not at this address, no forwarding address." In addition, all 21 potential participants were called at their last known phone numbers. Only the parents of two graduates were reached by phone: one of which was living out of state and the other on the North Carolina coast. The parent living out of state would only say that their child was not teaching. The parent living on the coast provided contact information for a teacher who eventually agreed to become a participant. Every effort was made to enroll every science education graduate of 2005/2006.

As mentioned earlier, all other cohort 3 participants were recruited into the study through personal contact. Project IMPPACT requested over sampling to insure ten participants in each cohort at the conclusion of the study. Enormous energy, effort, and expense went into the recruitment process to fill cohort 3. In the end, a total of eleven out of 18 graduates were located and enrolled in the study in this cohort.

An argument could be made that exclusion existed on a geographic level. The research associate began the search by visiting schools closest to Research University and progressively worked her way out from there until the cohort was filled. But in order to procure the eleven participants, the research associate had to travel over 100 miles away from campus to find the last two participants.

Over 200 letters were mailed in an attempt to fill cohort 4. Virtually every middle and high school in the state was sent a letter. A cover letter explaining project IMPPACT was mailed to principals asking them if they had graduates of Research University teaching science at their school. Over 100 science education students had graduated between 1996 and 2004. Yet very few responses to these letters occurred. After two massive mailing efforts, cohort 4 had fourteen participants. These teachers ranged in experience from 2 to 10 years and teaching in school located all over the state.

In the process of filling each of these cohorts with participants, exclusion was never an issue. Cohort 4 is the only cohort that an argument can be made for an overt selection bias. But even this group would be best described as self-selected. No

incentives (monetary or otherwise) were offered to any participants. All participants were rewarded with only the knowledge that their contributions may help to improve science teacher education at Research University.

Selection Biases

"Selection bias is a distortion of evidence or data that arises from the way that the data are collected" (StatSoft, 2007). Sample selection may involve pre- or post-selecting the samples that may preferentially include or exclude certain kinds of results (Weirers, 2007). While some individuals might deliberately use a biased sample to produce misleading results, more often, a biased sample is just a reflection of the difficulty in obtaining a truly representative sample (D. S. Moore, 2006). Another form of selection bias can occur when certain members of the population are over-represented in the sample (Weirers, 2007). Every science education student enrolled and recently graduated in 2005/2006 that could be contacted was invited to participate in this study. Ironically, some research literature describes this as a "convenience sample" (Maykut & Morehouse, 1994).

Another type of bias potentially found in this study is coverage bias in cohort 3. "Coverage bias error is the use of samples that are not representative of the population as a consequence of the methodology used" (Statsnetbase, 2008). In our case, cohort 3 was filled primarily by going directly to schools, looking for graduates of Research University who are teaching science. The researcher began looking for qualified participants who worked close to the campus and proceeded searching at

more and more distant schools from campus. Coverage bias error could be argued on the grounds that this big southeastern university's graduates teaching at greater distances from campus did not have as much of an opportunity to be selected because of the methodology.

"Ascertainment bias occurs when false results are produced by non-random sampling and conclusions made about an entire group are based on a distorted or non-typical sampling. If this is not accounted for, results can be erroneously attributed to the phenomenon under study rather than to the method of sampling" (Heckman, 1979).

One type of ascertainment bias is known as cluster sampling. By selecting participants from certain areas only, or certain time-periods only, this type of ascertainment bias can occur (Vaishnavi & Kuechler, 2007). In this study, cohorts were defined by time periods. Without this delineation, the study could not compare data within and between cohorts. Some research books refer to this as block sampling (L. Cohen et al., 2000; Vaishnavi & Kuechler, 2007). But because the research associate recruited participants by personal contact, beginning with nearby schools and working geographically outward, cluster sampling may have occurred.

Before going from school to school to enroll participants, letters were mailed to all middle and high schools in North Carolina. Clearly, non-response bias took place in the attempt to solicit cohort 3 and 4 participants. Characteristics of those who

agree to be interviewed and observed may be markedly different from those who decline to participate in the study (Statsnetbase, 2008).

Random sampling was not used in the solicitation process of any cohorts in this study. Every member of the population was solicited and those who agreed to the study became participants. Minimum numbers of participants were established by Project IMPPACT. The goal was to have at least ten participants in each cohort at the end of the study. This methodology was adopted for easier comparison to be made between sites rather then to somehow represent a relationship to the population (such as in a stratified sample). Unfortunately, due to the high attrition rate, even this simple goal failed to be realized at any of the university sites in the study. At every site, at least one cohort had less then the desired minimum number of ten.

How Were these Biases Minimized?

An extreme form of biased sampling occurs when certain members of the population are totally excluded from the sample (that is, they have zero probability of being selected. This would make estimations of population parameters impossible and the study would be limited to non-probability sample limitations (Sirkin, 2006). In cohorts 1 through 3, efforts were made to contact every member of the population. Therefore, bias sampling error did not occur. With respect to cohort 4, every one of Research University's graduate of science education who were practicing in North Carolina was actively solicited. Because this cohort solicited teachers with 2 to 10 years of teaching experience and the other three cohorts contained teachers from a

single graduating class, cohort 4 may have biased sampling error. Within this cohort, teachers of certain graduating classes are not represented at all, while other graduating years have as many as two participants. In this analysis of the data, cohort 4 is considered "experienced" teachers.

Ascertainment bias is concerned with not using randomization in the sampling design. Cluster sampling may have occurred in the case of cohort 3 where the associate recruited participants by personal contact starting near campus and working geographically outward. But this method was only employed after e-mails and letters were sent to all middle and high schools in the state requesting teachers to participate.

The most effective way to minimize non-response sample bias is to have large sample sizes.

The following table provides the number of participants by cohort and population:

Table 3.3 Sample Size as a Percentage of Population Size

Cohort	Population size	Sample Size	Percentage	Notes
1	**25**	**22**	**88**	
2	**23**	**21**	**91**	
3	**18**	**11**	**61**	
4	**More than 100**	**11**	**<10**	**The exact number of graduates between 1995-2005 is unknown**
Total	**>166**	**65**	**<40**	

With the exception of cohort 4, the initial sample sizes are large enough to reduce the concern of non-response bias. It is very unlikely that those participants who

responded to the invitation to participate in the study are significantly different from those who choose not to respond to the letter inviting them to participate.

Other Biases and How They were Minimized

Aside from biases that may result from the methods used to solicit participants into the study, the guided interview questions used in the study may have biases associated with them. In addition, the setting used when asking the questions as well as the way in which these questions were asked was the focus of lengthy discussions and additional training during the summer meetings of Project IMPPACT. This section is devoted to a discussion of these things.

Observations

"It should be noted that not all biases are necessarily errors" (Kaplan & Krueger, 1999). "A preference is a real or imagined choice between alternatives and the possibility of rank ordering of these alternatives, based on happiness, satisfaction, gratification, enjoyment, or utility they provide" (Funder, 1999). All participants in this study were observed and interviewed on the dates and times of their choosing.

Table 3.4 Number of Participants Enrolled by Year

Cohorts	**Number of Participants Enrolled by Year**		
	2006/2007	**2007/2008**	**2008/2009**
1	**22**	**17**	**9**
2	**21**	**8**	**8**
3	**11**	**11**	**10**
4	**11**	**11**	**10**
Total	**65**	**47**	**37**

Clearly, participants were given great leeway in allowing themselves to be seen in the best light by picking the classes in which observations were to be made. Researchers reading this study need to be aware that these observations were most likely the participants "best teaching practice." In all cases, teachers were asked if the observation made that day was representative of their teaching practice. If the participant did not answer in the affirmative, another observation was scheduled.

There were monthly phone conferences during the course of this study and one theme that kept arising was the concern about the Hawthorne effect. This occurs when research study participants know they are being studied and alter their performance because of the attention they receive from the experimenters (Ritchie & Lewis, 2003). One research associates left the camera with the participant and asked them to video record themselves presumably as a way to minimize this effect. This practice did not last long because of the problems it produced. First, the project only had two cameras at the big southeastern university and leaving a camera with a participant for a week or more was problematic for a limited resource. Second, teachers would forget to record themselves during the time they had the camera. One teacher recorded herself, didn't like what she saw and returned the camera with only a deleted file. Lastly, teachers that recorded themselves simply left the camera in a stationary position and recording while they moved into and out of frame. This made it almost impossible to complete RTOPs on these observations.

The experimental designed in the study called for non-participatory observations (e.g. no interactions with students, teachers or events as they occur) (Marshall & Rossman, 1998). “An experimenter effect occurs when the experimenters subtly communicate their expectations to the participants, who alter their behavior to conform to these expectations”(L. Cohen et al., 2000). We asked these teachers to be observed on a day that they are actually teaching (i.e. not showing a movie, giving a test, doing bookwork, etc.). This imposed teaching limitation could be interpreted by the participant as having to lecture. I feel that this experimenter effect is minimal because a variety of lessons were presented by different teachers during the course of this study. Although most teachers observed did lecture the entire period.

“The observer-expectancy effect (also called the experimenter-expectancy effect, observer effect, or experimenter effect) in which a researcher's cognitive bias causes them to unconsciously influence the participants of an experiment” (Maykut & Morehouse, 1994). The only effective means to control for this type of effect is through conducting double-blind experiments. In a double-blind experiment, neither the individuals nor the researchers know who belongs to the control group and the experimental group. There is no control group or experimental groups in this study. This is an ethnographic study and as such, internal validity is always a concern due to observer-expectancy effect.

Another concern is the Pygmalion effect. This occurs when students alter their behavior to meet teacher expectations (Marshall & Rossman, 1998). The authors: Catherine Marshall and Gretchen Rossman warn that this affect can be cause by bias, stereotyping, and "have clearly shown in experiments involving stereotyping threats". If the observed students altered their behavior during my observations to meet the teachers' expectations, I would have to argue that these expectations are far too low. I can't definitively claim that this effect didn't take place perhaps on some level, but in most cases, students seem to quickly forget that they were even being video recorded. In one case a student threatened a teacher with physical violence while being recorded. There was an ethical discussion when the teacher requested the recording for the use in prosecuting the student. The request was denied and the student was successfully prosecuted without use of the video recording. The student freely accepted his punishment. The position of the advisory counsel to the IMPPACT project felt that if the school insisted on having the video recording, law enforcement would subpoena the video.

Most biases cited by authors with respect to observations fall into the category broadly described as reactivity phenomenon. "Reactivity is a phenomenon that occurs when individuals alter their performance or behavior due to the awareness that they are being observed. The change may be positive or negative, and depends on the situation" (L. Cohen et al., 2000). Similar to quantum mechanics where physicists who research at minute scales must use tools that actually interact with the phenomena they

are observing (Heisenberg, 1927). Clearly, these interactions need to be acknowledged and those that could be minimized were.

Interviews

Much time was spent wording and rewording the open ended questions used in all of the guided interviews. The term "scientific inquiry" has many different definitions even within the science educational community. Yet teacher's beliefs about the use of scientific inquiry in the classroom and how it relates to their understanding about the nature of science were major goals of project IMPPACT. Asking teachers to define scientific inquiry in their own words appeared to be offensive during instrument trials (2005). In fact, the test subjects felt the question to be too broad. Subjects also stated that they felt belittled by the question. They thought that researchers were looking for a specific definition and the subjects felt intimidated and/or afraid of looking ignorant. This question was re-written as: "When you think of science, what do you think of?" The follow-up question: "how is this view incorporated in your teaching?"

Most of the questions used in the interviews originated from surveys that had extensive and proven psychometrics completed. Unfortunately, many of these questions were linked to ***Likert*** scales, true false or short answer responses (SURVEYS, 2008). Converting these to open ended questions effectively erased any reliance on the original questions' psychometrics. But these questions did provide a

good starting point for the guided interviews. The vast majority of the work in writing and evaluating the interview questions was accomplished by the principal investigators and advisory panel to project IMPPACT. Research associates, like me, only field tested a small number of interview questions and made limited suggestions for changes.

During the summer project IMPPACT meeting of 2007 and 2008, training research associates on interviewing techniques was conducted. Because coding rubrics for the interview questions had yet to be developed, all of the associates were puzzled by certain questions. Research assistants had no idea what the investigators were looking for or curious about. Questions like: “How does your school district’s views about science education reform affect your beliefs and practice?” Or “How does the community affect your teaching beliefs and practice?” I was asking these questions of students still in college. Not only were the participants confused, but so were all of the research associates. Once the coding rubrics were produced for the Beliefs and NOS interviews at the end of the summer of 2007, it became easier to ask the questions because we understood what the researchers were looking for.

Unfortunately, this presented another problem. Once the research associates understood what the question was looking for, they had to guard against leading the participant to specific answers in the rubric. Improving interviewing techniques consumed much of the time spent at the summer 2008 project IMPPACT meeting.

Here again the Pygmalion effect reared its ugly head. Just as with observations, participants (students) may alter their behavior to meet researcher (teacher) expectations (Marshall & Rossman, 1998). This is particularly true of cohort 1 and 2 participants.

Much discussion was given to interviewing techniques used during in the summers of 2007 and 2008. Particularly what terms are acceptable for "probing" an answer to an "interview question?" Research associates suggested proper way to "reword" a question if the participant asked. Much debate and discussion on how to interview occurred. In the end, the study seemed to prefer the participant declining to answer question rather then interviewers attempting to elicit responses from the participant. Clearly, concerns about the Pygmalion effect won out.

Limitations Associated with Small Convenience Samples

This research questions in this study focus on beliefs and practices of Research University science education graduates. The sample sizes are small because the populations of interest are small. The findings in this study should be reflective of many experiences science education graduates of Research University encounter. Many other universities employ pre-service education techniques similar to Research University. This study should provide extensive insights into the interventions that were effective during pre-service education at Research University as well as those universities using similar approaches to preparing science teachers. In addition, this

study should provide researchers with an accurate picture of school cultures and policies in North Carolina that help shape science education. It may be found that these same cultures exist elsewhere in the country when project IMPPACT completes its analysis.

This dissertation is strictly limiting its findings at Research University and North Carolina and will not be using any data collected from Iowa or New York. Hence, serious pause must be given prior to generalizing the findings in this dissertation to a national or international scale. Once the findings from this dissertation are compared and incorporated with the other findings made by project IMPPACT, the full importance of this dissertation will be realized.

The Observation Component

Observations were made of all pre-service and in-service teachers as well as university faculty as they taught lessons. Each group of participants posed unique observation problems.

Pre-service Participants

Cohort 1 participants were observed while teaching a lesson to fellow students during the fall of 2006 in their Methods I class. Each participant was required to teach one lesson using inquiry-based teaching strategies during that semester. This observation was recorded and a Reformed Teaching Observation Protocol (RTOP) was completed on each participant. This was the only observation made of cohort 1 students during the 2006/2007 data collection cycle.

Cohort 2 participants were observed during the fall of 2006. Most student teaching at Research University occurs only during fall semesters. Observations of the participant's student teaching were made over three consecutive days in an effort to capture the teacher presenting a "complete" lesson. After reviewing video of all thee days worth of recordings, one Reformed Teaching Observation Protocol (RTOP) was completed reflecting a summation of the teaching practice for all three days.

Scheduling observations for cohort 1 in 2006/2007 was done by securing the cooperation of the professors teaching Methods I. With the instructor's and participants' permission, recordings were made during the last eight weeks of Methods classes during the fall of 2006.

In-service Participants

In 2007/2008, student teachers became full-time science teachers. The study still referred to them as cohort 2, but they were now in-service participants. During the fall of 2007, contact with almost half of the cohort 2 participants was lost. Many of the participant's home phones and/or cell phones were disconnected and letters were returned. Even after locating some of them through the Department of Public Instruction and school faculty directories, many did not want to continue with the study due to time constraints.

It was clear that a new information sheet needed to be developed that included parent home phone numbers and permanent addresses. These new information forms were completed by all participants. Scheduling was accomplished through e-mail. As

before, once the dates and times were agreed to, an e-mail confirming this was immediately sent. The weekend before the visits, another e-mail was sent and the day before the visits, the last confirmation e-mails were sent.

As per Project IMPPACT's protocol, teachers were to be video recorded for three consecutive days to capture a "complete" lesson. These three days of video were to be summarized on one Reformed Teaching Observation Protocol (RTOP). As mentioned earlier in North Carolina, the lengths of class periods vary from school to school. With class periods varying between 48 -280 minutes in length, the number of class periods needed to teach an entire lesson varied (summer school sessions were the longest). With longer class periods, perhaps only one class period would be sufficient to capture the teaching practice. Those with short class periods may require more than three visits. The study's methodology was adjusted in the fall of 2007 to take this variance into account.

Personal concerns also influenced the scheduling of these newly inducted teachers. Most did not want to be videoed during their first or last class of the day. In addition, many did not want to be video recorded early in the year and others did not want to be video recorded too close to the holidays. Some did not want to have their classes recorded during the first part of the week and almost no one wanted their classes recorded on Fridays. Logistically, great care was taken when scheduling participants. [The bias produced by this limitation to methodology was addressed earlier in this chapter].

In the fall of 2007, the new standard was 1-3 days of observations was adopted. The number of days of observations now depended upon whether the participant felt the lesson was reflective of their typical teaching practice rather then the old standard of a "complete" lesson.

University Faculty Participants

Twenty five university faculty participated in the study: Four professors from science education, four professors from general studies (diversity education, educational psychology, school and society), and the remainder from science content areas. Most of these professors were observed twice. The first observation was the first day of class. This is not usually indicative of an instructor's teaching style, but many times the professors discuss their teaching philosophy on the first day of class. This is also the day that professors hand out course syllabi and other course materials. The first day of class typically gives the researcher a good overview of how the instructor intends to teach the course. No Reformed Teaching Observation Protocols were completed for first day of class observations.

Professors were e-mailed just a few days before class and asked for permission to video record the first day. Before class the professor was asked to sign a consent form and given a brochure about the project. In the body of the thank you e-mail, a request was made for an interview with the professor and permission to observe another lesson at the discretion of the professor. The interview was usually scheduled

for the same day (if possible). The interview usually took place immediately after class in the professor's office.

Data Analysis

The objective of any research project is to answer those questions posed by the investigation. Using only observations and interviews collected between 2006 and 2009 in North Carolina, all these questions will be answered. Each research question will be restated and the methodology selected to answer it will be presented:

A. To what extent is inquiry taught to graduates at Research University?

To answer this research question, results take the form of quotations. Evidence supporting or refuting the claim that inquiry-based instruction is taught at Research University is presented. A conclusion was made based on a preponderance of the evidence found in the pre-service interview. The method used to assure that internal validity is maintained are described in detail in Steinar Kvale's book: *Interviews: An Introduction to Qualitative Research* (Kvale, 1996).

Again, an ethnographic approach was used to determine if the responses given by professors support or refute the hypothesis. Of particular interest was the cultural meaning that inquiry-based instruction may have for professors. Through careful examination of what the professors said, what they did, and what artifacts they produced, this study answered this research question (Spradley, 1979). Observations were used in addition to the interviews to completely answer this question. The results section takes the form of a dialogue using quotes as evidence.

The responses to the following interview questions provided the greatest insight:

What are the objectives of the course(s) you teach?

What philosophy of (a) science, and (b) teaching do you stress in your courses?

How satisfied are you with your program and courses? Why?

With the exception of the department head of the science education department, university faculty participants were never directly asked if they expected their graduates to use inquiry. This was deliberate to avoid queuing, soliciting or causing the flow of the interview to go in this direction. Drawing on the responses to the interview questions identified above, a table was prepared with an interpretation of the participant's beliefs about inquiry-based instruction using grounded theory (Hammersley & Atkinson, 1995). If the participant believes that they use inquiry-based teaching practices in there courses and/or if inquiry-based elements are present in the objectives of the course(s) taught by the professor, then the professor were coded as expecting graduates to use inquiry in their teaching practice upon graduation.

As with the students, professors were observed and RTOPs were completed on faculty teaching practice. Using only the total RTOP score, professors are categorized as either mostly inquiry or mostly traditional in their teaching practice.

The last component used from the study to answer this question was the pre-service interview that students and graduates completed. In this interview, the following questions gave the greatest information in order to answer this question.

In general, how would you describe your typical science course?

- What formats were used (lecture, lab, demonstrations, seminars, discussions, projects, etc.)?
- What equipment or technologies were used? (Did you use instrumentation, textbooks, equipment, etc.?)
- Were there any specific skills, or certain knowledge, that you found really useful?
- Were independent research or individual projects a part of these courses?
- How were you typically evaluated in these courses? (Describe the tests, homework, etc.)
- Was cooperative learning used in these courses?
- Which science courses stand out in your mind as particularly important to you, and why?
- How would you describe the student-faculty relationship in your science program?

In general, how would you describe your typical teacher education course?

- What formats were used (lecture, lab, demonstrations, seminars, discussions, projects, etc.)?
- What technologies were used? (Did you use instrumentation, textbooks, equipment, etc.?)
- Were there any specific skills, or certain knowledge, that you found really useful?
- How were you evaluated in these courses? (Describe tests, homework, faculty or peer critiques, etc.)
- How would you describe your field experiences in science education?
    - Describe each of them, including what you did, who supervised you and how they evaluated you.
- Which science education courses stand out in your mind as particularly important to you, and why?
- What was the relationship between what you learned in your science courses and what you learned in your teacher education courses, including your methods courses?
- How would you describe the student-faculty relationship in your science program?
- What was the philosophy of your teacher education program related to science education?

Comparing the students recollections of the class, the professor's description of the class and the observation made of the class, an accurate description about the

extent to which inquiry is taught to Research University students.

B. To what extent do graduates believe they are using inquiry in their practice?

A comparative and analytical study of the responses to several interview questions yielded the beliefs of graduates. The questions of interest were:

1. How do you maximize student learning in your classroom?

2. How do you describe your role as a teacher?

3. How do you know when your students understand a concept?

4. In your school setting, how do you decide what to teach or what not to teach?

5. How do you decide when to move on to a new topic in your class?

6. How do your students learn best?

7. How do you know when learning is occurring in your classroom?

C. To what extent do graduates use inquiry in their practice?

D. Does the use of inquiry by teachers change over time?

E. What changes in classroom practice can be observed over time?

These three questions all use RTOP scores in an effort to answer. A sample RTOP is found in appendix 5. The RTOP instrument allows teachers to be ranked on a scale of zero to one hundred by simply adding up all of the item scores. If the total score is above fifty, the teacher is considered to use more of a "reformed" based practice. Total RTOP scores less then fifty: the teacher is considered more "traditional" in their teaching practice.

The RTOP has twenty five items. Each item is evaluated on a zero to four Likert scale. These twenty five items are broken into five groups of five questions each. These are the sub-sections that RTOP is divided into:

1. Lesson Design and Implementation
2. Propositional knowledge
3. Procedural knowledge
4. Communicative interactions
5. Student/Teacher Relationships

Using the sub-scales of RTOP, a closer analysis will be made of what elements of inquiry are most often found in the science classrooms of graduates. This is the center piece of this study. The quantitative analysis of the over 3,500 data points was very revealing.

Data was collect from participants who were organized by cohort. See Table 3.5. A total of 20 of these tables were produced (4 cohorts times 5 observations).

Table 3.5 RTOP Analysis by Cohort

Cohort 1: Fall 2006						
Participant	Lesson Design	Propositional Knowledge	Procedural Knowledge	Communicative Interactions	Student/Teacher Relationships	Total score
NC 01-01						
NC01-02						
NC 01-xx						
Average						

When this data is rearranged in such a way that the data could be compared by professional development year, a much more interesting comparison is made possible. See Table 3.6.

Table 3.6 RTOP Sub-scale Scores by Professional Development Year

Professional Development Year	Average Lesson Design Score	Average Propositional Knowledge Score	Average Procedural Knowledge Score	Average Communicative Interactions Score	Average Student/Teacher Relationships Score	Ave. Total score
Pre-service						
Student Teaching						
First Year						
Second Year						
3+ years						
Average						

F. What are the perceived barriers to inquiry-based teaching?

Many teachers have sent me e-mails with reflections about their practices and identified many of these barriers. In addition, copious amounts of data have been amassed during interviews. This section took the form of numerous quotes as evidence.

Closing

This dissertation is the culmination of four years of work and study at Research University. These findings should have implications for this university, the state of North Carolina, and nationally.

A STUDY OF THE INFLUENCE OF A PRESERVICE SCIENCE TEACHER EDUCATION PROGRAM OVER TIME

CHAPTER 4: RESULTS

Introduction

This dissertation examined which teaching practices taught to Research University students persist when these students become science teachers in public schools. In particular, this study was interested in a typed of teaching practice referred to as inquiry-based. This umbrella term encompasses many different components. As mentioned in chapters one and two, a debate still rages about what constitutes inquiry-based instruction. For the purposes of this dissertation, the elements of inquiry that I am concerned with are those measured by the Reformed Teaching Observation Protocol (RTOP).

This dissertation is a longitudinal study that followed thirteen participants at different stages in their development as science teachers. The participants had different starting points. The first three participants: Kerry, Bella, and Laurel (pseudonyms) entered the study (fall, 2006) during pre-service, a year before student teaching. Misty Kate, Marcella, Rob, and Shannon (pseudonyms) were in the final year of the program and were student teaching in the fall of 2006. Seth, Ronald, and Nadia (pseudonyms) were in their first year of teaching when the study began. Mara, Peggy, and Rose-Abby (pseudonyms), were all already experienced teachers with four

or more years of teaching experience in the fall of 2006. Although the starting points were different for the participants in this study, all of them began their teaching careers at Research University (RU).

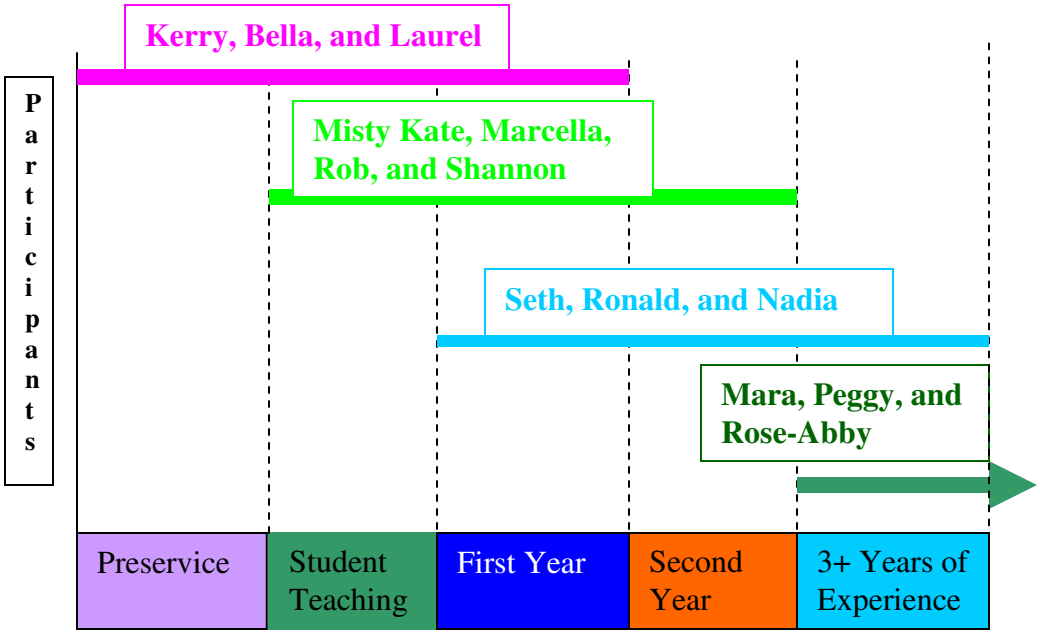


Figure 4.1 Participants by. Stage of Teaching Experience Diagram

Between 2006 and 2009, all of these participants were observed and interviewed at least once per year. During the first year of the study, an introductory interview was administered to each participant in the study. Drawing quotes from those interviews, biographies of each participant are presented here. This rich description of each participant will provide the reader with a reference point to associate the quotes made in future parts of this chapter with the participant who said them.

The data collection followed a particular protocol, as indicated in the following flow diagram.

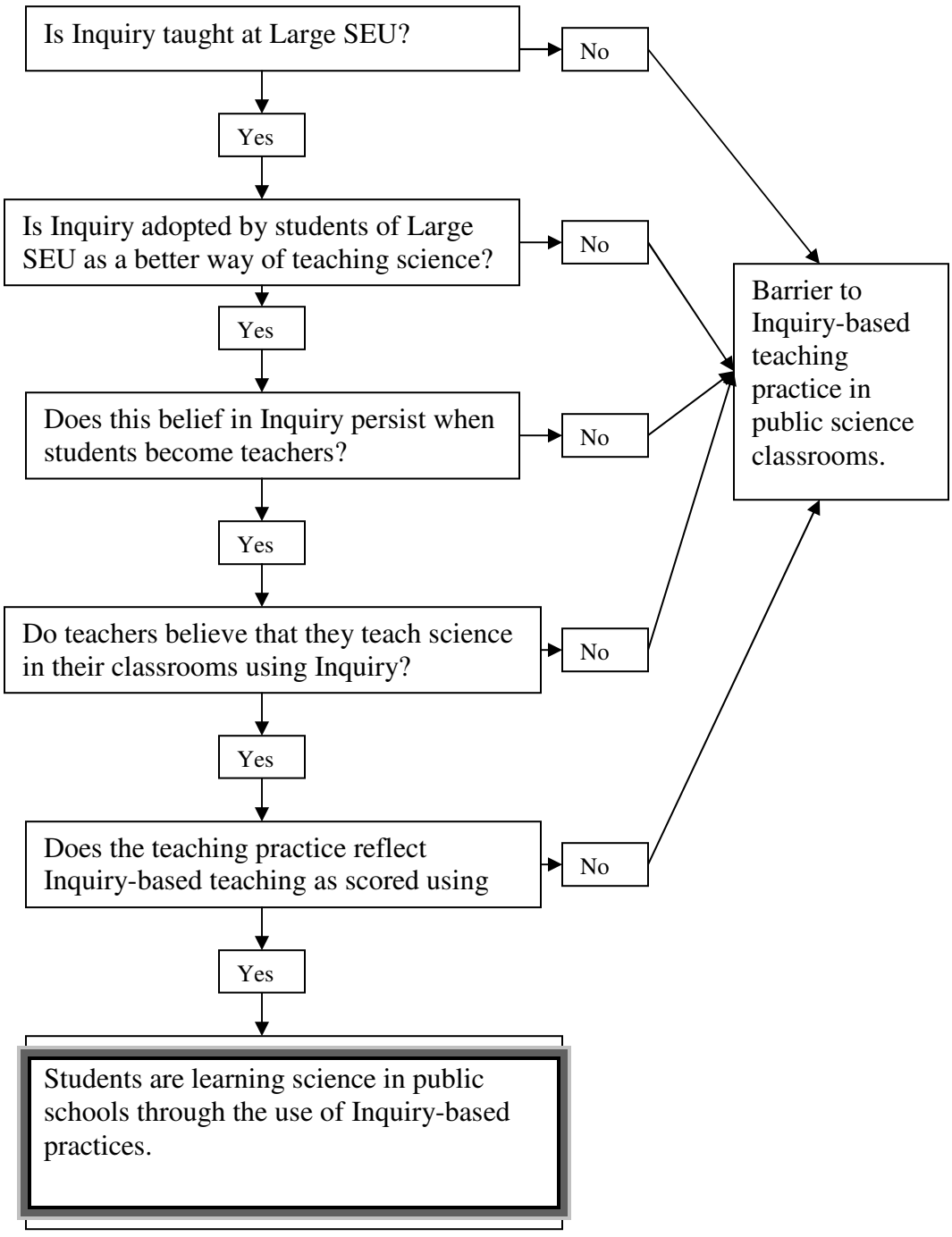


Figure 4.2 Flow Chart of Research

Participant Biographies

Among the many participants in Project IMPPACT, thirteen were selected for in-depth analysis. These participants were not only observed and surveyed, but also thoroughly interviewed about their backgrounds, beliefs and practices. Each of them was extensively quoted to document their education relative to inquiry methods, their beliefs in inquiry as an effective way of teaching, and their perceptions of barriers to using inquiry in real-world classrooms. Therefore, each of them is briefly described below to provide some context for those quotes.

Biographies of Cohort 1 Participants

Three in-depth participants were members of cohort one: Kerry, Bella and Laurel. When the study began, they were involved with methods courses and other preservice education, but they were still a year away from student teaching. During the three years of data collection, they went from being students, to student teachers, and finally to first-year professional teachers.

Kerry

Kerry is a young teacher in her early 20's. She has a sturdy stature, long red hair and a face sprinkled with freckles. She dresses professionally but comfortably, reflecting the practicalities of working in a science lab. Kerry has a friendly smile and an air of easy confidence. She seems comfortable surrounded by a classroom full of teenagers, especially when that room is in the rural, mountainous region where she grew up. Kerry has come home to teach.

Kerry's path to teaching was shaped by this environment. She says, "I like to play outside a lot so the schedule of having your summers off and the break at Christmas was really nice for skiing and kayaking in the summer." Growing up in the mountains, Kerry enjoyed outdoor activities and wanted to continue that lifestyle in adulthood. Teaching fit well with that goal. Her choice of science was inspired by a favorite teacher. Kerry remembers, "My high school chemistry teacher was awesome. Yeah. We had a lot of fun. We'd just blow stuff up. If class was getting boring, she would interrupt class completely and say, 'Let's do a lab!' just out of the blue which was really nice. Otherwise, we kind of sat there in the lecture. It was more her personality I think than the actual content of the course." She elaborates, "I think my high school chemistry teacher, her room wasn't just the chemistry. It was like the cool room in the school to hang out in. Like we'd eat lunch in there and stuff, which probably wasn't up to code, it being a lab classroom and all. So, I guess just sort of forming relationships with the students instead of just being a teacher was kind of the cool thing about her."

With that inspiration, Kerry graduated from high school and moved several hours away to the more urban locale of Research University to study science education. After college, though, she quickly returned to her rural hometown and accepted a position at the same high school where she fell in love with science education.

Bella

Unlike Kerry, Bella came to teaching later in life. She is a woman in her 40's, old enough to be a mother to most of her teaching cohort. She has a crisp, professional demeanor, but her warm smile reflects an ease at working with students the age of her own teenage children. She has a quiet confidence and a comfort with students that belie her recent entry to the profession.

Teaching was not Bella's first career. Instead, she was a scientist who discovered a desire to teach later in life. For most of her adulthood, Bella worked for the federal government as an ecologist. Along the way, she earned a PhD in soil science and geology. She distinguished herself in that career, often educating other scientists and writing scientific publications. After nearly 25 years, she decided it was time for a change. Bella explains, "Working with government bureaucracies, you don't always get to see the good that you do, a lot of times. So, my job moved to [the Pacific Northwest], and I elected not to move, because I have two daughters, and a husband who works at [a research facility near Research University], and other family things here, like an elderly mother-in-law. So, well, this is my chance to try teaching. I had thought about it, several years ago." She recognizes that education has changed quite a bit since she was in high school, with No Child Left Behind and related policies. Bella acknowledges, "Yeah. I know about that, because I try to follow the policies in the paper, but when you have children in school, too, you learn about it. I mean, I'm not a 19 year old. I guess I have experience with children." It is this

interest in children that actually drew her to teaching. When asked, "Why did you decide to become a teacher?" she says, "Because, I wanted to give back something to the community. [She laughs] That's the usual answer, isn't it?" She explains, "After working with the government, I decided I wanted to see something concrete, whether good or bad, you know. If I could make a difference with one kid, especially a woman, a girl, a young girl. I think that they need to be encouraged to be in science." This desire to use her experience as a scientist to inspire young women is Bella's motivation to serve as a science teacher.

Laurel

Like Kerry, Laurel is a young teacher in her early-20's. She has dark hair, an athletic build and a serious demeanor. Laurel's approach to teaching seems very sincere. She cares about her students and wants to help them learn. Early in the study, she expressed some definite ideas about the teaching profession and a strong desire to treat her students like adults, expecting them to behave as responsible, motivated learners. Beneath that apparent confidence, though, her voice and facial expressions often reflect a sense of self-doubt, as if hoping she was capable of meeting the high standard she sets, not only for her students, but for herself. This sincerity and seeming air of confidence permeated by an underlying self-doubt seem to define Laurel's manner, not only in interviews, but also in the classroom.

Laurel's journey to teaching began hundreds of miles from Research University. She grew up in a small town in a rural region of a neighboring state.

Laurel's inspiration for teaching came from an instructor she encountered in her high school years. She explains, "I guess I've always been interested in education ever since I've been thinking about what I'd like to do, but I guess science education—I had a physics professor in high school who really had a big influence on my life. So, he sort of pushed me in the direction without knowing it, I guess." When asked about the best science teaching she's ever experienced, Laurel names this teacher, saying, "He was just remarkable. He made everyone want to take his class. It wasn't a mandatory class. He just had such a personality that he could draw anyone into his class and then really be able to make them understand the material. He was just… I know I've thought back on it now that I've taken science education courses and how we're supposed to make it so creative and interactive, and I don't know if it was necessarily activities that he did with us. He was just so excited about the information. I guess his typical class would be we would take notes off the board and then we'd have a little bit of discussion and maybe we'd go through some sort of lab or demonstration, but you could just see the smile on his face that he was just so excited about what he was teaching that it was very infectious for everyone." With this inspiration, Laurel entered teaching with the hope that she could motivate her own students to learn science.

Sadly, Laurel's first professional experience proved very disappointing. After graduation, she accepted a teaching position at a large urban high school that provided very little support for new teachers. She found the students disrespectful and the

workload overwhelming. Within just a few weeks, she resigned, literally in tears. Laurel still expresses a love for learning and for students, but she's now exploring options for working with younger children, perhaps as a school counselor rather than as a secondary science teacher.

Biographies of Cohort 2 Participants

Four in-depth participants were members of cohort two: Misty Kate, Marcella, Rob, and Shannon. When the study began, they had completed most of their preservice courses and were already student teachers. During the three years of data collection, they went from being student teachers, to first-year teachers, and finally, to second year professional teachers.

Misty Kate

Misty Kate is another young teacher in her early-to-mid 20's. She has long, thick, strawberry blonde hair and a lighthearted air about her. She smiles often and is quick to laugh. She seems focused and professional. At the same time, her manner is relaxed and calm. If not for her southern accent, one might easily mistake her for a Southern California surfer. As a young girl, Misty Kate enjoyed math and hoped to use it as a tool to achieve her dream. She says, "I thought I was planning on working for NASA, or something like that."

She even began college as a math major. However, this changed after several years in the program. "I saw that I really didn't like math. I especially didn't like calculus," she declares laughingly. So, she decided to explore other careers. Misty

Kate explains, “I had already been going to [Research University] for math, and I heard something about their education program was really good. So, I tried it out, and I figured, you know, I could always try to teach for a while. And, I always liked science. I liked physics. So, I thought I’d try that and then I’d see what I really wanted to do. And, it turned out I really liked teaching,” she smiles.

Misty Kate’s decision may have been influenced by one of her own teachers. When asked to describe the best science teaching she’s ever experienced, she says, quietly, “Oh gosh. Um, probably my high school chemistry class. My teacher was really, really difficult. [Smiling] She didn’t cut anybody a break. Yeah, it was really difficult.” She found this teacher challenging. When asked how this has affected her own teaching, if at all, she laughingly responds, “I’m not that big of a pushover.”

Misty Kate’s path to teaching seems different from that of Kerry, Bella and Laurel. While they seem drawn to teaching by their desire to help children and their passion for science, Misty Kate seems to have stumbled into the field and found it a comfortable professional home.

Marcella

Marcella is a young teacher in her early 20’s. She is small and willowy, with a fragile and winsome appearance. Marcella always dresses very well. Whether she is attending her preservice classes, venturing out into student teaching or working as a novice teacher, her clothing is always stylish and professional, consisting of suits and conservative ensembles impeccably coordinated. Marcella’s beautiful golden skin

reflects her Philippine heritage. She has long, thick black hair which she sometimes twirls or stokes while deep in thought or feeling stressed. She often smiles shyly when discussing herself or her teaching. Marcella's most striking feature is her large, dark brown eyes. They are very expressive, sometimes gazing upward as she ponders a point, other times filled with self-effacing laughter, and often as wide-eyed as a deer caught in a predator's sights. In comparison with Kerry's, Bella's and Misty Kate's easy, confident manner, Marcella seems less sure of herself, but very eager to be a good teacher.

Marcella's journey to this profession began in the early years she spent in the middle of this, her home state. Education was very important in her family, and Marcella says, "Science was always my favorite." She was especially influenced by one experience. "Well, when I was in high school, I decided to go out for the 'Oceans Science Bowl' team. And, I lived in [the center of the state], so there were no oceans in [there]. It was about three hours from the ocean. So, it was something I really wanted to do, 'cause it was something new that I wouldn't learn in school. And, I learned so much from the teacher that was the team advisor, and did so much research and learning outside of school. Well actually, the teacher who was the advisor for that team, she was also probably my favorite science teacher. I kind of think back on the richness of information that she would convey to her students, on the science teams and also in her classroom. And, when I teach, I try to go a little deeper into what their textbook says. Using real world examples and things like that.

It was Marcella's love of science that took her on to college. She explained, "Well, I chose Research University originally, because I know it's a great research institution, so. My major was originally biological sciences, and I wasn't sure what I wanted to do, when I started college, but I knew I wanted to major in science. And, Research University had a great science program and a great life sciences department." In describing her college science coursework, Marcella says, "I think they trained pretty much for scientists. I don't ever remember being introduced to teaching in my science courses here."

Eventually, she ventured into teaching. Marcella describes her choice this way: "I decided I wanted to be a teacher, because I felt like it really suited my skill set. I like to direct. And, I also, I like working with youth was a big part of it. And, the reason I wanted to be a science teacher, or the reason I wanted science teaching instead of something else, because science was always my favorite."

Unlike some teachers, who are primarily driven by a desire to help children and, in the process, share their love of science, Marcella's real passion is science. Teaching seems an attractive setting in which to apply that vocation.

Rob

Rob provides a contrast from the typical new teacher. He is older, entering the profession in his early 40's. He is average in height and build, but anything but low-key. Everything about his appearance reflects his passion for teaching. He dresses professionally, in nice pants, shirts, and ties, but only when he is required to do so by

the school's dress code. His sleeves are often rolled-up as he busily moves about the classroom, engaging students and encouraging their active participation. His mop of blonde hair is usually disheveled. The expression on his Caucasian face changes often, from focused concentration to bemusement to humor, with twinkling eyes and a wry smile. His speech is quick and often infused with laughter and zeal.

Like his personal appearance, Rob's classroom is chaotic. Yet it is rich with everything from posters and books to plants, live animals and even video games. Early on, while Rob was a student teacher, he knew it would be this way. Back then he laughingly explained, "I want a messy classroom!"

Rob's manner and environment reflect his views of his role as a teacher. He says, "Well, I could say when I first started thinking about teaching, I had this image of the wise storyteller, in front of the class, that would be able to speak and keep his classroom glued to his every words as they came out. Now, no. [laughing] That has been modified highly since then. I guess I view the role as a teacher is that there's a learning community. And, each of your classrooms is going to be a learning community group. It's going to be a learning community. And, I guess I view the role of the teacher, I guess in an instructional sense, as being the person who would kind of guide that group of people within that community. I really like collaborative working projects, where people, students, get together to solve problems, go over the projects, discuss their work. So as a teacher, I see my role as to prod them on, or cordially invite

them to explore the topic. [Laughing] If I could just accomplish that even a little, that would be absolutely wonderful.

Rob came to this role through a circuitous route. His own experiences with school were often unrewarding. He describes one example: "I was a horrid high school student! Out of 650-some students, I graduated four from the bottom [He smiles somewhat wistfully.] which was quite a surprise to me! But, if you're in that group, it may be a surprise to you! [He laughs heartily.] . . . [He holds up both arms, still laughing] I had no idea they actually ranked it. [His tone becomes more serious.] But, I remember, as a junior, we had to write a paper on a legal aspect. John Hinckley had just happened. So, I remember we talked about the insanity defense, and had this big issue which I didn't believe in at all. At the time, I thought it was a crock. If you did the crime, do the time, thing. So, we had to write this paper. And, I grew up in the Washington, D.C. area. And, Georgetown Law Library is right next to the Capitol. And, it's what's used by all the Senators, and the Congressmen and their staff to do legal research. So, I'm looking at great big signs on the door, and policemen. Um . . . So, as a high school junior, I managed to get in there. I went upstairs and I got the law clerks and research fellows at the law library to help me look up the case study history of all the stuff going on. They were really [laughs] they had to know I didn't belong there [laughs again] but, they were pretty cool about it. So, I put this phenomenal amount of work into this paper. It was completely cited correctly. How did I know? I had law clerks helping me make sure that everything was correct. Turned it in to the

teacher and got a C on it. And, his comment was, 'This is kind of a dry, morbid-like paper.' [He closes his eyes momentarily with a look of dismay.] Now, at the time I was incapable of advocating [gesturing toward his heart]. If this would have happened now, I would have been, like, all over the place. 'Here's your syllabus, your job description for this piece of paper. Nowhere in here does it say this has to be a happy, flowery, paper. It's got references. It's got case studies. It's got documentation of the implications. And, da, da, da, da da. What does this all mean for society?' in it. This paper's an A. There's not one that's [better].' But, at the time, you don't self-advocate for yourself. It was just another failure by another teacher."

Rob might have continued this low opinion of himself as a student, were it not for a teacher he met later while attending community college. He explains, "I graduated from high school as a particularly horrid student. And, after a couple of years of working for not very much money, when in construction, you're working pretty hard, I went back to school and was going to do business. I had [this instructor] as my biology teacher. And, he was so much fun, to be in his class. And that was the first time I really experienced a lot of success as a student. So all of the sudden . . . He would curve the test based on the score of the highest scoring person in the class, and the tests were out of 104, and I consistently scored 104. I would go out of the classroom, and people would go, 'He's the one that got 104.' And I was like, 'Yes!' [He laughs]. So, I had had success with it, and he was very charismatic as a teacher. And, so that's when I switched over to biology from business administration. And

then the following semester I had [another instructor], who taught chemistry. And, it was a very small class, community college, but everyone there was very motivated. And, it was a hugely rewarding class. To accomplish that textbook, I don't know another way to put it. It was a lot of work. And, the two of those [teachers] is how I got into science teaching. Or, [they] were my inspiration for science. I think both of them kind of were the reason I got into college." Rob later adds, "I guess there's a deeper lesson about teaching. That, if you can reach that student, and you can give him that success, in some way. They've got to earn it. But, if you can create the environment where they can earn a victory, then maybe you can change their lives. Maybe 10 or 15 years later, they'll be sitting in [an interview], going, "Mr. [Rob]! I was a C student, until that guy inspired me!"

With this inspiration, Rob continued his education. He says, "Originally, in college, I was interested in medical school. And then I really wasn't. The idea of 12-years of work and I had other values that came into play. I wasn't certain that's what I really wanted to do. And, the idea of being a P.A., physician's assistant, for two years of schooling, would allow me to do, apply the stuff I learned in science, and impact people's lives, and be able to work with them on a personal level." After graduating from college, he chose to spend some time working as a P.A. before making a final decision about medical school. He accepted a position working with brain-injured adults in a neurological rehabilitation center. About 12 years ago, as Rob was in the process of applying to med school, the physicians who owned the center began to

disagree about its operation. He asserts that, "Although I got along with all my physicians quite well, they all started fighting. And, they all went their separate ways, and the company fell apart. And, I lost all of my recommendations." By then, Rob was married. He and his wife decided to start a real estate business together, and they ran it for the next nine years.

Then, life intervened again. The couple became parents to twins. One of them fell gravely ill. Rob describes that period of time in this way: "So, my son was born, one of two twins, and we brought him home from the hospital, he developed bacterial meningitis. And, I spent the next eight months away from work altogether. Going in and out of hospitals, and so forth. At the end of that, it was August. And, I kept thinking that, well, I've got to got back to work. And then, I can't really start work, 'cause we're going on a family vacation in two weeks. I can't work. I mean, I can't really start work until I get back from vacation. I've gotta get back from vacation and a couple weeks later, I'm a little slow [laughs] to figure out I didn't really want to continue selling real estate at all, with my wife. And so, I went back and contemplated my options and what would be. And, what I liked about the idea of medicine was working with people. I really loved talking [about] science and being around issues and understanding them. And, teaching seemed to provide a format where I could work with people. Maybe change their lives [he laughs]. Being in a topic that I absolutely loved, and so it kind of went from there. And so, I contacted Southeastern . . . for [about three years], full-time," laughing, "To get to go and stand in front of a

bunch of kids!" Rob finishes his story, saying ironically, "So, that's my short answer. That's how I got into teaching."

Shannon

While Rob followed an indirect path to teaching, Shannon always knew that education was her destination. She really seems to enjoy the high school environment, thriving with an enthusiasm that exudes the spirit of this former cheerleader and current cheerleading coach. Shannon is a young teacher in her early 20's with dark hair and big brown eyes. She speaks professionally, but intersperses her conversations with rolling eyes, expressive hand gestures and other dramatic elements. She enjoys working with teenagers and seems to fit in well in this setting.

It was this desire to work with kids that attracted Shannon to science teaching. She says that she wanted to become a teacher because, "I think, overall, I'm personable. I work well with people. Um, I love science, but I didn't want to work in the field [smiling]. I don't . . . you know, I didn't want to spend my life in the lab, doing biomedical research, or working at [a local research park]. So [still smiling] . . . Being that I love science, and I love kids. And, teaching is a special profession. For me, it's wasn't something, 'Well, I'll major in biology. And then, I guess I'll get my licensure.' You know, I went into college knowing that I wanted to teach. And, I think I've always wanted to teach. I think, those of us who are in it to be real teachers . . . [Her expression turns serious and sincere.] We're not here for the money, obviously. We're not here for the prestige; there's not very much, but, you know.

Hopefully, I'm here because I want to teach kids science. But, even more than that, I want to be a mentor for them. I want to be a source for them to come to when they need help, not with just biology, and not with anything that's inappropriate [laughing] but, you know [smiling and nodding] I want to be something for them that they can admire and respond to. And, I try to do a good job with that."

Biographies of Cohort 3 Participants

Three in-depth participants were members of cohort three: Seth, Ronald, and Nadia. When the study began, they had graduated from the preservice program and were beginning their careers. They were in their first or second years as professional science teachers. During the three years of data collection, they went from being first- or second-year teachers to being slightly more experience educators, refining their teaching practices and adjusting to professional teaching.

Seth

Seth is the consummate professional, in both his appearance and his approach to teaching. He is always impeccably groomed, and he usually dresses well, in crisply-pressed dress shirts and ties. He looks like an attorney or a rising young executive with a serious mission. Seth is articulate and organized, both in his interviews and with his students. He is also very comfortable with technological tools to support his teaching. He often posts tech tips for other teachers on his district's website, and has developed tools such as ways to use the social networking service "Twitter" to distribute homework and other messages to students. Within his school's website, he has well-

designed pages to provide students with detailed syllabi for each class he teaches, including material to be covered and expectations from his students. He also includes links to materials that will assist his students in achieving the high goals he sets for them. In addition, Seth is constantly seeking ways to improve his knowledge and his opportunities for success. During the course of the study, he continued to teach full-time while also earning his master's degree in science education.

Seth's teaching philosophy is ambitious and pragmatic. He knows that his school has a strong reputation for academic success, and that he is expected live up to that high standard. He explains, "Well, our school has very, very high expectations of the students. It's expected that every student makes high scores on their end-of-year tests because, in years past, we've been one of the highest-scoring schools. It's just always been expected that students will learn when they are in class. [He emphasizes the word "will".] It's just sort of expected of that. And so, that carries over into my classroom. I expect that all of my students will pass the state testing at the end of the semester, and work towards that goal."

Ronald

Ronald came to teaching with an extensive military background, and his appearance and manner reflects this. This middle-aged man has a short, neat haircut and a wardrobe that is neat but not "flashy." Like Seth, Ronald's manner is practical. However, he seems less motivated by a desire for high achievement and more motivated by trying to do his job as efficiently and effectively as possible under the

less-than-perfect environment of the public schools. When asked to describe his role as a teacher, he once replied, "I would love to believe my role is to facilitate [laughing]! I'm sure that's the answer that [pointing toward the interview questions]. But, sometimes I do have to do, kind of, direct instruction where I'm not just facilitating, but I'm, 'This is what you've got to do,' [using his arm to direct the process]. As much as I'd like to say [extending his arms up and to the sides],'Oh, my kids? I just ask them a question, and they can run with it!' It doesn't always work that way [lowering his arms] in reality."

Ronald does express a desire to see his students learn and grow, and he's willing to try new approaches to make this happen. He says he became a teacher because, "I wanted to impact students' lives and I wanted to have the opportunity to have students experience science education and get excited about science." Ronald is willing to try new techniques in furtherance of these goals. After many years as a military scientist, he retired and completed a lateral-entry program in science education. Even after he began teaching, he continued his education, earning a master's degree and now working toward his doctorate. He tries to employ what he's learned in designing his classroom environment to promote student learning.

Nadia

Nadia's background is very different from that of Ronald. While he came to teaching after a long military career, Nadia's background was in sports and dance. Her appearance reflects that experience. A slender woman in her early 20's, she usually

wears her dark hair pulled back in a tidy bun. Her teaching wardrobe usually consists of dark, often black, skirts or pants and turtleneck sweaters, giving her a serious and disciplined look.

Nadia was first attracted to the discipline of science as a high school student. When asked about the best teaching she ever experienced, she cited two science courses, anatomy and chemistry, in part because they were so difficult. She explains, "[They were] the first classes in high school that I liked that challenged me. Because like English challenged me and I didn't like it. I didn't care about anything in it. But I liked science and so it – it challenged me for the first time and I really had to work and I still did well." Still, science teaching did not immediately jump out as her first career choice. She explains, "Oh Lord. Why did I decide to become a teacher? Uh, I found – I actually went to school as a math major and then I was really not happy and so after about two years I started looking for a new major and then I looked at like jobs I had done in the past and I was a tennis instructor, dance instructor, an orientation counselor and all these different teaching positions so I went into education and I was really happy and young and so I started here."

Though she settled on this career, she doesn't always seem entirely comfortable in it. She often struggles with her desire to make her classes challenging and interesting for her students. At the same time, she often has to adjust these goals to fit the expectation that students memorize enough data to pass the tests by which they, and she, are judged. For example, when asked how she decides what to teach and

what not to teach, Nadia responds in a frazzled tone, "Um, Standard Course of Study. And then, also, we talk to our AP teachers. Because, usually Honors Chem is a direct link to any AP course, except for AP Physics. But, they have to have Honors Chem to move on to most of the other AP's. So, we get from them what they need to know. As well as, what's on the EOC. So, that's how we differentiate between honors chemistry and an academic chemistry. Because, academic chemistry, we're really trying to strip it down to the bones . . . of where, they get what they need . . . and then, if they're a higher class, teach them some of the extra things that . . . I mean, these students are probably college-bound . . . so that, if they do take that chem class, they're prepared for it. Um, and in the honors chem, we know that they're going to college. We make sure that they see the different things that aren't necessarily on the EOC. Also, to make sure that they have a deeper understanding, so when they take that academic EOC [courses] it's the easiest test that they've seen all year." This conflict—between wanting to teach science and needing to focus on test scores—seems to define Nadia as a science teacher.

Biographies of Cohort 4 Participants

Finally, three in-depth participants were members of cohort four: Mara, Peggy, and Rose-Abby. When the study began, they had graduated from the preservice program and already had between three years and nearly ten years of teaching experience. During the three years of data collection, they went from being experienced educators to being true veterans of the teaching profession.

Mara

Mara is very experienced in the classroom, having served as a science teacher for nearly 10 years. A woman in her 30's she has a medium build and a relaxed appearance, with curly brown hair, a pleasant demeanor and comfortable clothing. On occasion, she even dresses in casual pants and t-shirts bearing her school's logo. She seems at ease in the classroom, at least when dealing with students.

However, at this point in her career, Mara is growing unhappy with some aspects of teaching. Toward the middle of the study, she seriously considered quitting. She explains, "The current administration doesn't make me not want to teach anymore. So, I'm actually seeking other positions because of the current administration and the decisions that they've made. To me, I've worked under three administrations. And, this one is by far the most ineffective administration of the three. The previous administrations; if I turned a student in, they got a consequence very quickly. And, it was pretty harsh. So, the students were more in line. And, I didn't have as many discipline problems. I didn't have as many problems getting support from administration for parent problems and with different things. This current administration [pausing] I don't know why. But, they don't seem to be able to get to discipline matters quickly. They don't get to e-mails quickly. And so, when I ask them for things or for discipline problems, it's maybe a week before they see the student, if they see the student at all. And, it makes the biggest difference in my classroom [emphasizing these words]. In eight years of teaching, the last two years

I've seen the most discipline problems ever! [She shakes her head.] And it's very disheartening. And, it makes me not want to teach." She doesn't seem to blame the students for this problem, but rather the lack of support from her administrators.

Mara sees her role as teacher as someone who organizes the classroom to promote learning and who assesses that learning through interactions with her students. She views these administrative problems as disrupting this environment and frustrating her ability to teach.

Peggy

Peggy is another very experienced teacher; when the study began, she had already been teaching for many years. She is a tall and slender woman in her early 40's, with a short, curly haircut and a neat, professional appearance. Peggy has a real enthusiasm for teaching science, and it shows in both her teaching and her discussion of the importance of science in everyday life.

In fact, Peggy's love of science drew her to work in that field for seven years before she ever became a teacher. She served as a medical technician, working in hospitals to conduct vital lab work that impacted her patients' lives. Eventually, she decided to become a teacher for several reasons. Peggy explains, "I found that I enjoyed the teaching aspect of being at the hospital, and so when we moved to [this state], I decided that I was going to go back to school, and that's why I went to [Research University] and got a degree in education. Because I enjoyed teaching, and being in the hospital I worked every shift and every holiday and every Christmas and

every New Year's, and once I had kids I decided that I wanted more of an 8 to 3 kind of job to be at home with my kids. Not that it's less work, but at least I'm home with them, and right now my daughter is at this high school with me, and that makes it worth every single second that I'm here with her, and it's been nice for both of us that I can keep my eye on her and I know where she's at, and stuff." Ironically, Peggy often expresses dismay that she's found teaching very time-consuming. She often mentions the many hours she spends outside of class, grading papers and preparing lessons. In spite of this, she still seems very excited about teaching science and inspiring students to care about a subject she believes is vital to their lives.

As passionate as Peggy is about teaching, she is equally fervent about the factors that stand in her way. She is outspoken about the environment of high-stakes testing and the way it shapes science teaching.

Rose-Abby

Each of these participants came to teaching for their own reasons; but, for Rose-Abby it was less of a choice than a calling. This veteran teacher is a woman in her 30's, with a warm, encouraging way about her that seems to put everyone at ease. She cares deeply about her students and really seems to put her heart into teaching them, not just as science students, but as people.

Rose-Abby sees teaching as her purpose in life. Growing up, she didn't plan to teach. Instead, she wanted to work with animals. She even majored in animal science in college. She explains, "I did finish my degree [at Research University] and, I was

wanting to do veterinarian school." One experience changed everything. She continues, "I was approved to go one summer to Malta to be an international Baptist missionary. And, I worked with high school students. And, actually one of the ways that I got into mission with them was teaching them science. I enjoyed—I just had a 'chemistry' with students. And when I came back, after spending two months there, in Malta, I just knew. It was more of a religious focus, that I have a gift of working with teenagers. And that's just where I redirected my focus. [She smiles and nods slightly, her expression calm but confident.]" This sense of purpose is reflected in her teaching. In one interview, she explains her role as a teacher, saying sincerely, "[I'm] more of a facilitator. I don't want to look like, 'Oh, she's the one that has all the right answers,' because, I'm human, and I don't [always have all the right answers]. There's several times I, had to tell my kids, 'Honestly, I don't know. But, I'm gonna look it up.' And, when I say that I really do like to be an encourager, I really do. 'You can find the answer. We can work on this together.' Someone who looks beyond just the content of the class to try to find something that's good about each of my students, something that they're comfortable with doing, a strength of theirs, and use that strength so that they can exceed in my class. So [shaking her head], it doesn't always work. And, I know that it sounds like a whole bunch of words that I'm saying. But really, that's something that I try to do [nodding]."

A year later, she answered that question in much the same way, saying, "I think I have many roles, kind of, as a teacher. Sometimes it's just as a facilitator.

Sometimes I do supply the needed instruction. But, I try to let them figure out what I'm talking about before I get to that point. So: as the facilitator, the lead person, also the motivator, in a sense, to get the students to stay on task, to give them hope, and to encourage them, that they can succeed."

Rose-Abby has achieved success as a teacher, in the eyes of her students, her peers and her administrators. She has received recognition as one of the state's best science teachers. Now, she teaches not only teenagers, but also her colleagues, serving as a science department chair and mentor for other science teachers. Rose-Abby is following her calling and striving to inspire others to succeed, both in academics and in life.

Summary of Biographies

It was clear that these thirteen teachers came to the profession for many reasons. Some, like Misty Kate, became teachers almost by accident but feel comfortable in the profession. Some, like Bella, Marcella and Peggy, chose teaching as a good place to pursue their love of science and instill that passion in their students. Others, like Rose-Abby feel teaching is a calling, allowing them to share their gifts and make the world a better place, For most, like Rob, it was a combination of these motivations that led them to teach the science they enjoy to students they hope to educate and inspire.

Research Questions

The focus of this dissertation was inquiry-based teaching practices as reflected by the research questions:

A. To what extent is inquiry taught to graduates of Research University?

B. To what extent do these graduates believe they are using inquiry in their practice?

C. To what extent do these graduates use inquiry in their practice?

D. Does the use of inquiry by these graduates change over time?

E. What changes in classroom practice can be observed over time?

F. What are the perceived barriers to inquiry-based teaching?

Does Research University Teach Inquiry?

In the following pages, the science education program of Research University will be described in detail. Using evidence derived from the program of study, the faculty who teach in the program, the students who are currently taking the classes, and those who have graduated from this university, a case will be made that inquiry is valued and taught at Research University (RU).

Next the research will show that students of the science education program of RU demonstrated satisfactory abilities in teaching using inquiry. University faculty who teach methods courses use grading rubrics to evaluate mini-lessons taught by science education majors. The students must incorporate elements of inquiry-based teaching practices in their lessons in order to pass the courses. These mini-lessons were video recorded and further evaluated using RTOP. These same students were

independently found to exhibit inquiry-based teaching practices in their lessons. To complete the triangulation of data, quotes from interviews with both current students and graduates provided further evidence that these participants believe that inquiry is taught at RU.

The journey for all of the teachers in this study began with pre-service education. This section provides an overview of the science education program beginning with the program of study. University general requirements such as English, Humanities, or Foreign Language will not be discussed. Only those classes that may have some direct relevance to inquiry-based science instruction will be looked at in detail.

The evidence from the following sources suggests that RU teaches Inquiry:

- The program description
- University faculty descriptions
- Student descriptions
- Graduate-of-the-university descriptions and
- RTOPs of faculty teaching.

The science education program can be divided into three categories: general studies, science education, and science content courses. The general studies include courses that are required for any teacher of secondary or middle school in the state.

General Studies for Teachers

- Public Speaking
- Educational Psychology
- School and Society
- Teaching Exceptional Students and
- Psychology of Adolescent Development.

The early science education courses also are designed to help students decide if teaching in secondary science is a good career choice. The program begins by providing opportunities for students to observe middle and high school teachers in addition to learning in campus based classes. Gradually students are given greater classroom responsibilities with time and this culminates with them actually teaching their own class. During the following classes, students are exposed to many methods of science instruction, with emphasis placed on inquiry.

Math and Science Education

- Orientation to Math and Science Education
- Introduction to Teaching Math and Science
- Introduction to Teaching Math and Science Lab
- Instructional Materials in Science
- Methods of Teaching Science I
- Methods of Teaching Science II
- Student Teaching in Science
- Senior Semester in Science and Math Education

Regardless of the science to be taught, all graduates of this pre-service program in science education were required to complete a one year sequence of study in biology and chemistry, as well a one semester of study in geology.

Science Content

- Molecular Chemistry
- Molecular Chemistry Lab
- Chemistry: A Quantitative Science
- Chemistry: A Quantitative Science Lab
- Introduction to Biology I
- Introduction to Biology II
- Geology Physical
- Geology Lab

In addition to these basic science content courses listed above, graduates in science education complete an additional 12-18 hours of credit in a specific science field such as general science, middle grades science and mathematics, biology, chemistry, earth science, or physics. For a complete listing of required courses for each specialty, see Appendices 13 – 18.

Although most class titles are self explanatory, appendix 23 contains course descriptions for each of the above stated courses. These descriptions were obtained from the Research University course catalog.

Little evidence of inquiry-based teaching practices could be found for the general study courses. The syllabi of these courses made no mention of inquiry. The instructors of the courses made no comments with respect to inquiry-based science teaching practices during interviews. The students and graduates of these courses made no mention of inquiry-based teaching practices associated with the classes listed in table 4.1 with the exception of *School and Society*. On the day of the observation for that course, students were giving presentations. This is coded as reformed teaching on the RTOP (score >50) because students are transmitting and receiving as opposed to the teacher being the transmitter and students being the receivers of information. One graduate reflecting back on her pre-service education recalled *School and Society* as being a very useful class for this reason. “It was the only time in school that I had to teach an entire 75 minute lesson (Laurel, 2007).

Table 4.1 RTOP Scores in General Study Courses

Class Title	RTOP Score
Public Speaking	Declined observation and Interview
Educational Psychology	39
School and Society	83
Teaching Exceptional Students	43
Psychology of Adolescent Development	20
Mean Score	46*

*Without *School and Society*, the mean becomes 34.

Unlike the science content and general studies, in the science education courses, students, graduates and teachers all claimed that inquiry was taught. The following table contains quotes from these instructors that seem to support this claim.

Table 4.2 Instructor Quotes from Science Education

Class Title	Instructor Quotes
Orientation to Math and Science Education	We do try to model for them, the way that we would like them to teach. And, we try to make it inquiry-based, as much as possible.
Introduction to Teaching Math and Science	We had a different topic every day that we tried to couch it within a science investigation. So, what I would do some sort of lab activity some type of inquiry activity. For example, if we are focusing on inquiry one day, instead of talking about inquiry, we will do an inquiry activity. So, I will model that for them. Then, we will do it as if I were teaching it in a science class.
Instructional Materials in Science	It's part of the inquiry approach to teacher education. They're not going to learn by us telling them how to do it. They have to do it themselves. We won't say, "today, we're going to do a think pair share!" They're just doing it.
Methods of Teaching Science I	We gave them models of different kinds of instruction…inquiry-based teaching. I would say [that we teach a] constructivist philosophy where people learn from each other.

Table 4.2 (Cont.) Instructor Quotes from Science Education

Methods of Teaching Science II	Science knowledge comes from thinking about things; it's not discovered. People construct knowledge…. Science is doable. It's useful. It has application. They can make up science knowledge. That the goal is not to learn the definitive, correct science knowledge, but to understand how to use the knowledge they find. And so, the other part of it would be a very heavy emphasis on sourcing out and vetting knowledge, in terms of the applications they have. So, I would do a lot of applications in my courses.
Student Teaching in Science	Quote from a cooperating teacher: The first day I meet them, I can tell if they're going to be good or bad just by their attitude. You can tell if they're excited. But, they've all been well prepared. They know their curriculum. They remember things from their methods classes. It's just putting it into practice.

In addition to the above quotes, one methods instructor had this to say: "We have them do a micro-teaching as an inquiry. So, again, there are rubrics that they're well aware of before, as they're preparing. And, certainly, that's what we grade them on."

The following table is a list of quotes from students and graduates of Research University about their science education classes. Words in brackets [ ] are inserted in the quote for clarity. Sometimes the question that the participant is answering is included in the quote if necessary for clarity. Questions are in italics. These types of brackets are used to indicate other relevant information **( )**.

Table 4.3 Student and Graduate Quotes about Science Education

Participant	Quotes
Kerry	It was sort of a lead-by-example, which was nice. Here's how you do it! Now, go do it! I think that was how I picked up some of my teaching strategies, would be especially from doing activities [that] would be from my education classes.
Bella	I think most of the professors were very much activity based. They wanted us to include science activities. And, mostly Inquiry-based. They were very big on that.
Laurel	There was a lot of lecture. There was a lot of cooperative learning. We did that one, in an Inquiry-based way. So, it was neat because, they did a really good job of modeling what they wanted us to do.
Misty Kate	I think the methods courses are just much more useful. They seemed pretty important, most of those education courses I took.
Marcella	I don't lecture. It's more of a question and answer period. That's what I try to do, because, that's what I was taught to do at State.
Rob	There are ideas that are introduced and some kinds of thinking processes that were introduced and were pretty much just introduced. And then, we moved on. **(lateral entry)**
Shannon	We did lots of work in groups. We did get together and get ideas going and talk about things. So, much more than my other classes.
Seth	Pre-service interview was not administered
Ronald	One that [I] was not overly successful in – one I can think of is a methods course I took. I swear the professor had not been in the classroom in like fifteen years. I'm not trying to badmouth her by any means but I think the professor had not been in the classroom for fifteen years and I looked – really I looked at her and I was just like there is no way you can convince me that my kids would even remotely go along with some of that stuff. It was – things like projects or Inquiry learning – not that I disagree fundamentally with it but it's just I think things have changed and one of the things that they can do is put the professors back in the classroom for a little bit.
Nadia	[Inquiry] it's a very hard thing to get but I think it's a great thing to go toward but I think it's a very hard thing for me who's never done much Inquiry-based stuff. I did do it in college. That's one thing we did in college. We did inquiry-based stuff.

Table 4.3 (Cont.) Student and Graduate Quotes about Science Education

Mara	I think methods is what I remember as being the most valuable. Because it taught us about how to write a test and they taught us about doing labs and they taught us about actual discipline and that was while I was student teaching so that would have been nice maybe prior to but yes that was probably the most valuable. There wasn't a whole lot of lecture. It was a lot more group work, presentations, a lot more of assignments that the professors guided.
Peggy	*How was the course taught? The science method course?* All Inquiry-based. Everything was inquiry-based.
Rose-Abby	Hands-on. Every time I was in his class, he had something that he showed me. He started off with this on the table [miming the activity] and said, "What is it?" And, we had to try to sit there and figure it out. The Inquiry-based lesson is what I can remember most.

The word "inquiry" was never used in any interview questions. Yet almost all students and graduates mentioned "inquiry" or an element of inquiry such as cooperative learning. Instructors of science education courses felt that they teach inquiry-based science education, and students as well as graduates remembered learning the inquiry-based science being taught to them. Observations made of faculty teaching science education courses were scored using RTOP. These score reflect that inquiry was being taught in science education courses at Research University (see table 4.4).

Table 4.4 RTOP Scores in Science Education Courses

Class Title	**RTOP Score**
Orientation to Math and Science Education	Declined observation
Introduction to Teaching Math and Science	40*
Introduction to Teaching Math and Science Lab	40*
Instructional Materials in Science	60
Methods of Teaching Science I	74
Methods of Teaching Science II	97
Student Teaching in Science	78
Senior Semester in Science and Math Education	30
Mean Score	60

*Taught by the same instructor

Finally, the study examined the science content courses taught at Research University. Appendix 23 contains the class descriptions found in the Research University catalogue. The instructors of the science content courses were asked to describe their courses, and quotes supporting inquiry-based instruction are presented in table 4.5. Once again, inquiry was never mentioned in any of the questions. Elements of inquiry-based practices are in **bold**.

Table 4.5 Instructor Quotes from Science Content Courses

Class Title	Instructor Quotes
Molecular Chemistry*	I use a combination of things. Of course, I do use a lecture, to be certain. But, that isn't all I do. One of the things I want to try to do is have them solve problems. We formed a **panel discussion** on the recent fire that burned down a chemical plant in Apex. We try to force people to **think critically about issues**. All the chapters are related to the **STS [Science, Technology, and Society]** and the average citizen. Air pollution, water pollution, landfills, nuclear power, things like this.
Molecular Chemistry Lab*	For example, they may test the [Local] Creek as it flows through campus, to see if there's any change in the conditions as it meanders across the campus. I have them collect temperature and pH for a month. **Their actually doing science as a method for learning science.**
A Quantitative Science	But, the clicker system has allowed us to bring **some interactivity** into the lecture hall, by **having students pair up** and think about some issues, and then **putting up some plausible answers up on the screen**, and then they can click on what they think is the best answer, according to their opinion. And then [nodding], as a class we discuss, "Why did some people answer this . . . one answer versus the other?" And of course [nodding], we also have just straight objective questions that they can use to review for exams.

Table 4.5 (Cont.) Instructor Quotes from Science Content Courses

A Quantitative Science Lab	We have developed a curriculum that fully integrates the lab, **inquiry approach** with lecture passive modes. So for example, the students come to our class three times a week, for two hours each time, instead of going to a lecture for three hours and a lab for three hours; they come to this room three times a week, for two hours. **The instruction is hands-on, activity-driven instruction.**
Introduction to Biology I*	So, I try to get them to understand that this stuff doesn't appear in textbooks just because someone dreamed it up. It's a product of research, **of peer-reviewed research.**
Introduction to Biology II*	We want them to leave, not just with a bunch of facts, but with the ability to **think scientifically, and leave with the culture of science really ingrained into them.**
Geology Physical	The types of knowledge that I aim for, since I'm teaching geology, would be, generally, what is in the textbook. I have a national textbook, and it's obviously been gone over by people who have an idea of what national knowledge should be, here in geology. So, I direct people towards that.
Geology Lab	Declined interview and observation

*the same instructor

Many of the quotes above suggest that inquiry-based science teaching was occurring in science content courses. Yet students and graduates of Research University have a much different take on science content courses. Table 4.6 contains quotes from current students and graduates of Research University.

Table 4.6 Student and Graduate Quotes about Science Content Courses

Participant	Quotes
Kerry	In some of the entry-level biology classes that you take, you were able to **design your own scientific experiment.** And, you had a list of things just like a **science project** but it was sort of on a higher level, in that you had to **actually write a scientific paper**. So, I thought that that was cool—that you actually got to choose something that you were interested in, even though it was from a list, and sort of **apply the scientific method** to that. In my cell biology class. I had to do, we had to do, all sorts of protein pathways . . . projects and things like that. Which was really cool! So, we got to take a protein pathway that interested us, and that was fun to do also.
Bella	**Lateral entry**. She did not take any science content courses at RU.
Laurel	It [homework] was just unrealistic to do it yourself. It took that long [15 hours/week] with a group of ten people solving problems. So, to do it by yourself. You would have spent all of your time.
Misty Kate	**In botany, for instance, we broke off into groups and we had times, during lecture. Other courses, not so much.** It was mainly lab sections. I'd say mostly the lab stuff . . . just that hands-on and the applications . . . of the concepts. I think, mostly because I'm teaching and, I think that helps kids, when I have the hands-on, not just the standing up lecturing.
Marcella	Had nothing to say about her science content courses.
Rob	**Lateral Entry**. Did not take science content courses at RU.
Shannon	If there was group work, it was in the lab. **There wasn't very much group work in the class itself.** There wasn't … I mean, occasionally … I mean, we really didn't have discussions. If someone was brave enough to ask a question in front of the 150 of us, then they did. But, that didn't really spark discussion. So, it was very much, **just direct instruction**, very little, if anything, else. The only time that they were ever used, utilized, would be in the lab. That is, not ever in the lecture, really. I didn't learn much [inquiry]. Not from my science classes in college. I didn't really pick up any. Professors, especially science professors in college, they're for the most part, not there to educate. They're there to do research. And, that comes across very strongly in science classes in college**. I think [that] I didn't learn a lot of effective teaching strategies from my science classes.**
Seth	Pre-service interview was not administered
Ronald	**Lateral entry.** No science content courses taken at RU.
Nadia	*How often were cooperative learning techniques used in science classes?* In the science courses**? Not very much.**

Table 4.6 (Cont.) Student and Graduate Quotes about Science Content Courses

Mara	Oh you know we had lecture which was spewing out information to memorize. There were a lot of notes and you had a three hour lab where you came, you did a lab, you answered questions, you turned it in. That was a typical. I remember one project in a genetics class and that was it. That project did require research and that was it. [Otherwise] **it was all lecture.** They [labs] were you know, what we call **recipe labs** where you do step one, do step two, do step…**there were no inquiry labs**. We partnered up with be it two or three. That was about it. We had to do the lab so we would share duties.
Peggy	**Lateral entry.** No science content courses taken at RU.
Rose-Abby	A chemistry course: 300 students in an auditorium, and listening to the professor down front, maybe with the PowerPoint up with a few pictures. The lab portion being a smaller section was more intimate being able to work with a set of students, collaborate, and, having more freedom of talking to that lab teacher**. *How often were cooperative learning techniques used in your science courses?* Just within the lab section. Never within the class.**

Most of the participants did not mention inquiry-based science instruction as part of their science content courses. Yet instructors of these courses seem to espouse inquiry-based teaching methods. Although these lower level classes did not include much inquiry, it may be that inquiry-based teaching practices are found in upper division science classes. Recall that in addition to the introductory level biology, chemistry, and geology classes, 12-18 hours of additional science classes must be taken in order to graduate. The introductory science content courses were observed coded using RTOP. Table 4.7 shows the results. Only Molecular Chemistry had an RTOP score high enough to be considered inquiry-based science instruction.

Table 4.7 RTOP Scores in Science Content Courses

Class Title	RTOP Score
Molecular Chemistry	63*
Molecular Chemistry Lab	63*
A Quantitative Science	18
A Quantitative Science Lab	24
Introduction to Biology I	34*
Introduction to Biology II	34*
Geology Physical	20
Geology Lab	Declined Observation and Interview
Mean Score	37

* Taught by the same instructor

The RTOP scores seem to support the students and graduates recollections of their science content courses. It is also important to note that four of the thirteen participants were lateral entry and one graduate who took science content courses at RU had no comment. All of the lateral entry participants have degrees in science from other universities. Therefore, the reflections of their science content courses were not relevant to the research question asked in this section.

Summary of the First Research Question

To what extent is inquiry taught to graduates of Research University?

Evidence shows that teachers of general studies teach very little inquiry. With the exception of "School and Society," students, graduates, and instructors of these courses did not consider inquiry-based instruction as being taught in their classes. In contrast, inquiry-based science instruction was found to be pervasive in science education courses as evidenced by students, graduates, faculty, and RTOP scores. Science content courses had mixed results. While most instructors feel that inquiry

was taught to some extent in their classes, students and graduates don't seem to share that opinion. RTOP scores are mixed with molecular chemistry showing inquiry and all others, more traditional. Furthermore, upper division science content courses were not observed and instructors were not interviewed.

To What Extent do These Graduates Believe They Are Using Inquiry in Their Practice?

This question had two purposes. The first was to identify the participant's belief with respect to inquiry-based instruction. In particular, did they respect the soundness of the approach or did they dismiss it as an academic exercise required for pre-service education? The second purpose was to determine if participants believed they were using inquiry in their practice. To answer this question, two tables of quotes for participants will be presented. In the first table, quotes relate to the participant's beliefs about the appropriateness of inquiry-based education. The comments reflect participants' commitment to inquiry as being an important and as some say, the most important way to teach science. In the second table, quotes relate to their implementation of inquiry-based teaching in their practice. In this table, teachers cite how they use elements of inquiry in their everyday teaching. Taken together, these two tables of quotes suggest that teachers believed in the validity of inquiry-based teaching and further believed that they were using inquiry-based teaching in their practice. Participant Quotes Related to Belief in using Inquiry-based Teaching Practices, is

found in Appendix 26. Participant Quotes Related to use of inquiry in Their Practice, is found is Appendix 27.

Summary of the Second Research Question

To what extent do these graduates believe they are using inquiry in their practice? Given the evidence presented in the previous two tables (now found in Appendix 26 and 27), the answer to this question is: "To a large extent, graduates believed that they were using inquiry in their practice." The evidence shows that all participants had a strong belief in inquiry as a valid science teaching strategy and all cited examples of how they used inquiry in their classes.

To What Extent do These Graduates use Inquiry in Their Practice?

Participants knew weeks in advance of when their classroom observations were scheduled. The participants approved the days, the times, the classes, and the lessons that presumably represented their best teaching practice. For most of these observations, research associates were present during the lessons to observe and video record. Some teachers were loaned cameras over several weeks to video record themselves, and the research associates observed them by viewing those recordings. After the observations, each participant was asked if the lesson was representative of his or her teaching. If they said no, another visit was scheduled. This is a significant point because participants may complain that the day of observation was just a bad teaching day. Hence the results of the study are invalid. Using this protocol assures that every participant had at least a representative 'average' teaching day and allowed

for an exemplary teaching day. Therefore, if any bias occurred, it was in favor of the participant. All RTOP scores were therefore based on average to exceptional teaching practices.

Appendix 5 contains a copy of the RTOP. Before proceeding, the reader is urged to review the document and note the factors that comprise an RTOP score. Table 4.8 shows the **total** RTOP score for each participant by semester. In addition, the last column shows the average total RTOP score over the five semester of the study.

The total RTOP score is a relative measure on a teaching continuum. Rarely is teaching completely traditional or entirely reformed. The RTOP uses a scale of zero to one-hundred representing the entire continuum of traditional vs. reformed teaching. Total RTOP scores of less then fifty are considered traditional on the continuum and total scores of fifty or higher are considered evidence that the participant is using reformed (inquiry-based) teaching practices. Although these teachers did have some elements of inquiry-based teaching, a majority of their teaching was more traditional then reformed. For all but one teacher, the average of their RTOP scores over the course of the study was under 50 (and that exception scored only a 51).

RTOP scores obtained during Methods 2 or student teaching were not included on Table 4.8 because they may not have represent the teachers' preferred practice, but rather that of their professors or cooperating teachers.

Table 4.8 RTOP Scores for Teaching Practice

Participant	Fall 2006	Spring 2007	Fall 2007	Spring 2008	Fall 2008	Average
Kerry	Methods 2		Student Teaching		51	**51**
Bella	Methods 2		Student Teaching		24	**24**
Laurel	Methods 2		Student Teaching		23	**23**
Misty Kate	Student Teaching		15	22	21	**19**
Marcella	Student Teaching		25	53	33	**37**
Rob	Student Teaching		25	35	45	**35**
Shannon	Student Teaching		49	37	27	**38**
Seth	34	33	23	23	54	**33**
Ronald	33	27	48	25	38	**34**
Nadia	48	40	49	20	26	**37**
Mara	28	25	40	29	41	**33**
Peggy	30	19	35	21	45	**30**
Rose-Abby	54	71	29	32	*	**47**

* no observation made

Summary of the Third Research Question

To what extent do these graduates use inquiry in their practice? With the exception of Kerry, all participants had a total RTOP score of less then fifty. This reflects a traditional rather then reformed teaching practice according to the RTOP manual (Pilburn et al., 2000). Kerry was the exception with a score of fifty-one. This score was based on only one measurement. Given these facts, it's safe to say that all participants reflected more of a traditional rather then a reformed teaching practice.

Does the use of Inquiry by These Graduates Change Over Time?

To answer this question, all total RTOP scores (including methods 2 and student teaching) are included in Table 4.9.

Table 4.9 Total RTOP Scores for All Participants

Participant	Fall 2006	Spring 2007	Fall 2007	Spring 2008	Fall 2008
Kerry	69		36		51
Bella	60		16		24
Laurel	69		41		23
Misty Kate	*		15	22	21
Marcella	48		25	53	33
Rob	70		25	35	45
Shannon	*		49	37	27
Seth	34	33	23	23	54
Ronald	33	27	48	25	38
Nadia	48	40	49	20	26
Mara	28	25	40	29	41
Peggy	30	19	35	21	45
Rose-Abby	54	71	29	32	*

* No observations were made

A case could be made that students in college were teaching to a rubric that rewarded inquiry-based teaching, and that is the reason why those score are the highest in the study. But the strong support of inquiry-based teaching practices expressed by these participants, even after graduation, would indicate that these pre-service scores don't simply reflect an academic exercise done to placate science education professors. These participants seemed to strongly believe in the merits of inquiry-based teaching instruction.

Data were collected for three years, from 2006 through 2008. In order to capture the continuum of teaching experience, the participants were selected with different teacher experience starting points (see figure 4.2). At the study's inception in fall 2006, cohort one (pink) was in pre-service, cohort two (green) was student teaching; cohort three (blue) was in the first year of teaching and cohort four (turquoise) participants had three or more years of teaching experience.

In order to answer this research question: *Does the use of inquiry by these graduates change over time?* It was necessary to look at the data in relationship to the stage of professional development of the participant. In figure 4.3, the length of each line represents the three years of the study. The color of the line represents the cohort (from the paragraph above). The placement of the lines represents how teachers in each cohort spent those three years.

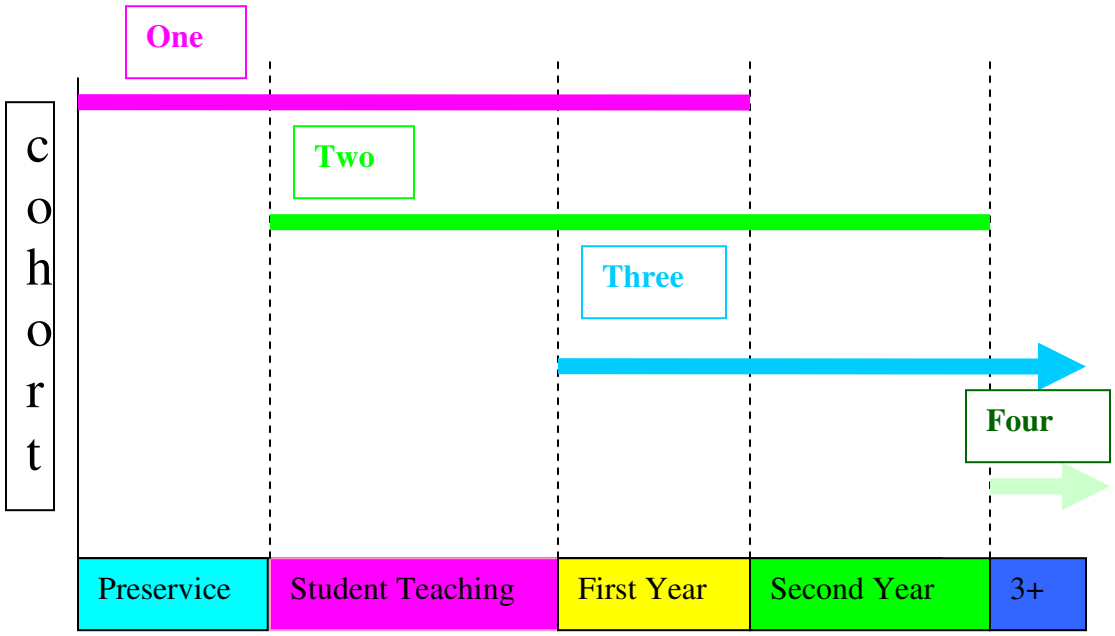


Figure 4.3 Conversions of Cohorts to a Professional Development Relationship

Table 4.10 is created by averaging the total RTOP scores by professional year. Referring to Appendix 24, the three participants of cohort 1, Kerry, Bella, and Laurel, had individual total RTOP scores of 69, 60, and 69 respectively. These three total RTOP scores average 66. This is the value found in the last column of Table 4.12.

Table 4.10 Total RTOP Scores vs. Professional Development

Professional Developme	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Average
Preservice	69	60	69															66
Student Teaching	36	16	41	48	70													42
First Year Teaching	51	24	23	15	25	25	49	22	53	35	37	34	33	48	33	27	40	34
Second Year Teaching	21	33	45	27	23	48	49	23	25	20								29
Three + Years Teaching	54	38	26	28	30	54	25	19	71	40	35	29	29	21	32	41	45	36

Table 4.10 reorganizes the data found in Table 4.09. This reorganization reveals that the highest average RTOP scores occurred during pre-service education (66). The scores decreased significantly during student teaching to 42 (a thirty six percent decrease from pre-service). The average total RTOP score continued to decrease in the first year of teaching to 34 (a nineteen percent decrease from student teaching). The average total RTOP score continued to decrease in the second year of teaching to the lowest score of all at 29 (a fifteen percent drop from the first year of teaching). The downward trend stopped with teachers who had three or more years of experience. The total average RTOP score jumped from 29 to 36 (a twenty-four percent increase). The only scores reflecting reformed based teaching were those earned during the pre-service experience.

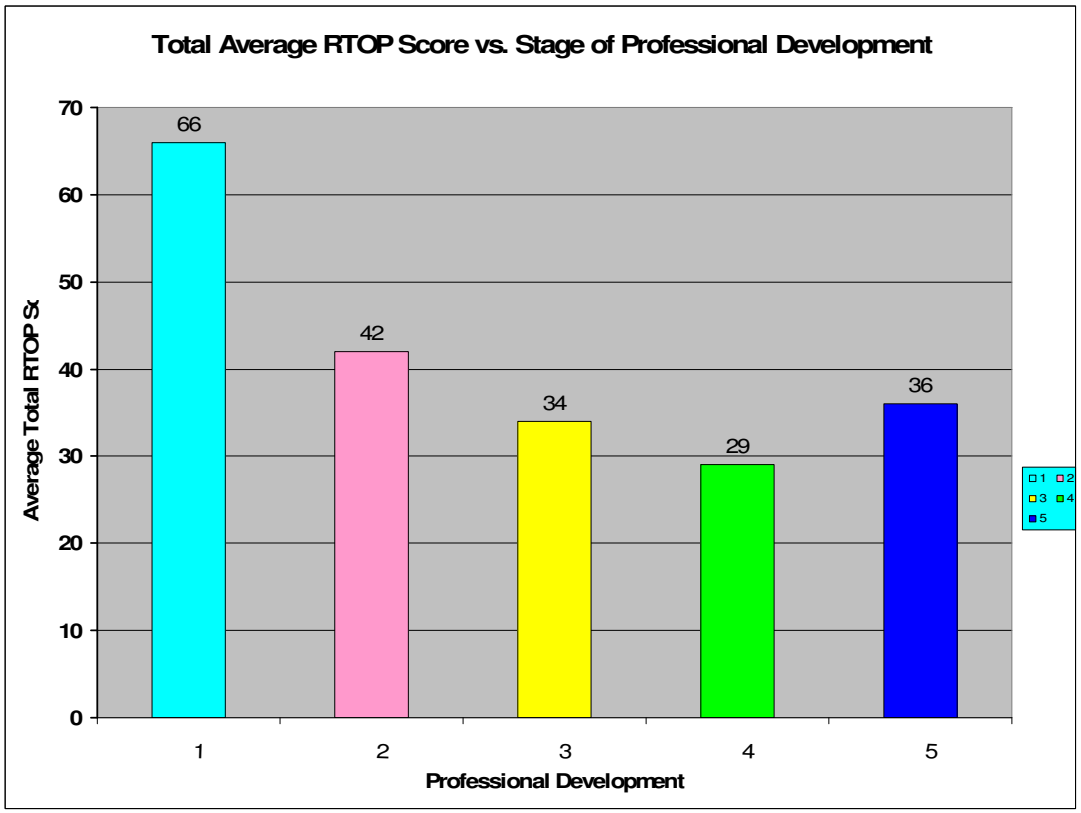


Figure 4.4 Chart: Total Mean RTOP Scores vs. Stages of Professional Development

Summary of the Fourth Research Question

Does the use of inquiry by these graduates change over time? Yes. The total RTOP scores averaged 66 in college, reflecting a reformed based teaching practice. As teachers begin student teaching, scores dropped to 42. They continued to decrease to 34 during the first year of teaching, reaching an all time low of 29 during the second year of teaching. With teachers who had three or more years of experience, the average total RTOP score increased slightly to 36.

What Changes in Classroom Practice can be Observed Over Time?

To answer this question, an examination the sub-scale scores of the RTOP instrument was necessary. Appendix 24 is a spreadsheet of the RTOP sub-scale scores. The values found on the table are the sum of the five questions in each sub-section. These scores can be found on the spreadsheet. Table 4.11 contains the titles of the five sub-scales of the RTOP.

Table 4.11 RTOP Sub-scales and Question Numbers

Sub-Scale	Title	Question Numbers
A	Lesson Design and Implementation	1-5
B	Propositional Knowledge	6-10
C	Procedural Knowledge	11-15
D	Communicative Interactions	16-20
E	Student/Teacher Relationships	21-25

The spreadsheet in Appendix 24 has data organized by cohort and the semester the data were actually collected. This research question looks for how sub-scale scores change over time.

Table 4.12 reorganizes this large spreadsheet in Appendix 24 into a manageable display of applicable data. If the reader looks in Appendix 24, they will see that one observation of each of the three participants in cohort 1 was made in fall of 2006. The spreadsheet shows the sum of questions one through five for Kerry as '13'. Questions six through ten summed up to be '15' for Kerry and so on. The second participant listed in Appendix 24 is Bella who had a sum of '10' for questions one through five and a sum of '16' for questions six through ten. Table 4.12 shows the average sum for all participants. To read the Table 4.12 correctly, follow this example.

On the spread sheet in Appendix 24, Kerry, Bella, and Laurel had the following scores for questions one through five: 13, 10, and 13 respectively. Each of these scores represent the sum of questions one through five for each of the three participants. The average of 13, 10, and 13 is 12. This is what appears on Table 4.12.

Because there was only one cohort in pre-service in the fall of 2006, there is only one row on Table 4.12 to represent this fact. There are two rows for student teaching on Table 4.12. The first row is the average sums for the three participants in cohort 1: Kerry, Bella, and Laurel. The second row is for cohort two participants: Misty Kate, Marcella, Rob, and Shannon. The second to last column shows the total of the average sum scores for questions one through twenty-five. Looking at the first row, Pre-service teachers had a mean sum subscale scores of 12, 15, 12, 12, and 13. The total of these five scores was 66. The last column on Table 4.12 shows the cohort and the semester where the data originated.

Table 4.12 clearly shows that column "B": Propositional Knowledge, is the subscale with the highest score. The subscale score for Propositional Knowledge seems unaffected by time. Teachers started out with high propositional knowledge and it remained high throughout their teaching careers. The other sub-scales are a little more difficult to interpret on Table 4.12.

Table 4.12 RTOP Sub-scale Scores

	A	B	C	D	E	Total	cohort
Preservice (Average)	12	15	12	12	13	66	C1 (f 06)
Student Teaching (Average)	5	11	3	5	7	31	C1 (f 07)
	8	14	10	10	16	59	C2 (f 06)
First Year Teaching (Average)	3	12	2	7	8	33	C1 (f 08)
	4	13	2	4	6	29	C2 (f 07)
	6	12	3	7	10	38	C2 (s08)
	7	12	4	8	9	40	C3 (f06)
	4	13	4	8	8	33	C3 (s07)
Second Year Teaching (Average)	4	13	1	6	8	32	C2 (f08)
	6	14	4	8	9	38	C3 (f07)
	2	12	0	5	6	24	C3 (s08)
Three + Years Teaching (Average)	3	13	4	7	8	35	C3 (f08)
	5	15	4	7	7	37	C4 (f06)
	6	14	4	7	7	38	C4(s07)
	3	14	7	8	8	35	C4 (f07)
	3	12	1	4	7	27	C4 (s08)
	4	13	5	10	12	43	C4 (f08)

The data on Table 4.12 are collapsed into Table 4.13 in an effort to identify changes in sub-scale scores over time. The values found in each cell of Table 4.13 are the mean of the sums of each RTOP sub section. To read Table 4.13, look at the two entries for student teaching on Table 4.12 (8 and 5). The average [(8+5)/2] = 6.5. Rounding 6.5 to 7, this is the score that appears in the first column, second row of Table 4.13. The last column of the Table 4.13 shows the number of RTOPs used in gathering these scores. By collapsing the data in Table 4.12 down to the mean sums (Table 4.13), some interesting trends become apparent. Scores of 10 or more reflect reformed teaching practices.

Table 4.13 Table of Mean Sub-scale RTOP Scores by Professional Development Year

Professional Development	Mean Sums A	B	C	D	E	Total	RTOP (n)
Preservice	12	15	12	12	13	66	3
Student Teaching	7	13	7	8	12	47	5
First Year Teaching	5	12	3	7	8	35	17
Second Year Teaching	4	13	2	6	8	33	10
Three + Years Teaching	4	14	4	7	8	37	14

Mean Sum A: Lesson Design and Implementation, scores decreased dramatically, by forty two percent, when the student began teaching in the public schools. Furthermore, the table shows that scores continued to decrease with continued public school teaching experience. The data show a sixty seven percent decrease from pre-service teaching.

Mean Sum B: Propositional Knowledge, scores showed exactly what was found in Table 4.13; they began high, well within the range of inquiry-based teaching practice and remained high throughout the professional growth of the teacher.

Mean Sum C: Procedural Knowledge, scores showed the most dramatic decrease of all the sub-scale sums. The score dropped by forty six percent between pre-service and student teaching. The score continued to fall by fifty-seven percent between student teaching and first year teaching. And then the same score fell another forty percent between the first and second years of teaching. Then the score increased over two-hundred and fifty percent with teachers who had three or more years of experience.

Mean Sum D: Communicative Interactions, scores decreased dramatically, by almost fifty percent when the student began teaching in the public schools. The table shows a stabilization of this score in the first and second years of teaching and a small jump with teachers who had three or more years of experience.

Mean Sum E: Student/Teacher Relationships, scores showed a decline from pre-service to first year teaching and then remained constant throughout the remainder of the teaching continuum.

The total RTOP scores showed a steady decline as teachers entered the public schools. The scores improved slightly (by four points) with teachers who had more then three years of teaching experience. This was primarily due to an increase in procedural knowledge. But this increase was far from inquiry-based instruction.

Table 4.13 shows that for the propositional knowledge questions (6-10), participants scored between 12 and 15 (out of a maximum 20) across all professional development stages. These were the highest scores of all sub-scales measured on the RTOP. Teachers began their careers with good content knowledge and it remained high, on average, throughout their years of teaching. Table 4.13 also shows that the average total RTOP score was highest (within the inquiry-based instruction range) during pre-service. This average total RTOP score decreased to the level of traditional based instruction through student teaching, first year teaching, and the second year of teaching. There was a slight increase in RTOP scores when teachers reached 3 or more

years of experience, as shown in the area chart of figure 4.5, but this average still reflected tradition based teaching practices.

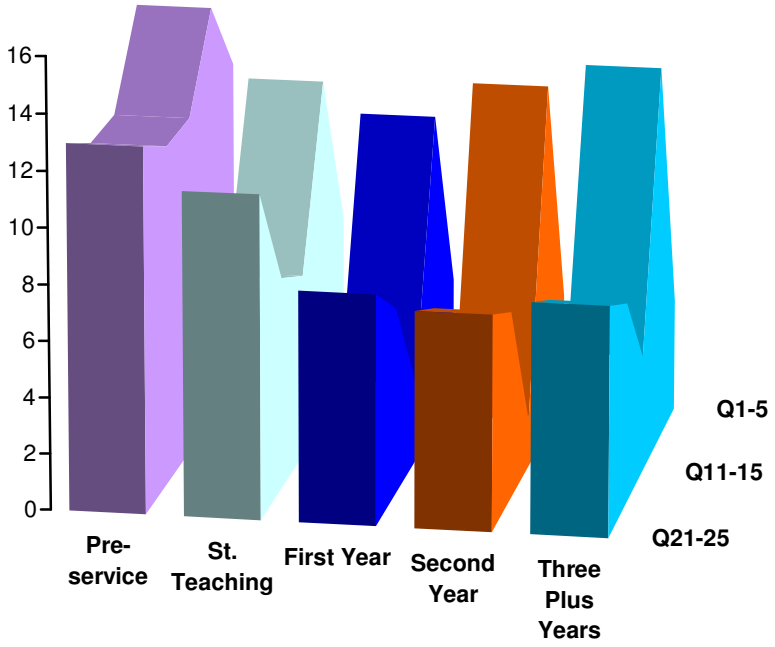


Figure 4.5 Area Chart for RTOP Questions 1-25

Figure 4.2 shows some remarkable patterns. The general shape of each block was similar from year to year with the exception of the pre-service year. This may indicate that RTOP is a reliable instrument. In addition, the three plus year area box is slightly larger then those of years one and two. This reflects the slightly higher RTOP total score. Why do teachers have decreasing scores in all by one area from pre-service to first year, to second year, then suddenly have a slight increase in sub-scale scores?

Summary of the Fifth Research Question

What changes in classroom practice can be observed over time? With the exception of content knowledge, the scores for all areas measured by RTOP decreased with exposure to the public secondary school environment. In pre-service education, the average RTOP score was 66 in this study. This score decreased with more years of public school teaching and stabilized around 36. Teachers are introduced to and demonstrate inquiry-based teaching practice in college, but their practice became more traditional as teaching experience grew.

What are the Barriers to Inquiry-based Teaching?

After conducting dozens of interviews and reviewing thousands of pages of transcripts, the following barriers (perceived or otherwise) to the teaching of science through inquiry can be sorted into three general categories:

- Limitations of students (or teachers)
- Limited resources or support
- A culture of high stakes testing

Barriers Created by Limitations of Students (or Teachers)

Of all the reasons participants provided for why they don't employ more inquiry in their science classrooms, blaming students or themselves was cited the least. This issue was not mentioned at all by most teachers and the ones who cited it did so much less frequently and with less emphasis than other barriers.

In this category, teachers are sometimes troubled by the sense that inquiry can give students too much freedom. When this issue arises, it usually appears in a discussion of poorly-performing academic students. Teachers cited challenging home lives, poor academic skills, and disciplinary problems as reasons these students are hard to teach in an inquiry setting. The issue also arises in discussions of high-achieving students. Teachers cited the pressure these students face to show academic success, saying this makes the students uncomfortable with activities that don't directly feed them the information they need to score well on tests. In other words, teachers mentioning this barrier say either that some students are so weak academically that they need more structure, or that some students are so used to academic success that they demand more structure. Only one teacher (Laurel) cited herself as a barrier. She felt unsure of her ability to create inquiry activities in a classroom, especially when teaching a subject in which she had little experience.

Appendix 28 provides examples of the kinds of quotes that are evidence for this barrier to inquiry-based teaching that arises from problems intrinsic to students or their teachers.

Barriers Created by Limitations on Resources

A more common reason teachers cited as a barrier to using inquiry practices can be best summarized as a lack of resources. In this category, teachers cited overcrowded classes as causing increased workloads. This increase in workload allowed less time for lesson planning, and inquiry-based instruction requires more

planning then "canned" lessons and labs. Teachers also cited meager budgets and inadequate equipment and supplies. In addition, they mentioned lack of support from parents or administrators. Quotes illustrating this barrier appear in Appendix 29. Unlike the intrinsic factors mentioned previously, these extrinsic resource issues arose with relative frequency. This was still not the most important barrier to inquiry.

Barriers Created by a Culture of High Stakes Testing

Of all the factors mentioned as barriers to using Inquiry in the science classroom, the one mentioned the most was high-stakes testing. This was a pervasive and overwhelming problem discussed by every participant over and over again throughout the course of the study. Table 4.14 indicates which participants mentioned each barrier. Note that it is clear that the only barrier mentioned by everyone was high-stakes testing.

Table 4.14 Participants Mentioning High-Stakes Testing Versus Other Barriers

Participants		Culture of High-Stakes Testing	Limited Resources/Support	Limited by Students
Kerry		√	√	
Bella		√		
Laurel		√	√	√
Misty Kate		√		
Marcella		√		√
Rob		√	√	
Shannon		√		
Seth		√	√	
Rob		√		
Nadia		√		√
Mara		√	√	
Peggy		√	√	√
Rose-Abby		√		

From the interview transcripts for these 13 participants alone, 96 pages of single spaced quotes have been harvested in support of the fact that high-stakes testing created a barrier to Inquiry. Many participants repeated issues cited by other participants, and many of these issues arose at all stages of professional development. Appendix 30 includes representative quotes from the in-depth participants. While these participants believed inquiry was the best way to teach science, it is very difficult to teach that way in the current culture, in which high-stakes testing is the benchmark used to judge the success of students and their teachers..

Summary of the Sixth Research Question

What are the barriers to inquiry-based teaching? In order of importance (starting with most important):

1. High stakes testing
2. Overcrowded classrooms
3. High work loads
4. No administrative support
5. Little equipment and few resources especially with exceptional students, both academically challenged and gifted.

Inquiry-based science teaching is believed by most researchers to be the best way to teach science. In today's schools, inquiry is believed by most science teachers to be the best way to teach science and for students to learn science. But the school culture

promotes traditional teaching practices, and success seems only to be judged by how well students perform on standardized tests.

CHAPTER 5: DISCUSSION AND RECOMMENDATIONS

> *…science education, a term that is incorrectly defined in current usage. Rather than learning how to think scientifically, students are generally being told about science and asked to remember facts… Vast numbers of adults fail to take a scientific approach to solving problems or making judgments based on evidence. Instead, they readily accept simplistic answers to complicated problems that are confidently espoused by popular talk-show hosts or political leaders, counter to all evidence and logic… Their science teachers failed to make it clear that science fundamentally depends on evidence that can be logically and independently verified; instead, they taught science as if it were a form of revealed truth from scientists... What would it take to get scientists to teach their college courses in a way [that teaches students to think scientifically]? I suggest that we start with new assessments. It is much easier to test for the facts of science than it is to test for the other critical types of science understanding, such as whether students can participate productively in scientific discourse* (Alberts, 2009).

Bruce Alberts is the Editor-in-Chief of the journal *Science*. The passage above is taken from his editorial of February 6, 2009. A well-known and influential scientist, Dr. Alberts is one of the few scientists who recognize the real danger to our democracy and way of life if science education is not reformed (Gardener, 1983). "Democracy cannot succeed unless those who express their choice are prepared to choose wisely. The real safeguard of democracy, therefore, is education (Roosevelt, 1940)." If many college graduates in the United States see no difference between scientific and nonscientific explanations of natural phenomena such as evolution (J. A.

Moore, 1985), then understanding of these phenomena and potential solutions will suffer. “The function of education is to teach one to think intensively and to think critically. Intelligence plus character - that is the goal of true education (King, 1960).” When the most educated in our society are products of an educational system that instills corruption, what is the future of our country (Nichols & Berliner, 2005)? If American citizens are not taught to think logically and critically at evidence, it’s not just the children who are at risk; our entire nation is at risk (AAAS, 1989).

Introduction

This dissertation focused on two ways that science can be taught. In the traditional way of teaching science, students are taught names, dates, discoveries, and facts about natural phenomena (Wallace & Louden, 2002). Students are passive receivers of information and teachers are transmitters (Solomon & Aikenhead, 1994). The students are given multiple choice tests about these scientific facts (Bereiter, 1994). With inquiry -based science teaching, students are taught to think like scientists (Schwab & Brandwein, 1962). They are presented with phenomena and asked to develop hypotheses, design experiments, reach logical conclusions, and share their findings with others in the class (Bell et al., 2003). Inquiry-based teaching practices have been shown to be at least as effective as traditional practices in terms of student performance on standardized tests (R. D. Anderson, 2002).

In this dissertation at Research University (RU), thirteen participants representing the science teaching continuum were studied for three years. The study

found that these teachers were educated in the ways of inquiry-based science teaching. The study further showed that most of these teachers believe that inquiry is the best way to teach science. Their practices showed inquiry-based teaching in college, but with continued experience in public schools, their practices became increasingly traditional. Data from these participants provide insights into barriers that limited their ability to turn their inquiry beliefs into practice.

Research Questions

A. To what extent is inquiry taught to graduates of Research University?

B. To what extent do these graduates believe they are using inquiry in their practice?

C. To what extent do these graduates use inquiry in their practice?

D. Does the use of inquiry by these graduates change over time?

E. What changes in classroom practice can be observed over time?

F. What are the perceived barriers to inquiry-based teaching?

Review of the Findings

A. To what extent is inquiry taught to graduates of Research University?

Ron Anderson (2003) and others assert that most teachers don't even know what inquiry is, nor do science educators agree on a definition (Abrams & Southerland, 2003; Moss, 2003; Settlage, 2003). Contrary to Anderson, this study shows that graduates of Research University had a definition of inquiry-based teaching and clearly demonstrated the practice during pre-service education, as measured by a reportedly valid instrument, RTOP.

Inquiry-based teaching practices emphasize the importance of science literacy and are strongly supported and recommended by The American Association for the Advancement of Science (AAAS) *Project 2061: Science for All Americans* (AAAS, 1989). The science education department head of Research University fully subscribes to this viewpoint by insisting during an interview that students should "learn about inquiry, have inquiry modeled for them, learn through inquiry, practice inquiry teaching and skills, and develop a disposition to use inquiry (Penick, 2008)." Through interviews with students, graduates, and professors of RU, data shows that for the most part this objective was achieved. The data show that in science education classes inquiry was being taught, modeled, learned, and practiced, and a disposition for using inquiry was adopted by students. Interviews with graduates showed that they believe in the merits of inquiry, but the disposition to practice inquiry was being minimized, primarily by the public school culture of high stakes testing.

B. To what extent do these graduates use inquiry in their practice?

Despite decades of effort and financial support very little inquiry-based science has been documented in classrooms (Frechtling et al., 1995; Keys & Bryan, 2001; Woodbury & Gess-Newsome, 2002). This dissertation supports these findings and indicates some causes. Total RTOP scores of less then fifty reflect more traditional teaching practices then scores greater then fifty. Table 5.1 shows the average total RTOP scores obtained in this study and indicates that traditional science teaching remained the pervasive mode of educating students in public schools of this study.

Table 5.1 Table of Mean Total RTOP Scores

RTOP Score by Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Average
Preservice	69	60	69															66
Student Teaching	48	70	36	16	41													42
First Year	15	22	25	53	25	35	44	34	33	48	33	33	27	40	51	24	23	33
Second Year	21	33	45	31	23	48	49	29	23	25	20							32
Three +	23	54	38	26	28	30	54	25	19	71	40	35	29	21	32	41	45	36

C. To what extent do these graduates believe they are using inquiry in their practice? All participants seemed aware that they were not using as much inquiry in their practice as they would have liked.

D. Does the use of inquiry by these graduates change over time? Table 5.1 shows that the use of inquiry diminished with time spent in the public schools. There was a small increase in the average total RTOP score with teachers who had three or more years of teaching experience.

E. What changes in classroom practice can be observed over time? Table 5.2 shows the subscales of the RTOP instrument.

Table 5.2 RTOP Sub-scale Scores and Question Numbers

Sub-Scale	Title	Question Numbers
A	Lesson Design and Implementation	1-5
B	Propositional Knowledge	6-10
C	Procedural Knowledge	11-15
D	Communicative Interactions	16-20
E	Student/Teacher Relationships	21-25

Table 5.3 shows that Propositional Knowledge started out high and remained high throughout the teaching continuum as measured by RTOP. The small gain in Procedural Knowledge is the reason for the slight increase in total RTOP scores for

teachers with three or more years of teaching experience. The RTOP questions for Content (Propositional Knowledge) are shown here:

Content (Propositional Knowledge). Teachers knowing their science and teaching lessons that:

6) involve fundamental concepts;
7) promote coherent understanding across topics and situations;
8) demonstrate teacher content knowledge;
9) encourage appropriate abstraction; and
10) explore and value interdisciplinary contexts and real world phenomena.

This study shows that teachers scored high in content (Propositional Knowledge) throughout their teaching careers. Teachers with three or more years of experience increased slightly in their Procedural Knowledge. The following statements refer to this kind of knowledge.

Content (Procedural Knowledge). Science lessons that use scientific reasoning and teachers' understanding of pedagogy to:

11) use a variety of representations to represent phenomena;
12) make and test predictions, hypotheses, estimates or conjectures;
13) are actively engaging and thought-provoking and include critical assessment;
14) demonstrate metacognition (critical self-reflection); and
15) show intellectual dialogue, challenge, debate negotiation, interpretation and discourse.

Table 5.3 Table of Mean Sub-scale RTOP Scores by Professional Development Year

	Q1-Q5	Q6-Q10	Q11-Q15	Q16-Q20	Q21-Q25	Average
Preservice	12	15.00	12.00	12.00	13.00	66.00
St.Teaching	6.5	12.50	6.50	7.50	11.50	45.00
First Year	4.4	11.40	2.80	6.60	8.20	33.00
Second Year	4	12.67	1.67	6.67	7.67	31.67
3+ Years	4	13.50	4.17	7.17	8.17	35.83

F. What are the perceived barriers to inquiry-based teaching? Analysis of over 1,000 pages of transcripts collected over three years of this study identified the following reasons teachers cited for not using more inquiry-based teaching in their classrooms, in order of frequency and intensity (with the most frequent and intensely expressed listed first):

1. High stakes testing
2. Overcrowded classrooms
3. High work loads
4. No administrative support
5. Lack of equipment/resources

Table 5.4 shows the most often cited reasons teachers in this study gave for not using inquiry-based instruction in public schools. It also lists some representative authors who have written about these barriers. The most cited barrier to inquiry-based instruction is a school culture of high stakes testing.

Table 5.4 Top Reasons Cited by Teachers for Not Using Inquiry-based Practices

#	**Reasons Cited For Not Using Inquiry**	**Author(s)**
1	School culture of high stakes testing and no support for inquiry-based science teaching from the administration, fellow teachers, or parents	(Allen, 2006; Amrein & Berliner, 2002; Boger, 2002; Fowler & Walberg, 1991; Horn, 2003; M. G. Jones et al., 2003; Mabry et al., 2002; M. L. Smith & Fey, 2000; Veal et al., 2006)

Table 5.4 (Cont.) Top Reasons Cited For Not Using Inquiry by Participants

2	Too much material in the curriculum	(Grossman, 2003; McKinney et al., 2007; Rees, 2007; Shaver et al., 2007; Timperley & Robinson, 2000; Wright & Wright, 2007)
3	Overcrowded classrooms/facilities/changing rooms	(Butt & Lance, 2005; Finn & Achilles, 1990; Garfield, 2008; Gilbert, 2008; Johnstone, 1993; Luiselli et al., 2005; Rees, 2007)
4	Lack of planning time	(Darling-Hammond & Baransford, 2005; Rees, 2007; Reyes & Imber, 1992; Schaufeli et al., 1997; Watson, 2006)
5	No equipment/textbooks/budgets	(Bradford, 2005; Dworkin, 1987; Escalada & Zollman, 1998; Felder & Brent, 1996; Henriques, 2002; Report, 1998; Wiemann, 1981)
6	Students Resist inquiry-based instruction: A. Good students don't want to make mistakes. B. Some students can't read. C. Academically challenged students can't handle the freedom. (The inquiry-based teaching method invites discipline problems.)	(R. D. Anderson, 2002; Donahue et al., 1998; Education, 2001; Frechtling, Sharp, Carey, Vaden-Kiernan, & Westat, 1995; Fruge, 2007; Holt & O'Tuel, 1989; Keys & Bryan, 2001; Kohn, 1992; Moss, 2001; Rice, 1999; Settlage, 2007; Wagner, 1995; Woodbury & Gess-Newsome, 2002; Worling et al., 1999)
7	Lack of confidence, liability concerns	(Livingstone, 1994; Rice, 1999)

This dissertation supports these authors' findings. The schools of this study seemed plagued with the some of the same barriers to inquiry-based instruction as the schools of a decade ago (overcrowding, lack of resources, etc.) but that the burden was made much heavier with the pressure created by the culture of testing. This study found that high stakes testing was considered the greatest barrier by teachers although other reasons were also cited. Teachers insisted that high stakes testing forces them to teach an impossible amount of information to students with total disregard for student

ability, aptitude, or desire to learn. This environment values tests more than students or their learning.

Implications

Teachers educated at Research University are taught to use inquiry-based methods when they teach science. The video recordings of them teaching a lesson in college, coded using RTOP, reflected inquiry-based teaching practices. Yet, when these same students were observed a year later, during student teaching, their practice had become less inquiry-based and more traditional. These same teachers observed later, during their first year of professional teaching, were even more traditional in their science teaching practice.

This is happening to teachers at a time when their students are most in need of excellent and innovative teaching. First, middle-and-high school students bear the normal emotional baggage of adolescence (Ketterlinus & Lamb, 1994). This includes situational depression, romantic ups and downs, hormonal changes, feelings of isolation, social awkwardness, cliques and bullying, academic pressures, and so forth. As if that wasn't enough, these students now also live in an economic climate that heaps on additional burdens (Money, 2009). When they come to school, many adolescents carry with them this heavy load.

- Some have parents who have just lost their jobs.
- Many have families who have just lost their homes. Some of those have moved in with relatives, drastically changing the family structure and routines.

- Many students come to school hungry, because their parents struggle to provide food, but are too proud for food stamps or assistance in paying for school meals.

- North Carolina is a proud and long time friend of the military and boasts many military bases. Some parents are coming back from war with serious psychological wounds, and domestic violence is on the increase.

- With unstable home lives, some students may even find family in gangs.

- For many of these students, it is difficult to imagine a future where they will live in prosperity or even just financial security.

In such challenging times, students need teachers and a school environment that encourages learning, exploration, critical thinking and hope. What they find instead is an overwhelming, results-obsessed focus on test-driven teaching.

In today's schools, testing is king, and curriculum is rigidly defined to serve that master. Teachers complain of being spread so thin with academic demands and endless administrative paperwork, that student are secondary to the process instead of the focus. Often, these teachers' jobs depend not on their compassion for students and their excellence as educators, but instead on whether they can train their students to memorize material and regurgitate it through rote memory on standardized tests.

Is this really the best our society can offer? Should we settle for a system that increases stress for both teachers and students while decreasing meaningful learning? Surely, we can and should strive for higher goals.

Recommendations

Now more then ever, teachers are confronted with students in crisis. The *Journal of the American Medical Association* reported that teen suicide rates spiked in

2006 and 2007. This study goes on to show that the teen suicide rate is on the rise and that these spikes are not just anomalies (Bridge, 2008). Student-on-student and student-on-teacher violence is also up (Mohin, 2006). This dissertation study indicates that teachers may be preoccupied with test scores and may not be recognizing more serious problems confronting students (ie violence and suicide). If this trend continues, much more serous consequences then just poor test scores could result.

Inquiry calls for the science classes to be learning community. Teachers must learn what students already understand (or misunderstand) about a topic before a lesson can be designed. In an inquiry environment where the teacher is more of a listener than speaker, there is a greater possibility of identifying serious problems with student development.

Teachers in this study identified five major barriers to inquiry-based instruction in the school culture of today:

1. High stakes testing
2. Overcrowded classrooms
3. High work loads
4. No administrative support
5. Lack of equipment/resources

The following are recommendations for overcoming each of these barriers.

High Stakes Testing

Many professional educational organizations have spoken out strongly against the use of a single test score for promotion and/or graduation of students. The American Evaluation Association (AEA) recently released a position paper stating, "High-stakes testing leads to under-serving or miss-serving all students, especially the most needy and vulnerable, thereby violating the principle of `do no harm'" (Mabry et al., 2002). Basing its position on the 1999 Standards for Educational and Psychological Testing, the American Educational Research Association (AERA) writes, "Decisions that affect individual students' life chances or educational opportunities should not be made on the basis of the Test scores give us important information, but they do not give us all the information necessary to make critical decisions" (AERA, 2002).

First do no harm. This is the creed of all professions and is especially true in education. Yet end of course testing shows that this evaluative practice's harm outweighs the benefits. The following criticisms come from the American Evaluation Association (Mabry et al., 2002).

High Stakes tests:

- *are employed without credible independent meta-evaluation*
- *are flawed, both in technical adequacy and in accuracy of scoring and reporting*
- *promulgate undue centralized control of what is taught and how*
- *channel educational offerings to satisfy monolithic, narrow, test-defined state standards rather than address the differential needs of students in local schools*

- *draw schools into narrow conceptions of teaching and education that leave children deprived of the history, cultural perspective, personal experience, and interdisciplinary nature of subject matter*
- *narrow the curriculum to tested subjects, usually reading, writing, and mathematics and marginalize non-tested subjects, which often include the fine arts, physical education, social studies and science*
- *stimulate teachers and principals to manipulate test scoring and standards, change students' answers, send slow learners away on testing day, or otherwise invalidate test scores*
- *consume a disproportionate amount of student and teacher time that takes away from other valued school goals and activities, e.g., spending as much 30% of the school year preparing specifically for tests*
- *assume that all children, including English language learners and special education students, learn in the same ways at the same rate and that they can all demonstrate their achievements on standardized tests*
- *focus attention on particular students, such as those scoring just below the cut-off score and ignoring those who score well above and below the cut off score*
- *encourage, in direct and indirect ways, students who may not pass the test to stay home on testing days or to drop out of school altogether*
- *measure, for the most part, parental income and race, and therefore perpetuate racism, classism and anti-working class sentiment*
- *contribute to an atmosphere of distrust, fear, divisive competition, and hysteria that is antithetical to teaching and learning*
- *contribute to an atmosphere that pits teachers against teachers, students against students, and schools against schools in a bid for financial rewards and to avoid financial retribution are used unjustly to fire and discipline teachers and principals (p. 2-3).*

These are not just hypothetical concerns. A study conducted at Arizona State University found empirical evidence suggesting that the high stakes tests were flawed and the answers to the questions produced unreliable scores. These scores had direct and damaging consequences for students and teachers. "High-stakes testing produces teaching and testing practices that lead to inflated test scores and further disadvantage already disadvantaged students" (M. L. Smith & Fey, 2000).

Perhaps the most extensive report on high stakes testing was conducted by the Great Lakes Center for Education Research & Practice. The study concluded that high stakes testing causes corruption of the educational system. “Educators are trying either to win or not to lose in high-stakes testing environments, by manipulating the indicator for their own benefit. Some do this by pushing the weaker students out, or letting them drop out without helping them stay in school” (Nichols & Berliner, 2005). Thus the test scores of some schools were made to rise artificially. The most distressing finding was the total abandonment of an ethic of caring. Students became little more then a score.

This behavior demonstrates some teachers’ and administrators’ abandonment of an ethic of caring. For many teachers, this ethic is what brought them to teaching in the first place. Jones (1999) writes “The idealistic intentions that usually bring people into education -- a desire to make some contribution to a better world, to improve the lives of kids, to offer a caring environment to children, and so on -- become perverted by the limited pursuit of higher test scores and the crass exploitation of a few extra dollars for achieving "better" results” (Jones et al., 1999). The ethical dilemma caused by high stakes testing forces many of these fine teachers to leave the profession (Nichols & Berliner, 2005). This 190 page report concludes with the following:

> *The scores we get from high-stakes tests cannot be trusted—they are corrupted and distorted. Moreover, such tests cannot adequately measure the important things we really want to measure. Even worse, to us, is the other issue—the people issue. High stakes testing programs corrupt and distort the people in the educational system and that cannot be good for a profession*

> *as vital to our nation as is teaching. We need to stop the wreckage of our public educational system through the use of high-stakes testing as soon as possible (p. 180).*

High stakes testing should be abolished. Tests should be used the way in which they were designed. Tests in science should move away from fact loaded recall tests to inquiry-based tests. Even a cursory Google search for "inquiry based science assessment instruments" produced 170,000 hits. Clearly there are many inquiry-based science tests available to teachers, administrators, and school districts. As will be addressed, this should be an area of further research. This culture of high stakes testing creates its own barrier to inquiry. It also aggravates other the other barriers teachers encounter.

Overcrowded Classrooms

High stakes testing often cites teacher accountability as a justification. Teachers in this study have claimed that when class sizes are larger then 10 to 15 students, the preferred instructional strategy becomes one of mob management. Inquiry-based instruction often times calls on students to work as a class or in small teams to solve problems. Like many team sports or school band, each student in an inquiry-based science project has their own area of responsibility. Middle and high school age children place a premium emotional value on peer relationships (Ketterlinus & Lamb, 1994). Hence, inquiry-based science classrooms increase student and teacher accountability because if either is absent, the entire class may be

unable to solve the problem. By reducing class sizes, more time can be spent with each student and more attention can be given to problems, both academic and personal.

President Barack Obama, in his first major address to a joint session of Congress (2009), encouraged states to spend a portion of their economic stimulus package money to increase the number of public schools. More classrooms would allow fewer students in each classroom. Many of the classrooms I visited during the course of this study were crammed with students. Some rooms had no aisles between desks. In some I had difficulty finding a place to stand and video tape. If a real fire were to happen, it would be impossible for the students to leave the room in an orderly fashion in less than three minutes. If the classes are so crowded that students can barely move, it is very unlikely that they have sufficient equipment, space, and freedom to facilitate meaningful inquiry and learning. More classrooms and less-crowded class sizes would improve the quality of education tremendously.

High Work Loads

Teaching is a high work load job. But endless standardized tests make it even more of a burden. Department-wide tests, school-wide tests, district-wide tests, state-wide tests, and national tests--If students are not taking tests, they are taking practice tests for the next test. Some teachers even use take-home tests as learning tools to help students better prepare for actual tests. In her State of the State address this year Beverly Purdue, governor of North Carolina, promised to reduce the number of redundant tests students take (2009). This would help. Every time one of these

standardized tests is given, teachers often times need to code the test booklets, count books and answer sheets, code the books and answer sheets, and alphabetize them before submitting to the office. These same teachers are often held responsible for administering the test to students who were absent on a test day. This must be done before or after school, during lunch, or during the teacher's prep period. All of this cuts into planning time and class instruction for students. As mentioned before, many of these tests are so poorly written that scores are meaningless. But because the future of students, faculty, and administrators may be adversely affected by these score, corruption of these test scores has become a serious problem.

Beverly Purdue, governor of North Carolina, also spoke of increasing the length of the school day. If North Carolina follows the President's suggestion to build more public schools and the governor's suggestion to increase the length of the school day, students in this state could receive a quality education. Lengthening the school day would involve hiring more teachers, perhaps a group for the morning shift and one for the afternoons. However it is accomplished, it should be done with sensitivity toward reducing teachers' workloads, rather than increasing them.

No Administrative Support

School administrators need to attend more continuing education courses that address the problems and special needs of science teachers and science students. As mentioned earlier in the study, one teacher said that her test scores are posted weekly in the faculty office and reprimands are very public and personal. Another teacher had

a thinly veiled threat. An administrator told him that a lot of people are without a job right now and if he doesn't get on board with this "Blue Diamond" testing, well . . . implying that he could find himself unemployed. Another teacher said that she had attended a meeting where her principal told the faculty that research had shown that laboratory experience actually reduces standardized test performance and urged the science teacher to do fewer labs.

Arguably, this entire high stakes testing culture is the responsibility of the administrators. If they would put less emphasis on it, a more conducive inquiry-based teaching environment would be created.

Lack of Equipment and Resources

During this study, I saw classrooms without even a class set of text books; let alone each student having his or her own. There was one classroom that looked like a converted storage room. No windows, air conditioning, heat, or counters and the desks were crammed in with less then six inches for aisle width, with no equipment of any kind. Surprisingly, inquiry activities don't always call for lots of laboratory equipment. Many activities have students figure out ways to make their own research equipment. But the more equipment the greater the choice of activity the instructor and students have and the richer the experience. The more laboratory equipment a science teaching community has, the greater the chance that exceptional learning will take place.

Resources are critical to inquiry-based science. This method calls for students to study phenomena in their local areas. It encourages teachers to have students tour local science-related facilities like universities, business, dams, nuclear power plants, museums, aquariums, and zoos. Inquiry demands relevance to students' lives. The goal of inquiry is that students will learn science and perhaps find a passion for science. One teacher in this study had his students design a Wiki webpage with various topics in astronomy, and the unit called for a field trip to a large telescope. Local science attractions and resources can enlighten, inspire, and engage students in ways that can't be done in a classroom. Connecting what students learn in the classroom to real world phenomena is a goal of inquiry-based science.

So, it is clear that science teachers face many barriers to using inquiry in public school classrooms. It is also clear that specific changes can be made to minimize each specific barrier. However, it is possible to promote inquiry through more generalized and systematic change.

Meaningful Change to Encourage Inquiry

As this study shows, teachers at RU learn to use inquiry as the best way to teach science. They become believers in the philosophy of inquiry and develop the skills to implement their knowledge. However, once they are immersed in the public schools, they encounter significant barriers that cause them to sacrifice their beliefs in effective inquiry teaching and retreat to traditional methods that help them survive in

the overcrowded, under-supported culture of high stakes testing rather than to thrive in the nurturing, truly educational environment of inquiry communities.

Two general approaches can help teachers apply inquiry and teach science more effectively. One approach recognizes that the culture of high stakes testing is a reality, at least for now. If this is true, then teachers need strategies and support for practicing inquiry methods within a culture that works against them. Like soldiers forced to fight in a war not of their choosing, they can still learn to survive and thrive despite the hostile environment. We can at least make them as fit and prepared as possible and equip them with the weapons and protective gear to help them succeed in this battle, putting their beliefs in inquiry into practice, even in a world that works against them.

In this first approach, teachers need tools and strategies that allow them to create inquiry communities within a world of high-stakes testing. One suggestion is to ensure that inquiry methods are modeled and practiced extensively in their pre-service education. While students are exposed to inquiry practices in their science education courses, pre-service programs would be stronger if science education experiences were of longer duration, contained more classroom experience, and had more opportunities for self reflection (such as by viewing and analyzing video of themselves teaching). Inquiry must also be present in a more systematic way when these preservice teachers study science and general education courses.

The science content faculty in this study aspired to teach with inquiry, but did not consistently succeed. In addition, most future science teachers studied science in the same classes with students not planning to teach. It would help if either all science content courses were designed to consistently emphasize inquiry or at least if special sections in each science were designed for these future science teachers. For example, either all chemistry courses could be taught with an inquiry approach or special sections of chemistry should be offered as "Chemistry for Teachers." Either way, this would allow future science teachers to experience science taught through inquiry even within a more traditional university environment. We should also develop and implement in-service education programs specifically designed to offer fun, engaging, and effective inquiry activities that fit into the traditional curriculum and testing. These changes would equip teachers with specific activities and techniques that they could later apply to use inquiry in their own public school classrooms. Also, those classrooms should be designed with fewer students for each teacher and with more equipment, support, and resources. This would allow teachers to use more inquiry while still helping students pass the mandatory tests. These changes would encourage believers in inquiry to practice those beliefs while helping students learn science even in a hostile environment.

A second approach is to change that environment. In this approach, the focus would be not just on better equipping teachers to survive the "war" but in making "peace" with inquiry. Perhaps it is time to reassess programs like "No Child Left

Behind" and pervasive high-stakes testing and to focus on more meaningful and effective ways to really teach science.

In this second approach, we should reevaluate our need for this test-driven culture. The goal is not to create students who can memorize data and regurgitate it through rote memory on some year-end, multiple-choice exam. The more important goal is to help students become adults who are curious about their world, who can think critically about scientific issues, who can recognize problems and create solutions, and who can not only memorize but truly understand.

Also, tests should be used the way they were designed: as assessments of students' learning, not as judgments of teacher performance. The aim should be to encourage good teaching practices and meaningful learning, rather than to indict teachers and prosecute them for society's problems.

With this change in focus, we would move from an obsession with testing to a fascination with learning. Of course, the reality is that assessment will always be part of teaching. We need to assess what students are learning and we must encourage teachers to reflect on the effectiveness of their methods. Frequent and informal assessments are an important part of inquiry. What we do need to remember is that a high test score is no replacement for highly effective learning. Tests have their place, but they should be used to promote and assess inquiry and learning. In this way, you encourage and empower not only science teachers, but also the students they serve.

Further Study

This study chronicled the journey of just a few teachers across the teaching continuum. While the study was limited geographically, the RTOP instrument is widely used and the experimental design is sound and proven. The sample of this study was small, reflecting the work at a single site. Done on a larger scale, at multiple sites, we might have more insight into the characteristics of those teachers who do find ways to implement the inquiry methods they learned as pre-service teachers. We might focus on teachers who have managed to teach through inquiry while maintaining a truce with the barriers that prevent others from teaching in this manner. Thus, expanding this study with additional research questions and to a nationwide study seems to be a logical step.

Another study might be equally interesting. We might offer early induction teachers an Inquiry-based summer school class between their first and second years of teaching. Then, we could compare the RTOP scores of this experimental group with those early induction science teachers who did not take the class. See what affect if any, professional development has on inquiry-based teaching practice.

Finally, it is critical to search for alternatives to this culture of high-stakes testing. Further study should find, develop, and evaluate assessment tools that test for important goals, such as creativity, critical thinking, and clear comprehension of the world in which we live.

Future research should find ways to equip educators to survive in the war of traditional teaching and thrive in their use of inquiry and effective means of teaching. At the same time, it should seek ways to end that war and make peace with inquiry communities that effectively teach students to think, learn, and achieve.

Conclusions

"Books must follow science and not sciences books"(Bacon, 1616). Students must begin doing science and in doing so, develop their own understanding of the natural world. This is the philosophy of inquiry-based science teaching. This study shows that inquiry-based teaching practices are **not** being taught in all public science classrooms today. We need a fundamental shift away from high-stakes testing and towards inquiry-based methods that promote the meaningful teaching and learning of science.



REFERENCES

AAAS. (1989). *Science for All Americans: A Project 2061 Report*. Washington, D.C.: Washington, D.C.: AAAS.

AAAS. (1993). *American Association for the Advancement of Science. Benchmarks for Science Literacy, A tool for curriculum reform* (First ed.). New York: Oxford University Press.

ADA, U. (1990, 12-1-08). Americans With Disabilities Act Of 1990. Retrieved 12-2-08, 2008, from http://www.ada.gov/pubs/ada.htm

Adams, P. E., & Krockover, G. H. (1993). *American Association for the Advancement of Science. Benchmarks for Science Literacy, A tool for curriculum reform* (First ed.). New York: Oxford University Press.

Adams, P. E., & Krockover, G. H. (1998). Science Teacher Education: Concerns and perceptions of beginning secondary science and mathematics teachers. *Science Education, 81*(1), 29-50.

AERA. (2002). AERA position on high stakes testing. *American Educational Research Association*, from http://www.aera.net/about/policy/stakes.htm

Akiba, M., LeTendre, G. K., & Scribner, J. P. (2007). Teacher Quality, Opportunity Gap, and National Achievement in 46 Countries. *Educational Researcher, 36*(7), 369-387.

Alberts, B. (2009, January 23). Redefining Science Education. *Science 323,* 437.

Allen, R. (2006, October 29, 2006). On Wisconsin Education Association Council. Retrieved 11-30, 2008, from http://www.weac.org/Resource/test_glossary.htm

Amrein, A. L., & Berliner, D. C. (2002). High-Stakes Testing, Uncertainty, and Student Learning. *Education Policy Analysis Archives, 10*(18), 32.

Anderson, O. R. (1976). *The Experience of Science: A New Perspective for Laboratory Teaching*. New York: Teacher's College Press.

Anderson, R. D. (2002). Reforming Science Teaching: What Research Says About Inquiry. *Journal of Science Teacher Education, 13*(1), 1-12.

Appleton, K. (1995). Student teachers' confidence to teach science: is more science knowledge necessary to improve self-confidence? *International Journal of Science Education, 17*(3), 357 - 369

Association, N. S. T. (1971). NSTA position statement on school science education for the 1970's. *Science Teacher, 38*, 46-51.

Bacon, F. S. (1616). Proposition touching the Amendment of the Law. In M. Zander (Ed.), *The Law-Making Process* (pp. 517). London: Cambridge University Press, 2004.

Bell, R. L., Blair, L. M., Crawford, B. A., & Lederman, N. G. (2003). Just do it? impact of a science apprenticeship program on high school students' understanding of the nature of science and scientific inquiry. *Journal of Research in Science Teaching, 40*(5), 487-509.

Bereiter, C. (1994). Implications of postmodernism for science, or, science as progressive discourse. *Educational Psychologist, 29*(1), 3-12.

Blanchard, M. R. (2006). *Assimilation or transformation? An analysis of change in ten secondary science teachers following an inquiry-based research experience for teachers.* Unpublished Qualitative, Florida State University, Tallahassee, Florida.

Boger, J. C. (2002). *Education's "Perfect Storm?" Racial Resegregation, "High Stakes" Testing, & School Inequities: The Case of North Carolina.* Paper presented at the The Resegregation of Southern Schools? A Crucial Moment in the History (and the Future) of Public Schooling in America" Conference Retrieved 11-30-08, from http://eric.ed.gov/ERICWebPortal/custom/portlets/recordDetails/detailmini.jsp?_nfpb=true&_&ERICExtSearch_SearchValue_0=ED471935&ERICExtSearch_SearchType_0=no&accno=ED471935.

Bonnstetter, R. J. (1998). Inquiry: Learning from the Past with an Eye on the Future. *Electronic Journal of Science Education, 3*(1).

Bottorff, J. L. (1994). *Critical Issues in Qualitative Research Methods*. Thousand Oaks: Sage Publications, Inc.

Bradford, S. (2005). *Technology in Science Education: A Study of how Science Teachers and Students use Technological Equipment in a Rural Public High School.* Unpublished Science Technology, University of Missouri, Kansas City.

Brickhouse, N. W. (1990). Teachers' Beliefs About the Nature of Science and Their Relationship to Classroom Practice *Journal of Teacher Education, 41*(3), 53-62.

Bridge, J. (2008). Study: Teen suicide spike was no fluke. *electronic journal EurekAlert*.

Bryan, L. A., & Abell, S. K. (1999). Development of Professional Knowledge in Learning to Teacher Elementary Science. *Journal of Research in Science Teaching, 36*(2), 121-139.

BSCS. (2008, 6-20-08). Website. Retrieved 6-25-08, 2008, from http://www.bscs.org/

Education Flexibility Partnership Act, (1999).

Bush, G. W. (2008, 4-30-08). The White House: In Focus - Education. Retrieved 5-9-08, 2008, from http://www.whitehouse.gov/infocus/education/ http://www.ed.gov/nclb/overview/importance/difference/northcarolina.pdf

Butt, G., & Lance, A. (2005). Secondary Teacher Workload and Job Satisfaction. Do Successful Strategies for Change Exist? *Educational Management Administration & Leadership, 33*(4), 401-422.

Bybee, R. W. (1989). *Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction.* Boulder, CO: NETWORK, Inc., Andover, MA.; National Center for Improving Science Education, Andover, MA.; Biological Sciences Curriculum Study, Boulder, CO.

Bybee, R. W. (1997). *THE ROLE OF CURRICULUM IN SYSTEMIC REFORM*. Paper presented at the The National Institute for Science Education (NISE) Forum. Retrieved 5-12-08, from http://teech.terc.edu/papers/papers/bybee.htm.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically Authentic Inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks. *Science Education, 86*(2), 177-218.

Chronicle, T. (2007). The Chronicle of Higher Education, Facts & Figures: Top Research Universities Faculty Scholarly Productivity Index. The 2007 index compiles overall institutional rankings on 375 universities that offer the Ph.D. degree. Retrieved 11-17, 2008, from http://chronicle.com/stats/productivity/page.php?year=2007&institution=2731&byinst=Go

Chuah, P., C. (2007). *The Role of an Instructor: More than Meets the Eye*. Paper presented at The Sixteenth International Conference On Learning. Retrieved 10-15-08, from http://l09.cgpublisher.com/proposals/66/index_html.

Clabaugh, G. (1992). Teach for America? *Educational Horizons, 70*(3), 101-103.

Clark, D. L. (1984). Better teachers for the year 2000: A proposal for the structural reform of teacher education. . *Phi Delto Kappan, 66*(2), 116-120.

Clay, D., Cohen, M., Ligons, C., & Roff, L. (1994). Assessment in Restructured Teacher Preparation. Restructuring Texas Teacher Education Series 4. *ERIC Clearing House, Washington D.C.* Retrieved 5-1-08, ED421456, from http://eric.ed.gov/ERICWebPortal/custom/portlets/recordDetails/detailmini.jsp?_nfpb=true&_&ERICExtSearch_SearchValue_0=ED421456&ERICExtSearch_SearchType_0=no&accno=ED421456

Cohen, D. K. (1987). Educational Technology, Policy, and Practice. *Educational Evaluation and Policy Analysis, 9*(2), 153-170.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research Methods in Education*. London and New York: Routledge, Taylor & Francis Group.

Conle, C. (1996). Resonance in Preservice Teacher Inquiry. *American Educational Research Journal, 33*(2), 297-325.

Cornelius-White, J. (2007). Learner-Centered Teacher-Student Relationships Are Effective: A Meta-Analysis. *Review of Educational Research, 77*(1), 113-143.

Council, N. R. (1999). *Inquiry and the National Science Education Standards: A Guide For Teaching And Learning*. Washington, D.C.: National Academy Press.

Craven, J. A., & Penick, J. E. (2001). Preparing New Teachers to Teach Science: The Role of the Science Teacher Educator *Electronic Journal of Science Education, 6*(1), 1-14.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*(4), 613-642.

Cushing, K. S., Sabers, D. S., & Berliner, D. C. (1992). Olympic gold: Investigations of expertise in teaching. *Educational Horizons, 70*(3), 108-114.

Darling-Hammond, L. (1991). The Implications of Testing Policy for Quality and Equality. *Phi Delta Kappan, 73*(3), 220-226.

Darling-Hammond, L. (1992). *Model Standards for Beginning Teacher Licensing, Assessment and Development: A Resource for State Dialogue*. Retrieved 7-1-08. from http://209.85.215.104/search?q=cache:gZaGgMPynBIJ:www.ccsso.org/content/pdfs/corestrd.pdf+north+carolina+standards+and+assessments+for+beginning+teachers&hl=en&ct=clnk&cd=1&gl=us.

Darling-Hammond, L., & Baransford, J. (2005). *Preparing Teachers for a Changing World: What Teachers Should Learn and Be Able to Do*. Retrieved 11-30-08, from http://eric.ed.gov/ERICWebPortal/custom/portlets/recordDetails/detailmini.jsp?_nfpb=true&_&ERICExtSearch_SearchValue_0=ED496378&ERICExtSearch_SearchType_0=no&accno=ED496378.

Davis, R. B., Maher, C. A., & Martino, A. M. (1992). Using videotapes to study the construction of mathematical knowledge by individual children working in groups. *Journal of Science Education and Technology,, 1*(3), 24-47.

DeBoer, G. E. (1991). *A History of Ideas in Science Education, Implications For Practice* (First ed.). New York: Teachers College Press.

DeBoer, G. E. (2002a). Student-centered teaching in a standards-based world: Finding a sensible balance. *Science and Education, 11*(4), 405-417.

DeBoer, G. E. (2002b). Student-Centered Teaching in a Standards-Based World: Finding a Sensible Balance *Science and Education, 11*(4), 405-417.

Dede, C., Korte, S., Nelson, R., Valdez, G., & Ward, D. J. (2005). *Transforming Learning for the 21st Century: An Economic Imperative*. Napervill: 1120 East Diehl Road, Suite 200, Napervill, IL 60563-1486.

Desimone, L. M., Smith, T. M., Ueno, K., & Baker, D. (2005). Assessing Barriers to the Reform of U.S. Mathematics Instruction From an International Perspective. *American Educational Research Journal, 42*(3), 501-535.

Dewey, J. (1910). *How We Think.* . Boston: Courier Dover Publications.

Dewey, J. (1933). *How We Think.* (New Ed edition ed.). Boston:: Dover Publications.

Donahue, P. L., Voelkl, K. E., Campbell, J. R., & Mazzeo, J. (1998). The National Assessment of Educational Progress 1998 Reading Report Card for the Nation and the States. *Education Statistics Quarterly, 1*(2), 1-10.

DPI, N. C. (2000). *Student Accountability Standards: Implementation Guide.* Retrieved 11-30-08. from http://www.ncpublicschools.org/student_promotion/sas_guide/contents.html.

Draper, S. W. (2008, October 6, 2008). The Hawthorne, Pygmalion, Placebo and other effects of expectation: some notes. Retrieved 12-7-08, 2008, from http://www.psy.gla.ac.uk/~steve/hawth.html#Hawthorne%20overall Web site logical path: [www.psy.gla.ac.uk] [~steve] [this page] http://www.psy.gla.ac.uk/~steve/hawth.html

Drayton, B., & Falk, J. (2001). Tell-Tale Signs of the Inquiry-Oriented Classroom. *NASSP Bulletin, 85*(24), 24-34.

Dworkin, A. G. (1987). *Teacher Burnout In The Public Schools: Structural Causes and Consequences for Children*. Albany: State University of New York Press, Albany.

EDC. (2008). Educational Development Center Official Website. Retrieved 10-7-08, 2008, from http://main.edc.org/themes/schools

Education, D. o. (2001). Reducing Class Size to Enhance Learning [Electronic Version]. *Educational Policy Studies Laboratory*, 1-3. Retrieved 11-21-08 from http://www.asu.edu/educ/epsl/EPRU/articles/EPRU-0203-33-OWI.doc

Education, D. o. (2008, 12-1-08). U.S. Department of Education Official Website. Retrieved 12-2-08, 2008, from http://www.ed.gov/policy/elsec/leg/esea02/index.html

Escalada, L. T., & Zollman, D. A. (1998). An investigation on the effects of using interactive digital video in a physics classroom on student learning and attitudes. *Journal of Research in Science Teaching, 34*(5), 467-489.

Farrel, T. S. (2005). Conceptions of Grammar Teaching : A case study of Teachers' Beliefs and Classroom Practices. *Teaching English as a Second or Foreign Language, 9*(2), 5.

Felder, R. M., & Brent, R. (1996). Navigating The Bumpy Road To Student-Centered Instruction [Electronic Version]. *College Teaching*, *44*, 1-8 from http://www.usp.edu/lct/navigatingthebumpyroad1.pdf.

Finn, J. D., & Achilles, C. M. (1990). Answers and Questions About Class Size: A Statewide Experiment. *American Educational Research Journal, 27*(3), 557-577.

Flick, L. B., & Lederman, N. G. (2006). Scientific Inquiry And Nature Of Science: Implications For Teaching, Learning, And Teacher Education. *Journal of Math, Science, & Technology Education, 4*(2), 191-193.

Fowler, W. J., & Walberg, H. J. (1991). School Size, Characteristics, and Outcomes. *Educational Evaluation and Policy Analysis, 13*(2), 189-202.

Frechtling, J. A., Sharp, L., Carey, N., Vaden-Kiernan, N., & Westat. (1995). *Teacher Enhancement Programs: A Perspective on the Last Four Decades* Washington, D.C.: National Science Foundation.

Fruge, T. (2007). Examining the Use of Guided Inquiry in Local Classrooms: A Preliminary Investigation [Electronic Version]. *Physics Department, University of Notre Dame*, 12. Retrieved 01-18-08 from http://nd.edu/~sciwww/Pdf/2007%20REU%20Papers/GuidedInq_Class.pdf.

Fulp, S. L. (2002). *2000 National Survey of Science and Mathematics Education: Status of Elementary School Science Teaching*. Chapel Hill, NC: Horizon Research, Inc.

Funder, D. C. (1999). *Personality Judgment: A Realistic Approach to Person Perception*. San Diego: Academic Press.

Gardener, D. P. (1983). *A Nation at Risk: The Imperative for Educational Reform. A Report to the Nation and the Secretary of Education United States Department of Education* (Open Letter No. No. 065-000-00177-2). Washington, D.C.: National Commission on Excellence in Education.

Gardner, H. (1999). *The Disciplined Mind: Beyond Facts and Standardized Tests, the K-12 Education that Every Child Deserves* Harmondsworth: Penguin.

Garfield, M. (2008). Elementary Teachers Have Heavier Workload Say Researchers [Electronic Version]. *Publication: The America's Intelligence Wire. My Library*. Retrieved 11-22-08 from http://www.accessmylibrary.com/coms2/summary_0286-35084322_ITM.

Gilbert, S. (2008, 11-21-08). Dangerous Discussions: Class Size. Options for Effective Online/Hybrid/Blended

Teaching & Learning In "Larger" Classes. Retrieved 11-22-08, 2008, from http://www.tltgroup.org/ProFacDev/DangerousDiscussions/classsizehome.htm

Gillespie, R. (1991). *Manufacturing knowledge : a history of the Hawthorne experiments* Cambridge University Press).

Gillham, B. (2004). *The Research Interview*. Bodmin: Continuum International Publishing Group.

Goodman, J. (1988). Constructing a practical philosophy of teaching: A study of preservice teachers' professional perspectives. *Teaching and Teacher Education, 4*(2), 121-137.

Green, J. L., Camilli, G., & Elmore, P. B. (2006). *Handbook of Complementary Methods in Education Research: American Educational Research Association*. Mahwah: Lawrence Erlbaum Associates, Inc.

Gross, N. A., & Hickman, P. (2007). An Evaluation Protocol for 21st Century Instructors.http://homepage.mac.com/dbyrum/TIRHandbook/TIRInterestingInfo/RTOP_Article.pdf.

Grossman, H. (2003). *Classroom Behavior Management* (Third ed.). Lanham, Maryland: Rowman & Littlefield Publishing, Inc. 4501 Forbes Boulevard, Suite 200 Lanham, Maryland 20706 1-800-462-6420.

Grummer, E., & Champagne, A. (2004). Classroom Assessment of Opportunity to Learn Science Through Inquiry. In L. B. Flick & N. G. Lederman (Eds.), *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning and Teacher Education* (pp. 263-298). Dordrecht, Netherlands: Kluwer Academic Publishers.

Gunzenhauser, M. G. (2003). High-Stakes Testing and the Default Philosophy of Education. *Theory into Practice, 42*(1), 51-58.

Hammersley, M., & Atkinson, P. (1995). *Ethnography: Principles in Practice* (second ed.). New York: Routledge, Taylor & Francis Group, 29 West 35th Street.

Hazari, Z., Key, A. W., & Pitre, J. (2003). Interactive and Affective Behaviors of Teaching Assistants in a First Year Physics Laboratory. *Electronic Journal of Science Education, 7*(3), 38.

Heckman, J. J. (1979). Sample Selection Bias as a Specification Error. *Econometrica, 47*(1), 153-161.

Heisenberg, W. (1927, 2008). Quantum Mechanics: The Uncertainty Principle. Retrieved 10-16-08, 2008, from http://www.aip.org/history/heisenberg/p08.htm

Henriques, L. (2002). Preparing Tomorrow's Science Teachers to Use Technology: An Example from the Field. *Contemporary Issues in Technology and Teacher Education, 2*(1), 6-12.

Hofstein, A., & Lunetta, V. N. (1982). The Role of the Laboratory in Science Teaching: Neglected Aspects of Research. *Review of Educational Research, 52*(2), 201-217.

Holbrook, J., & Kolodner, J. L. (2000, 6-14 to 6-17). *Scaffolding the Development of an Inquiry-Based Classroom.* Paper presented at the International Conference of the Learning Sciences, Ann Arbor, Michigan.

Holt, S. B., & O'Tuel, F. S. (1989). The Effect of Sustained Silent Reading and Writing on Achievement and Attitudes of Seventh and Eighth Grade Students Reading Two Years below Grade Level. *Reading Improvement, 26*(4), 290-297.

Horn, C. (2003). High-stakes testing and students: stopping or perpetuating a cycle of failure? [Electronic Version]. *Theory into Practice*, 1-17. Retrieved 11-30-08 from http://findarticles.com/p/articles/mi_m0NQM/is_1_42/ai_99909368.

Hulley, S. B., Cummings, S. R., Browner, W. S., Grady, D. G., & Newman, T. B. (2006). *Clinical Research: An Epidemiologic Approach* (Third ed.). Conshohocken, PA: Lippincott Williams & Wilkins.

Ingersoll, R. M. (2002). The Teacher Shortage: A Case of Wrong Diagnosis and Wrong Prescription [Electronic Version]. *NASSP Bulletin*, *86*, 16-31. Retrieved 01-17 from http://bul.sagepub.com/cgi/content/abstract/86/631/16.

ITED. (2008). Iowa Tests of Educational Development. Retrieved 7-5, 2008, from http://www.education.uiowa.edu/itp/ited/ited_about_prp.htm

Johnstone, M. (1993). *ED368716 - Teachers' Workload and Associated Stress*. Edinburgh: Scottish Council for Research in Education.

Jones, Jones, B. D., Hardin, B., Chapman, L., Yarbrough, T., & Davis, M. (1999). The Impact of High-Stakes Testing on Teachers and Students in North Carolina. *Phi Delta Kappan, 81*(3), 1-5.

Jones, K. (2008, 11-20-08). Fair Test: The National Center for Fair and Open Testing. Retrieved 11-30-08, 2008, from http://www.fairtest.org/arn/caseagainst.html

Jones, M. G., Jones, B. D., & Hargrove, T. Y. (2003). *The Unintended Consequences of High-Stakes Testing* (1 ed. Vol. 1). Lanham, Maryland: Rowman & Littlefield Publishers, INC. 4501 Forbes Boulevard, Suite 200 Lanham, Maryland 20706 1-800 462 6420.

Judson, E., & Lawson, A. (2006, 1-19-08). *Are Constructivist Teachers Isolationists or Team Leaders? A Social Network Analysis* Paper presented at the ACEPT, Tempe, AZ.

Kang, N.-H., & Hong, M. (2008). Achieving Excellence in Teacher Workforce and Equity in Learning Opportunities in South Korea. *Educational Researcher, 37*(4), 200-207.

Kaplan, A., & Krueger, J. (1999). Compliance After Threat: Self-Affirmation Or Self-Presentation? [Electronic Version]. *Current Research In Social Psychology An Electronic Journal*, *4*, 178-197. Retrieved 10-15-08 from: http://www.uiowa.edu/~grpproc/crisp/crisp.4.7.htm.

Ketterlinus, R. D., & Lamb, M. E. (1994). *Adolescent Problem Behaviors*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Keys, C. W., & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching, 38*(6), 631-645.

King, M. L. J. (1960). Brainy Quotes. Retrieved 2-29-09, from http://www.brainyquote.com/quotes/quotes/m/martinluth402936.html

Klein, S. P., Hamilton, L. S., McCaffrey, D. F., & Stecher, B. M. (2000). What do test scores in Texas tell us? *Journal of Clinical Epidemiology, 1*(1), 1-12.

Kohn, A. (1992). *No Contest: The Case Against Competition. Why we lose in our race to win*. New York: Houghton Mifflin Company.

Kvale, S. (1996). *Interviews: An Introduction to Qualitative Research*. Aarhus, Denmark: Sage Publications

Lamb, R. (2008). Beliefs/Nature of Science Interview Transcript completed for Project IMPPACT. North Carolina State University.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. e. S. (2002). Views of Nature of Science Questionnaire: Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science. *Journal Of Research In Science Teaching, 39*(6), 497-521.

LHS. (2008, 12-27-2006). Home Page. Retrieved 10-7-08, 2008, from http://www.lhs.berkeley.edu/generalinfo/aboutmore.html

Livingstone, I. D. (1994). *The Workloads of Primary School Teachers: A Wellington Regional Survey* (Reports - Research; Tests/Questionnaires). Wellington, New Zealand: Wellington District Counsel.

Loadman, W. E., Freeman, D. J., & Brookhart, S. M. (1999). Development of a national survey of teacher education program graduates. *Journal of Educational Research, 93*(2), 1-14.

Lotter, C. (2004, April 1, 2004). Preservice Science Teachers' Concerns Through Classroom Observations and Student Teaching: Special Focus on Inquiry Teaching *Science Educator* Retrieved 12-7, 2008, from http://www.highbeam.com/doc/1P3-866075151.html

Luft, J. A., & Roehrig, G. H. (2007). Capturing Science Teachers' Epistemological Beliefs: The Development of the Teacher Beliefs Interview. *Electronic Journal of Science Education, 11*(2), 38-63.

Luft, J. A., Roehrig, G. H., & Patterson, N. C. (2002). Contrasting landscapes: A comparison of the impact of different induction programs on beginning secondary science teachers' practices, beliefs, and experiences. *Journal of Research in Science Teaching, 40*(1), 77-97.

Luiselli, J. K., Putnam, R. F., Handler, M. W., & Feinberg, A. B. (2005). Whole-school positive behavior support: effects on student discipline problems and academic performance. *Educational Psychology, 25*(2 & 3), 183-198.

Mabry, L., Mathison, S., Sanders, J., Stake, R. E., Stufflebeam, D., & Thomas, C. (2002). American Evaluation Association Position Statement On High Stakes Testing In Prek-12 Education American Evaluation Association.

MacIsaac, D., & Falconer, K. (2002). Reforming Physics Instruction Via RTOP. *The Physics Teacher, 40*, 479485.

MacLeod-Brudenell, I., Cortvreind, V., Hallet, E., Kay, J., & Walkup, V. (2004). *Advanced Early Years Care and Education: For Levels 4 and 5*. Oxford: Pearson Education.

Madaus, G. F. (1991). The Effects of Important Tests on Students. *Phi Delta Kappan, 73*(3), 226-302.

Marshall, C., & Rossman, G. B. (1998). *Designing Qualitative Research* (Third Edition.). Thousand Oaks, California: Sage Publications.

Maykut, P., & Morehouse, R. (1994). *Beginning Qualitative Research: A Philosophic and Practical Guide*. New York: Routledge Falmer.

Mayo, E. (1933). Ch.3. In *The human problems of an industrial civilization*. New York: MacMillan.

McKinney, S. E., Berry, R. Q., Dickerson, D. L., & Campbell-Whately, G. (2007). Addressing urban high-poverty school teacher attrition by addressing urban high-poverty school teacher retention: why effective teachers persevere. *Educational Research and Review, 3*(1), 1-9.

McMillan, M. B. (1999). *The Troubling Consequences of the ABCs: A report from the Common Sense Foundation, June 1999* Durham: The Common Sense Foundation.

Merton, R. K., & Storer, N. W. (1979). *The Sociology of Science*. Chicago: University of Chicago Press.

Mohin, A. (2006). Student Violence in America. *The New York Times*.

Money, C. (2009). World Bank: Economy worst since Depression [Electronic Version]. *CNNMoney.com*, *Special Report*, 1. Retrieved 3-15-09 from http://money.cnn.com/2009/03/09/news/international/global_economy_world_bank/?postversion=2009030907.

Monty, N. D., & Medina, N. J. (1989). Standardized Testing: Harmful to Educational Health. *Phi Delta Kappan, 70*(9), 688-697.

Moore, D. S. (2006). *The Basic Practice of Statistics* (4 ed.). San Francisco, CA: W.H. Freeman.

Moore, J. A. (1985). Science as a Way of Knowing [Electronic Version]. *Journal of College Science Teaching*, *14*, 530-532. Retrieved Feb 20 from http://eric.ed.gov/ERICWebPortal/custom/portlets/recordDetails/detailmini.jsp?_nfpb=true&_&ERICExtSearch_SearchValue_0=EJ319047&ERICExtSearch_SearchType_0=no&accno=EJ319047.

Moss, D. M. (2001). Examining student conceptions of the nature of science. *International Journal of Science Education, 23*(8), 771-790.

NASA. (1957, 10-10-07). Sputnik and The Dawn of the Space Age. *NASA History* Retrieved 10-7, 2008, from http://history.nasa.gov/sputnik/

National Committee on Science Education Standards and Assessment, N. R. C. (1996). *National Science Education Standards*. Washington D.C.: The National Academies Press 2101 Constitution Avenue, NW Washington, DC 20418.

NCDPI. (2008). Accountability Services. Retrieved 11-30, 2008, from http://www.ncpublicschools.org/accountability/testing/eoc/

NCTM. (1989, 2008). Curriculum and Evaluation Standards for School Mathematics (NCTM Standards, 1989). Retrieved 10-7, 2008, from http://mathforum.org/library/view/9270.html

NEA. (2008, 12-1-08). Title I Funding Gaps (FY 2002 – 2006) The Gap Between Actual and Authorized Levels. Retrieved 12-2, 2008, from http://www.nea.org/lac/funding/title1.html

Nichols, S. L., & Berliner, D. C. (2005). *The Inevitable Corruption of Indicators and Educators Through High-Stakes Testing*. Lansing: The Great Lakes Center for Education Research & Practice.

NRC. (1989). *Everyone Counts: A Report to the Nation on the Future of Mathematics Education*. Washington, D.C.: National Academy Press.

NSRC. (2008, 10-4-2008). National Science Resources Center Official Web Page. Retrieved 10-7-08, 2008, from http://www.nsrconline.org

Olsen, J. (2008). *Improving the Education of Future Physics and Physical Science Teachers* Paper presented at the PTEC Annual Conference 2008. Retrieved 10-15-08, from http://www.compadre.org/ptec/items/detail.cfm?ID=7207.

Park, J. C. (2006). Interview for Project IMPPACT. In T. P. Maher (Ed.) (pp. 15). Raleigh, NC.

Pearsall, M. K. (1992). *Relevant Research. Scope, Sequence, and Coordination of Secondary School Science. Vol. II.* (Vol. 2). Washington, DC: National Science Teachers Association, 1742 Connecticut Ave., NW, 20009

Penick, J. E. (1996). Questions Are the Answers. *Science Teacher 63*(1), 26-29.

Penick, J. E. (2008). Recorded Conversation. In T. Maher (Ed.). Cary.

Penick, J. E., & Yager, R. R. (1988). A model school-based program for science education majors. *Action in Teacher Education, 10*(4), 19-22.

Penn-Edwards, S. (2004). Visual Evidence in Qualitative Research: The Role of Video-recording. *The Qualitative Report, 9*(2), 266-277.

Piburn, M., Sawada, D., Falconer, K., Turley, J., Benford, R., & Bloom, I. (2001). Reformed Teaching Observation Protocol. Retrieved 10-7-07, 2007, from http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/index.htm

Pilburn, M., Sawada, D., Bartley, B., Benford, R., Bloom, A., Isom, M., et al. (2000). *Reformed Teaching Observation Protocol (RTOP): Reference Manual* (No. IN00-3). Flagstaff, Arizona: Northern Arizona University.

Preczewski, P. J., Tillotson, J. W., & Young, M. J. (2008). *Determination and Correlation of Factors Influencing the Reformed Science Teaching and Learning Questionnaire*. Paper presented at the 2008 ASTE International Conference.

Preczewski, P. J., & Young, M. J. (2007). *Correlating Teachers' Beliefs about Reformed Teaching to Actual Teaching Practice*. Paper presented at the at 2007 Annual NE-ASTE Meeting.

Pringle, R. M., & Martin, S. C. (2005). The Potential Impacts of Upcoming High-Stakes Testing on the Teaching of Science in Elementary Classrooms. *Research in Science Education, 35*(2-3), 347-361.

Rees, D. I. (2007). The Influence of Classroom Characteristics on High School Teacher Turnover. *Economic Inquiry, 34*(1), 152-167.

Report. (1998). Instructional Practice and Student Behavior. Retrieved 11-23, 2008, from http://www.ed.gov/pubs/ClassSize/practice.html

Reyes, P., & Imber, M. (1992). Teachers' Perceptions of the Fairness of Their Workload and Their Commitment. *Journal of Personnel Evaluation in Education, 5*(3), 291-302.

Rice, J. K. (1999). The Impact of Class Size on Instructional Strategies and the Use of Time in High School Mathematics and Science Courses. *Educational Evaluation and Policy Analysis, 21*(2), 215-229.

Richardson, L., & Simmons, P. (1994). Self-Q research method and analysis, teacher pedagogical philosophy interview: Theoretical background and samples of data. Department of Science Education, University of Georgia.

Ritchie, J., & Lewis, J. (2003). *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. Thousand Oaks: SAGE Publications Ltd.

Rogers, C. R., & Freiberg, J. H. (1994). *Freedom to Learn* (3 ed.). Princeton: Prentice Hall, Inc.

Roosevelt, F. D. (1940, 2009). Brainy Quote. Retrieved 2-26, 2009, from http://www.brainyquote.com/quotes/keywords/democracy.html

Salish. (1997). Beginning science teacher cognition and its origins in the preservice secondary science teacher program. *Journal of Research in Science Teaching, 34*(6), 633-653.

Sawada, D., Piburn, M. D., Judson, E., & Turley, J. (2002). Measuring reform practices in science and mathematics classrooms: The reformed teaching observation protocol. *School Science and Mathematics*, 10.

Schaufeli, W., Maslach, C., & Marek, T. (1997). *Professional Burnout: Recent Developments In Theory And Research*. Philadelphia: CRC Press: Taylor & Francis Group.

Schoenfeld, A. H. (1999). Looking toward the 21st Century: Challenges of Educational Theory and Practice. *Educational Researcher, 28*(7), 4-14.

Schwab, J. J. (1969). The Practical: A Language for Curriculum. *The School Review, 78*(1), 1-23.

Schwab, J. J., & Brandwein, P. F. (1962). *The Teaching of Science: The Teaching of Science as Enquiry and Science in the Elementary School*. Cambridge: Harvard University Press.

Settlage, J. (2007). Demythologizing Science Teacher Education: Conquering the False Ideal of Open Inquiry. *Journal of Science Teacher Education 18*(4), 461-467.

Shaver, A., Cuevas, P., Lee, O., & Avalos, M. (2007). Teachers' perceptions of policy influences on science instruction with culturally and linguistically diverse elementary students. *Journal of Research in Science Teaching, 44*(5), 725-746.

Simms, R. L., & Miller, J. R. (1988). Assault on Teacher Education in Texas. *Journal of Teacher Education, 39*(6), 17-20.

Sirkin, M. R. (2006). *Statistics for the Social Sciences* (Third ed.). Thousand Oaks, CA: Sage Publications, Inc.

Skinner, B. F. (2005). *Science and Human Behavior*. Cambridge: B.F. Skinner Foundation.

Smith, M. L. (1991). Put to the Test: The Effects of External Testing on Teachers. *Educational Researcher, 20*(5), 8-12.

Smith, M. L., & Fey, P. (2000). Validity and Accountability in High-Stakes Testing. *Journal of Teacher Education, 51*(5), 334-344.

Smith, N. (1974). The Challenge of Scientific Literacy. *Science teacher, 41*(6), 34-35.

Society, A. C. (1980). *Chemcom Chemistry in the Community* (First ed.). New York: W.H. Freeman and Company.

Solomon, J., & Aikenhead, G. S. (1994). *STS Education: International Perspectives on Reform. Ways of Knowing Science Series.* New York, NY: Teachers College Press, 1234 Amsterdam Ave., New York, NY 10027

Songer, N. B., Lee, H.-S., & McDonald, S. (2003). Research towards an expanded understanding of inquiry science beyond one idealized standard. *Science Education, 87*(4), 490-516.

Spradley, J. P. (1979). *The Ethnographic Interview* (Vol. 1). New York: Holt Rinehart and Winston

Statsnetbase, W. P. (2008, 7-25-08). Statistics for Psychology, Social Science And Law. Retrieved 8-30, 2008, from http://www.statsnetbase.com/default.asp

StatSoft, I. (2007). Electronic Statistics Textbook. Retrieved 8-30, 2008, from http://www.statsoft.com/textbook/stathome.html

Staver, J. R. (1998). Constructivism: Sound theory for explicating the practice of science and science teaching. *Journal of Research in Science Teaching, 35*(5), 501-520.

Supovitz, J. A., & Turner, H. M. (2000). The Effects of Professional Development on Science Teaching Practices and Classroom Culture. *Journal of Research in Science Teaching, 37*(9), 963-980.

SURVEYS, S. (2008, 7-5-08). SWEPT Multi-site Student Outcomes Instruments. Retrieved 7-5, 2008, from http://www.sweptstudy.org/instruments.html

Taylor, G., Shepard, L., Kinner, F., & Rosenthal, J. (2003). *A Survey of Teachers' Perspectives on High-Stakes Testing in Colorado: What Gets Taught, What Gets Lost* (No. CSE Technical Report 588). Santa Cruz, CA: University of California, Santa Cruz.

Tell, C. (2000). Fostering High Performance and Respectability. *Association for Supervision and Curriculum Development 1*(22), 1-7.

TERC. (2008, 9-23-08). Technical Education Resources Center. Retrieved 10-7, 2008, from http://www.terc.edu/

Tillotson, J. W. (2008a, 9-26-08). Project IMPPACT Web Page for Instruments Used in the Study. Retrieved 9-27, 2008, from http://imppact.syr.edu/instruments.html

Tillotson, J. W. (2008b). Summer Leadership Institute. Unpublished RTOP standardization and B/NOS coding. Syracuse University.

Tillotson, J. W., & Young, M. J. (2005). *The IMPPACT Project: A study of the influence of preservice programs over time*. Paper presented at the 2005 Annual NE-ASTE Meeting.

Tillotson, J. W., & Young, M. J. (2006a). *The IMPPACT Project: Researching the Influence of Preservice Programs on Science Teachers' Beliefs and Practices Across the Career Continuum*. Paper presented at the Poster presented at 2006 TPC PI Conference.

Tillotson, J. W., & Young, M. J. (2006b). *The IMPPACT Project: Researching the Influence of Preservice Programs on Science Teachers' Beliefs and Practices Across the Career Continuum*. Paper presented at the 2006 ASTE International Conference.

Tillotson, J. W., & Young, M. J. (2006c). *Investigating the meaningfulness of preservice programs across the continuum of teaching—The IMPPACT project*. Paper presented at the Poster presented at 4th Annual Hawaii International Conference on Education.

Tillotson, J. W., & Young, M. J. (2007a). *The IMPPACT Project: Year One Results*. Paper presented at the Poster presented at 2007 TPC PI Conference.

Tillotson, J. W., & Young, M. J. (2007b). *Investigating the Meaningfulness of Preservice Programs Across the Continuum of Teaching in Science Education (IMPPACT Project): Exploring the Links between Preservice Programs, Pedagogical Beliefs and Classroom Performance*. Paper presented at the 2007 ESERA Conference.

Tillotson, J. W., Young, M. J., Luft, J. A., Maher, T. P., Yager, R. E., & Penick, J. E. (2007). *Teacher Education Profession Continuum Projects: Cross-Project Comparisons*. Paper presented at the at NARST Annual Meeting 2007.

Tillotson, J. W., Young, M. J., Yager, R. E., Penick, J. E., Sadeghpour-Kramer, M. A., Maher, T. P., et al. (2007). *Investigating the Meaningfulness of Preservice Programs Across the Continuum of Teaching (IMPPACT) in Science Education: Identifying Issues, Negotiating Problems, Preliminary Results, and Reflections*. Paper presented at the 2007 ASTE International Conference.

Timperley, H., & Robinson, V. (2000). Workload and the Professional Culture of Teachers. *Educational Management Administration & Leadership, 28*(1), 47-62.

Treagust, D. F., Duit, R., Joslin, P., & Lindauer, I. (1992). Science teachers' use of analogies: observations from classroom practice. *International Journal of Science Education, 14*(4), 413-422.

Truman, H. (1946, 8-12-08). National School Lunch Program. Retrieved 8-28-08, 2008, from http://www.fns.usda.gov/cnd/Lunch/

Vaishnavi, V. K., & Kuechler, W., J. (2007). *Design Science Research Methods and Patterns*. Boca Raton, Florida: Auerbach Publications, Taylor & Francis Group, 6000 Broken Sound Parkway NS, Suite 300, Boca Raton, Florida 33487-2742.

Valenzuela, D., & Shrivastava, P. (2008). Interview as a Method for Qualitative Research Presentation Retrieved 12-7-08, 2008, from http://www.public.asu.edu/~kroel/www500/Interview%20Fri.pdf.

van Driel, J., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673-695.

Veal, W. R., Meban, D., & Randolph, K. (2006). *Online Science Methods For Lateral Entry Science Teachers*. Paper presented at the Science, Technology, Engineering and Mathematics Education Institute for Alternative Certification of Teachers. Retrieved 11-30-08, from http://www.stemtec.org/act/PAPERS/William%20Veal.doc.

Wagner, M. M. (1995). Outcomes for Youths with Serious Emotional Disturbance in Secondary School and Early Adulthood. *Critical Issues For Children And Youths, 5*(2), 90-112.

Wallace, J., & Louden, W. (2002). *Dilemmas of Science*. New York, NY: Routledge Falmer 2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN.

Watson, S. B. (2006). Novice Science Teachers: Expectations and Experiences *Journal of Science Teacher Education, 17*(3), 279-290.

Weber, R. (2005). FIRST II NATIONAL MEETING. *National Science Foundation, 3*(1), 4.

Weirers, R. M. (2007). *Introduction to Business Statistics* (6 ed.). Florence, KY: Cengage South-Western Publishing.

Welch, W. W., Klopfer, L. E., Aikenhead, G. S., & Robinson, J. T. (1981). The role of inquiry in science education: Analysis and recommendations, *Science Education, 65*(1), 33-50.

Welch, W. W., Klopfer, L. E., Alkenhead, G. S., & Robenson, J. T. (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education, 65*(1), 33-50.

Wheelock, A., Bebell, D. J., & Haney, W. (2000). What Can Student Drawings Tell Us About High-Stakes Testing in Massachusetts? [Electronic Version]. *Teachers College Record*. Retrieved 12-1-08 from http://www.tcrecord.org/Content.asp?contentid=10634.

Wideen, M. E., O'Shea, T., Pye, I., & Ivany, G. (1997). High-Stakes Testing and the Teaching of Science. *Canadian Journal of Education, 22*(4), 428-444.

Wiemann, J. M. (1981). Effects Of Laboratory Videotaping Procedures On Selected Conversation Behaviors. *Human communication Research, 7*(4), 302-311.

Wiesenmayer, R. L., & Koul, R. (2004). Level of Internet Use Among Science Teachers Involved in a Professional Development Project. *Journal of Science Education and Technology, 8*(2), 123-135.

Windschitl, M. (2002). Science Teacher Education: Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? . *Science Education, 87*(1), 112-143.

Woodbury, S., & Gess-Newsome, J. (2002). Overcoming the Paradox of Change without Difference: A Model of Change in the Arena of Fundamental School Reform *Educational Policy, 16*(5), 763-782.

Worling, D., Humphres, T., & Tannock, R. (1999). Spatial and Emotional Aspects of Language Interfering in Nonverbal Learning Disabilities. *Brain and Language, 70*(2), 220-239.

Wright, P. W. D., & Wright, P. D. (2007, 10-10-2007). High Stakes Testing. *No Child Left Behind* Retrieved 10-6-2007, 2007, from http://www.wrightslaw.com/info/highstak.index.htm

Yager, R. E. (1999). Scope, sequence and coordination: The Iowa Project, a national reform effort in the USA *International Journal of Science Education,, 21*(2), 169-194.

Young, M. J., & Fidler, C. A. (2006). *Using the RTOP for Teacher Reflection*. Paper presented at the 2006 Annual NE-ASTE Meeting.

Young, M. J., & Preczewski, P. J. (2007). *Graduates Perceptions of Science Teacher Preparation Program Experiences*. Paper presented at the 2007 Annual NE-ASTE Meeting.

Young, M. J., & Tillotson, J. W. (2007). *The IMPPACT Project: Investigating the Role of Pre-service Science Teacher Education Programs in Promoting Scientific Literacy.* Paper presented at the Poster presented at Building a Scientifically Literate Population and Workforce for the 21st Century Conference, Uniondale, NY.

Young, M. J., Tillotson, J. W., Yager, R. E., Penick, J. E., Holtz, K. R., Preczewski, P. J., et al. (2008). *Investigating the Meaningfulness of Preservice Programs Across the Continuum of Teaching (IMPPACT) in Science Education: Year One Results, Issues, and Reflections*. Paper presented at the ASTE International Conference.

APPENDICES

APPENDIX 1

IMPPACT Project

Introductory Interview Questions

1. Tell me about why you decided to become a teacher.

2. Thinking back, what was the best science teaching you ever experienced?

3. In what ways, if any, has that experience affected your own teaching?

4. In contrast, what was the worst science teaching you ever experienced?

5. How did that experience affect your teaching?

6. Why did you select Iowa / NC State / Syracuse for your science teacher education program?

COHORTS 1 & 2 STOP HERE

COHORTS 3 & 4 ONLY

7. How prepared were you to start teaching?

8. What would have made you better prepared?

9. What lessons have you learned from your teaching experiences thus far?

APPENDIX 2

IMPPACT Project Preservice Program Interview
New Teacher Form

1. How would you describe your typical science course?
Probe for:

a. Types of objectives, e.g., certain knowledge, specific skills, attitudes towards science.
b. Typical instructional strategies, e.g., lecture, labs, projects, seminar discussion, independent research, cooperative learning, etc.
c. Instructional resources, e.g., textbooks, instrumentation, technologies, etc.

2. How were you typically evaluated in science courses?
Probe for:
a. Written tests; b. Essays; c. Projects;
d. Oral presentations; e. Research performance; f. Homework assignments
g. Evaluation by peers.

3. How often were cooperative learning techniques used in your science courses?

4. Did you take science courses different from those taken by students not preparing to teach?

5. How often did you work on actual research projects or in actual research facilities as part of your science program?
Probe for: Nature and duration of field experiences

6. Which science courses, or experiences, stand out in your mind as particularly important to you? Why?
Probe for:

a. What was learned.
b. Specific instructional strategies.
c. Materials used.
d. Ways of evaluating student learning.
e. Course organization, e.g., cooperative learning.

7. How would you describe the student-faculty relationship in your science program?

8. Were you a member of a student cohort when studying science?

APPENDIX 2 (cont.)

Science Study IMPPACT Project Preservice Program Interview
New Teacher Form

9. What was the purpose of your science study? Did it include teaching as a career?

Teacher Education Study

10. How would you describe your typical teacher education course?
Probe for:

a. Types of objectives, e.g., certain knowledge, specific skills, attitudes toward science or teaching secondary school students.
b. Typical instructional strategies, e.g., lecture, labs, projects, seminar discussion, independent research, cooperative learning, etc.
c. Instructional resources, e.g., textbooks, instrumentation, technologies, etc.

11. How were you typically evaluated in teacher education courses?
Probe for:
a. Written tests; b. Essays; c. Projects;
d. Oral presentations; e. Teaching performance; f. Homework assignments
g. Evaluation by peers or faculty.

12. How often were cooperative learning techniques used in your teacher education courses?

13. How would you describe your field experiences?
Probe for:

a. Experiences in different schools or school settings.
b. What students did in field experiences.
c. Nature of supervision and evaluation.

14. Which courses, or experiences, stand out in your mind as particularly important to you? Why?
Probe for:

a. What was learned?
b. Specific instructional strategies.
c. Materials used.
d. Ways of evaluating student learning.
e. Course organization, e.g., cooperative learning.

APPENDIX 2 (cont.)

15. What was the relationship between what you learned in science courses, and what you learned in teacher education courses, including your methods courses?

16. How would you describe the student-faculty relationship in your teacher education program?

17. Were you a member of a student cohort in your teacher education program?

APPENDIX 3

IMPPACT Project
Beliefs Interview Map
Teacher Form

1. **How do you maximize student learning in your classroom?**
   Probe for:
   a. Classroom organization;
   b. Classroom environment;
   c. Instructional techniques employed.

2. **How do you describe your role as a teacher?** (Student knowledge)

3. **How do you know when you students understand?** (Understanding)

4. **How has the school environment or culture influenced your beliefs and actions as a teacher?**
In terms of:
a. Relationships between teachers, students, and administrators;
b. Mentoring;
c. District's philosophy about science education reform;
d. School-community relationship.

5. **In your school setting, how do you decide what to teach or what not to teach?** (Attention to students & standards)

6. **How do you decide when to move on to a new topic in your class?**
   Probe for:
   a. Formative assessment;
   b. Summative assessment.

7. **How do your students learn best?** (Learning)

8. **How do you know when learning is occurring in your classroom?**

APPENDIX 4

IMPPACT Project
Nature of Science Interview Map
Teacher Form

9a. How is the discipline of science represented in your teaching?

Probe for:

a. When you think of science, what do you think of? And how is that represented in your teaching?

b. What is it about science that separates it from other disciplines and how is this represented in your teaching?

9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction?

10a. Can scientific knowledge change over time? If so, how does this happen? If not, why?

10b. How do you represent this view of science in your teaching?

Experimentation

11a. What is the role of experimentation in science?
11b. What characterizes experiments in science?
11c. Are experiments necessary?

Theories, Laws and Facts

12. What are the roles of theories and laws in science?

Science as a Socially Constructed Entity

13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? Would they have gone through the same processes to get those conclusions?

13b. If they disagree, what happens?

APPENDIX 5



IMPPACT Project
Reformed Teaching Observation Protocol (RTOP)

I. BACKGROUND INFORMATION

Name of teacher _____

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 _____

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.
**** This should be done while observing the LIVE lesson if possible. ****

APPENDIX 5 (cont.)

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 preceeded 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

6)	The lesson involved fundamental concepts of the subject.	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 representation, 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

11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulative, 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

APPENDIX 5 (cont.)

V. CONTENT

Communicative 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					
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

VI. COMMENTS

Please add any additional comments about the lesson.

APPENDIX 6

IMPPACT Project
Survey of Teacher Education Program Graduates

PLEASE PROVIDE THE FOLLOWING:

Name: _____
Last First Middle Former

Address: _____
Street City State Zip

SECTION I

DEMOGRAPHIC DATA

[Reminder: all demographic data will be confidential and only reported as aggregate data for the study reports.]

(PLEASE CIRCLE YOUR RESPONSES)

1. What is your ethnic background?

   (1) American Indian or Alaskan
   (2) Asian or Pacific Islander
   (3) Black, non-Hispanic
   (4) Hispanic
   (5) White, non-Hispanic
   (6) Other

2. What is the highest degree or highest level of education you hope to attain?

   (1) BS degree
   (2) master's degree
   (3) specialist's degree/certificate of advanced study
   (4) Ed.D., Ph.D., or other advanced degree

SECTION II

EMPLOYMENT STATUS

Circle one option A through E and complete sections indicated:

A. I am employed in the field of education. **(Please complete through #4 of this section; then answer All Sections EXCEPT VI on Page 4)**

   3. How would you describe your current position in education?

      (1) full-time teacher
      (2) permanent substitute
      (3) part-time teacher
      (4) day-to-day substitute
      (5) educational specialist (e.g., librarian, counselor)
      (6) school administrator/supervisor
      (7) other

B. I am employed outside the field of education. **(Please complete through #4 of this section; then go to Page 4 Section VI and answer all questions from there on)**

   Employment

   Job Title _____
   Name of Organization _____

   City _____ State ____ Zip _____

   Phone _____

   Salary _____
   (Confidential; for statistical compilation only)

   4. To what extent is your position connected to your most recent degree?

      (1) Directly connected
      (2) Moderately connected
      (3) Slightly connected
      (4) Not connected

C. I am in graduate/professional school. **(Please Proceed to Section VII on Page 4)**

   University _____

   Academic Program _____

D. I am not seeking employment currently. **(Please Proceed to Section VII on Page 4)**

E. I am not employed and still job hunting. **(Please Proceed to Section VII on Page 4)**

APPENDIX 6 (cont.)

SECTION III

FOR GRADUATES WHO ARE TEACHING: INFORMATION ABOUT YOUR TEACHING POSITION

5. At what grade level do you teach?

(1) preschool
(2) early elem. (grades K-3)
(3) upper elem. (grades 4-6)
(4) middle school/jr. high
(5) senior high school
(6) more than one level/K-12

6. About what percent of your present teaching assignment is in the grade(s) or subject area(s) in which you were certified/endorsed?

(1) 25% or less
(2) 50%
(3) 75%
(4) 100%

7-9. How would you describe your school building?

7. Type:	8. Setting:	9. Number of Students:
(1) public	(1) inner-city	(1) less than 300
(2) parochial	(2) urban (pop. > 100,000)	(2) 300 to 599
(3) private	(3) suburban	(3) 600 to 899
	(4) town (pop. > 25,000)	(4) 900 to 1,200
	(5) small town/rural	(5) more than 1,200

10. Is the school in which you teach located within 50 miles of the...

(1) high school from which you graduated
(2) college from which you received your teacher preparation
(3) both of the above
(4) neither of the above

11. Are the socioeconomic backgrounds of most of your current students lower, higher, or similar to those of your high school classmates?

(1) lower
(2) higher
(3) similar

12. Approximately what proportion of the students in your class(es) are students of color?

(1) less than 10%
(2) 10%
(3) 25%
(4) 50%
(5) 75%
(6) more than 75%

13. Is this percentage lower, higher, or comparable to the proportion of students of color in your high school class?

(1) lower
(2) higher
(3) comparable

14. Are you a special education teacher?

(1) Yes If no, have you experienced inclusion in your classroom(s)?
(2) yes, of one or two students
(3) yes, of more than two students
(4) none

15. How would you characterize the level of academic motivation of your students?

(1) very low
(2) low
(3) average
(4) high
(5) very high

16. How would you characterize the frequency of discipline problems in your class(es)?

(1) few, if any, problems
(2) occasional problems
(3) many problems

17. How would you characterize the level of parent involvement in your school?

(1) very low
(2) low
(3) not sure
(4) high
(5) very high

18-22. **Management Practices**: Which of the following management practices does your school feature?

Circle all applicable answers.

18. Outcomes based management
19. Principal manages decisions
20. School governing board (including parents & other community representatives)?
21. Site-based management
22. Teacher-principal shared decision making and/or teacher empowerment

23. **School's Vision:** Does your school have a clear vision of what you want your students to know and be able to do by the time they graduate?

(1) No
Yes -- If Yes, were you in any way involved in the creation of this vision?
(2) No
(3) Yes, I was somewhat involved.
(4) Yes, I was actively involved.
(5) Yes, I played a significant role in the creation of the vision.

SECTION IV

FOR GRADUATES WHO ARE TEACHING: VIEWS OF TEACHING

24. Which of the following criteria are you most likely to consider when assessing your success as a teacher? The extent to which students..

(1) like and respect me as a teacher.
(2) learn what I try to teach them.
(3) gain a sense of self-confidence and self-worth in my classroom.
(4) get along with each other.

25. Student behavior problems may result from a number of different sources, including those listed below. Which of these would you rank as the most frequent source of student behavior problems in classroom settings?

(1) teachers' inadequate planning/classroom management
(2) teachers/failure to establish a supportive classroom environment
(3) unresolved problems students experience outside the classroom setting
(4) conflicts between values students acquire at home and those that are prized in schools
(5) parents' failure to support teachers/schools

APPENDIX 6 (cont.)

26. In adapting instruction to address differences in students' academic achievement, are you most likely to vary the...

(1) content you teach to different students
(2) instructional methods you use with different students
(3) standards of achievement you expect students to attain (higher standards for more capable students)?

27. Which of the following questions is most likely to occur to you when you are trying to decide what content to teach or what not to teach? Will knowing this content help students...

(1) succeed in later grades or later courses in this subject area?
(2) pass state or district tests?
(3) acquire the practical knowledge base they will need to function effectively as adults in our society?
(4) understand the people and events that are currently shaping their lives?
(5) enjoy richer or more meaningful adult lives?

28. Do you believe you can reach even the most difficult or least motivated students?

(1) Yes (3) Yes, with some qualifications
(2) No (4) No, with some qualifications

29. If students seem puzzled or confused at some point during a lesson, what are you most likely to do?

(1) try to resolve the confusion by providing a clearer example or better explanation.
(2) provide sufficient support for students to work through the source of the confusion on their own.
(3) downplay the seriousness of their confusion so students won't become discouraged.

30. When students fail to achieve intended goals and objectives, that failure is often attributed to one of the following sources. Which do you believe is the most frequent source of failure?

(1) students' home background
(2) students' indifference or lack of motivation
(3) parents' failure to stress the importance of school
(4) teachers' use of inappropriate methods of teaching
(5) teachers' failure to consider the unique interests and abilities of students

SECTION V

FOR GRADUATES WHO ARE TEACHING: CAREER SATISFACTION AND PROFESSIONAL DEVELOPMENT

31-38. On a scale of one to seven, how would you describe your response to each of the following features of your current job?

		(1) very negative						(7) very positive
31.	Salary/fringe benefits	1	2	3	4	5	6	7
32.	Opportunities for professional advancement	1	2	3	4	5	6	7
33.	Level of personal/professional challenge	1	2	3	4	5	6	7
34.	Level of professional autonomy/ decision making authority	1	2	3	4	5	6	7
35.	General work conditions (hours, class size, work load, etc.)	1	2	3	4	5	6	7
36.	Interactions with colleagues	1	2	3	4	5	6	7
37.	Interactions with students	1	2	3	4	5	6	7
38.	*Using the same scale*, how would you describe your overall level of satisfaction with your current job?	1	2	3	4	5	6	7

39. If you had it to do all over again, would you still enroll in a teacher education program?

(1) definitely no (3) probably yes
(2) probably no (4) definitely yes

40. Do you feel you are a(n) ...

(1) inferior teacher (4) better than average teacher
(2) below average teacher (5) exceptional teacher
(3) average teacher

41. How would you characterize your district's commitment to teachers' professional development (e.g., providing inservice workshops; making available professional materials)?

(1) very low (3) not sure (5) very high
(2) low (4) high

42. Which of the following activities is most likely to help you become a better teacher? **(Choose One)**

(1) Observe other teachers and talk to them.
(2) Be observed by other teachers or supervisors and talk with them.
(3) Read professional journals/publications.
(4) Take additional graduate courses in education.
(5) Take additional graduate courses in the subjects you teach.
(6) Participate in teacher inservices/workshops.

43. Which of the following activities is least likely to help you become a better teacher? **(Choose One)**

(1) Observe other teachers and talk to them.
(2) Be observed by other teachers or supervisors and talk with them.
(3) Read professional journals/publications.
(4) Take additional graduate courses in education.
(5) Take additional graduate courses in the subjects you teach.
(6) Participate in teacher inservices/workshops.

44. Do you have ready access to a personal computer in your school?

(1) No If yes, how do you use computers in your teaching?
(2) not at all
(3) as a tool in teaching or reinforcing student learning (e.g., in teaching writing or math).
(4) for my own record keeping, preparation of instructional handouts, etc.
(5) both of the above

APPENDIX 6 (cont.)

45. What other kinds of technology do you use in your teaching? **(Circle all that apply)**

(1) Videoconferencing
(2) Microwave transmission of teaching
(3) Graphing calculators/labs
(4) Probes
(5) Computer simulations
(6) Laser disks
(7) LCD panel
(8) Overhead projector
(9) Video camera

46. Five years from now, do you plan to be ...

(1) teaching
(2) a school administrator
(3) an educational specialist (e.g. math consultant, librarian)
(4) employed outside the field of education
(5) temporarily out of the work force (e.g., care for a family)
(6) permanently out of the work force (e.g., retired)
(7) counselor/school psychologist
(8) other

47. To what extent were college courses in the subject(s) you currently teach relevant to the needs of teachers?

(1) largely irrelevant
(2) moderately relevant
(3) very relevant

48. Consider your daily teaching and learning activities. Are these teaching and learning activities that you perceive to promote life long learning?

(1) definitely not
(2) probably not
(3) not sure
(4) probably yes
(5) definitely yes

49. Consider your knowledge, skills and abilities as a teacher. Would you recommend your science teacher education program to other prospective teachers?

(1) definitely not
(2) probably not
(3) not sure
(4) probably yes
(5) definitely yes

GO TO SECTION VII #55

SECTION VI *(For Those Who Circled B On Page 1)*

FOR GRADUATES WHO ARE NOT TEACHING

50. Which of the following statements best describes why you are not in a full-time teaching position at the present time?

(1) Teaching was not my first choice of careers at the time I began looking for a job.
(2) I was offered another job within the field of education (e.g., school administrator).
(3) I was offered another job outside of education.
(4) A full-time teaching position was not available in the geographic area where I hoped to reside.
(5) I tried, but I couldn't find a full-time teaching position anywhere.
(6) I wanted to continue my education.
(7) I needed to attend to home/family affairs.
(8) Other

51. Do you regret you are not a full-time teacher?

(1) Yes (2) No

52. Do you feel you are underemployed?

(1) Yes (2) No

53. To what extent did the work you completed in your teacher education program contribute to your preparation for your current job?

(1) no contribution
(2) minor contribution
(3) moderate contribution
(4) strong contribution

54. If you had it to do all over again, would you still enroll in a teacher education program?

(1) definitely not
(2) probably not
(3) probably yes
(4) definitely yes

SECTION VII

ALL GRADUATES:
RATINGS OF PRESERVICE PROGRAM QUALITY

55-62. On a scale of one to seven, how would you rate the overall quality of your preservice science teacher education program ...

	(1) exceptionally weak						(7) exceptionally strong
55. field-based experiences	1	2	3	4	5	6	7
56. program major	1	2	3	4	5	6	7
57. instructional resources i.e., library	1	2	3	4	5	6	7
58. your student teaching/internship experience	1	2	3	4	5	6	7
59. feedback from cooperating teachers/mentors	1	2	3	4	5	6	7
60. feedback from college coordinators/supervisors/faculty	1	2	3	4	5	6	7
61. advice/counseling from your academic advisor	1	2	3	4	5	6	7
62. advice/counseling from your faculty advisor	1	2	3	4	5	6	7

63. To what extent did your views of the professional roles and responsibilities of teachers change from the time you entered your teacher preparation program to program completion?

(1) not at all
(2) not much
(3) some
(4) a lot

64. Please rate your overall capability compared with other professionals with the same number of years experience in your professional practice.

(1) very low
(2) low
(3) average
(4) above average
(5) very high

65. Please rate your overall confidence in your professional practice.

(1) very low
(2) low
(3) average
(4) above average
(5) very high

APPENDIX 6 (cont.)

66. Please rate your overall professional behavior.

(1) very low
(2) low
(3) average
(4) above average
(5) very high

67. Overall, rate the quality of your courses.

(1) unacceptable
(2) below average
(3) average
(4) above average
(5) exceptional

68. The intellectual challenge of your course work.

(1) unacceptable
(2) below average
(3) average
(4) above average
(5) exceptional

69. The quality of instruction you received during your course work.

(1) unacceptable
(2) below average
(3) average
(4) above average
(5) exceptional

70. The quality of your cooperating/placement teacher.

(1) unacceptable
(2) below average
(3) average
(4) above average
(5) exceptional

71. The OVERALL quality of your University teacher education experience.

(1) unacceptable
(2) below average
(3) average
(4) above average
(5) exceptional

72-99. How would you have rated the adequacy of your skills in each of the following areas **at the time you completed your teacher preparation program:** (1) weak, (2) adequate, or (3) strong?

The adequacy of your skills in . . .	**weak**	**adequate**	**strong**
72. planning stimulating lessons.	1	2	3
73. motivating students to participate in academic tasks.	1	2	3
74. teaching basic knowledge and skills.	1	2	3
75. teaching problem solving and higher-order thinking to all students			
(a) in science and mathematics (elementary teachers).	1	2	3
(b) in the most challenging subject you teach (secondary teachers).	1	2	3
76. teaching problem solving, conceptual understanding, and other aspects of higher-order thinking.	1	2	3
77. developing a "sense of community" among the students in your classroom (i.e., a classroom that stresses meaningful collaborations among students).	1	2	3
78. team teaching and/or interdisciplinary planning and teaching.	1	2	3
79. selecting, preparing, and using educational media.	1	2	3
80. using educational technology as a learning tool	1	2	3
81. referring students for special assistance when appropriate.	1	2	3
82. working with gifted and talented students.	1	2	3
83. working in an inclusion setting or with special needs students.	1	2	3
84. using literature-based approaches to instruction (e.g., using literary works to teach social studies).	1	2	3
85. working with students from diverse racial and ethnic backgrounds.	1	2	3
86. adapting instruction to address differences in students/academic aptitude.	1	2	3
87. enhancing students' sense of personal achievement and self-worth.	1	2	3
88. monitoring students' progress and adjusting instruction accordingly.	1	2	3
89. designing/interpreting measures of student work and achievement.	1	2	3
90. using alternative assessment practices--portfolios, performance tests, student self-assessment strategies, etc).	1	2	3
91. communicating with parents.	1	2	3
92. using the community as a resource for teaching and learning.	1	2	3
93. using jigsaw, Teams-Games-Tournaments (TGT), and other cooperative learning techniques.	1	2	3
94. responding appropriately to disruptive student behaviors.	1	2	3
95. assessing the expectations of the community and school administration.	1	2	3
96. designing lessons and units of instruction that feature multiple representations of concepts.	1	2	3
97. designing lessons and units of instruction that feature multiple perspectives (e.g., a genetics unit on the bioethics of cloning).	1	2	3
98. planning and implementing a successful first week of school.	1	2	3
99. reflecting upon and improving your teaching performance.	1	2	3

100. What kinds of technology were you prepared (during your program) to use in your teaching? **(Circle all that apply)**

(1) Videoconferencing
(2) Microwave transmission of teaching
(3) Graphing calculators/labs
(4) Probes
(5) Computer simulations
(6) Laser disks
(7) LCD panel
(8) Overhead projector
(9) Video camera

APPENDIX 6 (cont.)

101-120. How would you rate the adequacy of your knowledge and understanding in each of the following areas?

Your knowledge and understanding of ...	weak	adequate	strong
101. curriculum development	1	2	3
102. special needs children	1	2	3
103. communication	1	2	3
104. educational research	1	2	3
105. child development	1	2	3
106. multi-cultural issues and perspectives	1	2	3
107. the historical and philosophical development of thought in your major field	1	2	3
108. contemporary educational issues	1	2	3
109. theories/principles of how students learn	1	2	3
110. child/adolescent growth and development	1	2	3
111. social and political roles of schools in American society	1	2	3
112. classroom management techniques/ procedures	1	2	3
113. legal and ethical responsibilities of teachers	1	2	3
114. the subjects you teach.	1	2	3
115. educational concepts and theories.	1	2	3
116. classroom research/inquiry strategies	1	2	3
117. measurement techniques	1	2	3
118. recent research in education.	1	2	3
119. professional practice/pedagogy.	1	2	3
120. a variety of assessment strategies	1	2	3

Thank you for the time and effort to complete this study!!!

The IMPPACT Project researchers respect your opinion and feedback.

APPENDIX 7

IMPPACT Project
The BARSTL Questionnaire

How to Answer Each Question
On the next few pages, you will find 32 sentences. For each sentence, circle only one number corresponding to your answer.

		Strongly Disagree	Disagree	Agree	Strongly Agree
14	During a lesson, students need to be given opportunities to test, debate, and challenge ideas with their peers.	1	2	3	4

- If you *strongly agree* that students should be given these opportunities during a lesson, circle the 4.
- If you *strongly disagree* that students should be given these opportunities during a lesson, circle the 1.
- Or you can choose the number 2 or 3 if one of these better reflects your beliefs.

3. How to Change Your Answer
If you want to change your answer, cross it out and circle a new number, For example:

14	During a lesson, students need to be given opportunities to test, debate, and challenge ideas with their peers.	1	2	3	4

4. Completing the Questionnaire
Now turn the page and please give an answer for every question.

APPENDIX 7 (cont.)

How People Learn About Science

The statements below describe different viewpoints concerning the ways students learn about science. Based on your beliefs about how people learn, indicate if you agree or disagree with each of the statements below using the following scale: Strongly disagree = 1, Disagree = 2, Agree = 3, and Strongly agree = 4.

		Strongly Disagree	Disagree	Agree	Strongly Agree
1	Students develop many beliefs about how the world works before they ever study about science in school.	1	2	3	4
2	Students learn in a disorderly fashion; they create their own knowledge by modifying their existing ideas in an effort to make sense of new and past experiences.	1	2	3	4
3	People are either talented at science or they are not, therefore student achievement in science is a reflection of their natural abilities.	1	2	3	4
4	Students are more likely to understand a scientific concept if the teacher explains the concept in a way that is clear and easy to understand.	1	2	3	4
5	Frequently, students have difficulty learning scientific concepts in school because their beliefs about how the world works are often resistant to change.	1	2	3	4
6	Learning science is an orderly process; students learn by gradually accumulating more information about a topic over time.	1	2	3	4
7	Students know very little about science before they learn it in school.	1	2	3	4
8	Students learn the most when they are able to test, discuss, and debate many possible answers during activities that involve social interaction.	1	2	3	4

Lesson Design and Implementation

The statements below describe different ways science lessons can be designed and taught in school. Based on your opinion of how science should be taught, indicate if you agree or disagree with each of the statements below using the following scale: Strongly disagree = 1, Disagree = 2, Agree = 3, and Strongly agree = 4.

		Strongly Disagree	Disagree	Agree	Strongly Agree
9	During a lesson, students should explore and conduct their own experiments with hands-on-materials before the teacher discusses any scientific concepts with them.	1	2	3	4
10	During a lesson, teachers should spend more time asking questions that trigger divergent ways of thinking than explaining the concept to students.	1	2	3	4
11	Whenever students conduct an experiment during a science lesson, the teacher should give step-by-step instructions for the students to follow in order to prevent confusion and to make sure students get the correct results.	1	2	3	4
12	Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class.	1	2	3	4
13	Lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, a reading, or a demonstration.	1	2	3	4
14	During a lesson, students need to be given opportunities to test, debate, and challenge ideas with their peers.	1	2	3	4
15	During a lesson, all of the students in the class should be encouraged to use the same approach for conducting an experiment or solving a problem.	1	2	3	4
16	Assessments in science classes should only be given after instruction is completed; that way the teacher can determine if the students have learned the material covered in class.	1	2	3	4

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APPENDIX 7 (cont.)

Characteristics of Teachers and the Learning Environment

The statements below describe different characteristics of teachers and classroom learning environments. Based on your opinion of what a good science teacher is like and what a classroom should be like, indicate if you agree or disagree with each of the statements below using the following scale: Strongly disagree = 1, Disagree = 2, Agree = 3, and Strongly agree = 4.

		Strongly Disagree	Disagree	Agree	Strongly Agree
17	Students should do most of the talking in science classrooms	1	2	3	4
18	Students should work independently as much as possible so they do not learn to rely on other students to do their work for them.	1	2	3	4
19	In science classrooms, students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say.	1	2	3	4
20	Teachers should allow students to help determine the direction and the focus of a lesson.	1	2	3	4
21	Students should be willing to accept the scientific ideas and theories presented to them during science class without question.	1	2	3	4
22	An excellent science teacher is someone who is really good at explaining complicated concepts clearly and simply so that everyone understands.	1	2	3	4
23	The teacher should motivate students to finish their work as quickly as possible.	1	2	3	4
24	Science teachers should primarily act as a resource person; working to support and enhance student investigations rather than explaining how things work.	1	2	3	4

The Nature of the Science Curriculum

The following statements describe different things that students can learn about in science while in school. Based on your opinion of what students should learn during their science classes, indicate if you agree or disagree with each of the statements below using the following scale: Strongly disagree = 1, Disagree = 2, Agree = 3, and Strongly agree = 4.

		Strongly Disagree	Disagree	Agree	Strongly Agree
25	A good science curriculum should focus on only a few scientific concepts a year, but in great detail.	1	2	3	4
26	The science curriculum should focus on the basic facts and skills of science that students will need to know later.	1	2	3	4
27	Students should know that scientific knowledge is discovered using the scientific method.	1	2	3	4
28	The science curriculum should encourage students to learn and value alternative modes of investigation or problem solving.	1	2	3	4
29	In order to prepare students for future classes, college, or a career in science, the science curriculum should cover as many different topics as possible over the course of a school year.	1	2	3	4
30	The science curriculum should help students develop the reasoning skills and habits of mind necessary to do science.	1	2	3	4
31	Students should learn that all science is based on a single scientific method—a step-by-step procedure that begins with 'define the problem' and ends with 'reporting the results.'	1	2	3	4
32	A good science curriculum should focus on the history and nature of science and how science affects people and societies.	1	2	3	4

APPENDIX 8

Because of the proprietary nature of the SEC survey, not all the questions on the survey are listed. The following questions are provided on the web site as examples:

Q29 Do a laboratory activity, investigation, or experiment.
Q31 Collect data (other than laboratory activities).
Q34 Use computers, calculators or other educational technology or learn science.
Q39* Use science equipment or measuring tools.
Q44* Design their own investigation or experiment to solve a scientific question.
Q59* Use sensors and probes (for examples, CBL's). Reliability Coefficient
For the most recent school year, how often have you participated in:
Q101a Workshops or in-service training related to science or science education
Q102a Summer institutes related to science or science education
Q103a College courses related to science or science education
For the most recent school year, how many total hours have you participated in:
Q101b Workshops or in-service training related to science or science education
Q102b Summer institutes related to science or science education
Q103b College courses related to science or science education
Q111 Observed demonstrations of teaching techniques
Q112 Led group discussions.
Q113 Developed curricula or lesson plans, which other participants or the activity leader reviewed.
Q114 Reviewed student work or scored assessments.
Q15 Developed assessments or tasks.
Q116 Practiced what you learned and received feedback as part of a professional development activity.
Q117 Received coaching or mentoring in the classroom.
Q118 Given a lecture or presentation to colleagues.
Q119 Designed to support the school-wide improvement plan adopted by your school.
Q120 Consistent with your science department or grade level plan to improve teaching.
Q121 Consistent with your own goals for your professional development.
Q122 Based explicitly on what you had learned in earlier professional development activities.
Q123 Followed up with related activities that built upon what you learned as part of the activity.
* Item appears in more than one scale.
Appendix C
Reliability Coefficient
Q124 I participated in professional development activities with most or all of the teachers from my school.
Q125 I participated in professional development activities with most or all of the teachers from my department or grade level.
Q126r (Reversed.) I participated in PD activities NOT attended by other teachers at my school.
Q128* State science content standards (for example, what they are and how they areused).
Q129* Alignment of science instruction to curriculum.
Q131 In-depth study of science or specific concepts within science (for example, earth science).
Q135 Classroom science assessment (for example, diagnostic approaches, textbook developed tests, teacher-developed tests).
Q136 State or district science assessment (for example, preparing for assessments, understanding assessments, or interpreting assessments).
Q137 Interpretation of assessment data for use in science instruction.
Q128* State science content standards (for example, what they are and how they are used).

APPENDIX 8 (cont.)

Q129* Alignment of science instruction to curriculum.
Q132 Study of how children learn particular topics in science.
Q133 Individual differences in student learning.
Q134 Meeting the learning needs of special populations of students (for example, second language learners; students with disabilities).
Q135 Classroom science assessment (for example, diagnostic approaches, textbook developed tests, teacher-developed tests).
Q138 Technology to support student learning in science.

APPENDIX 9

1

STUDENT ATTITUDES ABOUT SCIENCE INSTRUCTION

Start of Course

DIRECTIONS: The statements in this survey have to do with your opinions and beliefs about science instruction in
school and the importance of science in your life. Please read each statement carefully, and circle the number that
best expresses **your own** feelings.

Remember that this is not a test, and there are no "right" or "wrong" answers. Please respond to every item.

1. To what extent do you agree or disagree with each of the following statements about science? (*Circle one number on each line.)*

	Strongly disagree	**Disagree**	**Not sure**	**Agree**	**Strongly agree**
a. I enjoy science	1	2	3	4	5
b. Science is useful in everyday life	1	2	3	4	5
c. Scientists often don't have very good social skills	1	2	3	4	5
d. Doing science often makes me feel nervous or upset	1	2	3	4	5
e. Science challenges me to use my mind	1	2	3	4	5
f. The science instruction that I have received will be helpful for me in the future	1	2	3	4	5
g. Scientists usually work with colleagues as part of a team	1	2	3	4	5
h. I am good at science	1	2	3	4	5
i. Advancements in science and mathematics are largely responsible for the standard of living inthe United States	1	2	3	4	5
j. I usually understand what we are doing in science class	1	2	3	4	5
k. Knowing science really doesn't help get a job	1	2	3	4	5
l. Science is difficult for me	1	2	3	4	5
m. Working as a scientist sounds pretty lonely to me	1	2	3	4	5
n. Studying hard in science is not cool to do	1	2	3	4	5
o. Even without a strong background in science, I will probably end up with the kind of job I want	1	2	3	4	5
p. Overall, science and mathematics have caused more good than harm in our lives	1	2	3	4	5
q. I will probably take more advanced science courses available to me at this school	1	2	3	4	5

2. To what extent do you agree or disagree with each of the following statements about your parents' or guardians' involvement in your education? *(Circle one number on each line.)*

My parents/guardians.	**Strongly disagree**	**Disagree**	**Not sure**	**Agree**	**Strongly agree**
a. Expect me to complete college	1	2	3	4	5
b. Often help me with my school work	1	2	3	4	5
c. Reward me for getting good grades	1	2	3	4	5
d. Are very busy and don't have much time to help with my school work	1	2	3	4	5
e. Expect me to do well in science	1	2	3	4	5
f. Think that science is a very important subject	1	2	3	4	5
g. Would like me to have a career in science, mathematics, or engineering	1	2	3	4	5
h. Make sure I do my homework assignments	1	2	3	4	5
i. Ask me about what I am doing in school	1	2	3	4	5

APPENDIX 9 (cont)

3. Have you engaged in each of the following activities during the past 12 months? *(Circle one number on each line.)*

	Yes	No
a. Participated in a science, mathematics, or computer club	1	2
b. Visited a science museum	1	2
c. Watched scientific or mathematics TV shows (e.g., NOVA, Discovery Channel, Bill Nye the Science Guy, etc.)	1	2
d. Read science or mathematics magazines or news articles	1	2
e. Collected information about careers in science or mathematics	1	2

4. What grades do you usually get in science? *(Circle only one.)*
Mostly Ds (below 70) 1
Mostly Cs (around 70-80) 2
Mostly Bs (around 80-90) 3
Mostly As (around 90-100).... 4
Not sure 5

5. How much effort do you usually put into your science work? *(Circle only one.)*
I don't try at all 1
I do just enough to get by..... 2
I give an average amount of effort..... 3
I try pretty hard, but not as hard as I could 4
I work as hard as I can..... 5

6. How far do you expect you will go in school? *(Circle only one.)*
Will not finish high school.....1
High school diploma 2
Trade or vocational school.....3
Some college, but no degree.....4
2-yr (associate) degree.....5
4-yr (bachelor's) degree 6
Master's degree.....7
Ph.D. degree 8
Other advanced degree (*specify*) ……9
Don't know.....98

7. What is your gender? *(Circle only one.)*
Male 1
Female 2

8. Which best describes you? *(Circle only one.)*
American Indian or Alaska Native 1
Asian or Pacific Islander..... 2
Black, non-Hispanic..... 3
Hispanic..... 4
White, non-Hispanic 5

APPENDIX 9 (cont)

9. What is your father's/male guardian's educational level? *(Circle only one.)*
Less than high school..... 1
High school diploma 2
Trade or vocational school..... 3
Some college, but no degree..... 4
2-year (associate) degree..... 5
4-year (bachelor's) degree 6
Master's degree..... 7
Ph.D. degree 8
Other advanced degree (*specify*) ……9
Don't know..... 98

10. What is your mother's/female guardian's educational level? *(Circle only one.)*
Less than high school..... 1
High school diploma 2
Trade or vocational school..... 3
Some college, but no degree..... 4
2-year (associate) degree..... 5
4-year (bachelor's) degree 6
Master's degree..... 7
Ph.D. degree 8
Other advanced degree (*specify*) ……...9
Don't know..... 98

11. What kind of work does your father/male guardian normally do for a living?
Please be as specific as you can.

12. What kind of work does your mother/female guardian normally do for a living?
Please be as specific as you can.

13. Which of the following do you have in your home? *(Circle one number on each line.)*

	Yes	**No**
a. A daily newspaper.....	1	2
b. A computer linked to the Internet…… .	1	2
c. An atlas or globe.....	1	2
d. A calculator.....	1	2
e. More than 50 books	1	2
f. A microscope.....	1	2
g. A telescope.....	1	2

THANK YOU VERY MUCH FOR COMPLETING THIS SURVEY.

APPENDIX 10

IMPPACT Project
Preservice Program Interview
Science Faculty Form

1. How would you describe the science courses you teach?
   Probe for:
   a. Types of objectives, e.g., certain knowledge, specific skills, attitudes towards science.
   b. Typical instructional strategies, e.g., lecture, labs, projects, seminar discussion, independent research, cooperative learning, etc.
   c. Instructional resources, e.g., textbooks, instrumentation, technologies, etc.

2. How do you typically evaluate students in your courses?
   Probe for:
   a. Written tests; b. Essays; c. Projects;
   d. Oral presentations; e. Research performance; f. Homework assignments
   g. Evaluation by peers.

3. How often do students work in groups in your courses?

4. Do you teach courses only for students preparing to teach science?

5. How often do students work on actual research projects or in actual research facilities as part of your courses?
   Probe for: Nature and duration of field experiences

6. What role do you play in managing or evaluating your program?

7. What relationships exist between your department and those responsible for science education and teacher education in general?
   Probe for:
   a. Formal; b. Informal; c. As facilitating reform;
   d. As obstacles to reform; and e. Internal politics.

9. How satisfied are you with your program and courses? Why?

10. What are the procedures for changing courses of programs in your institution?
    Probe for:
    a. What changes have occurred in the past 5 years?
    b. What changes are in progress?
    c. Why did you make these changes?
    d. What prompts you (personally) to change?

APPENDIX 10 (cont.)

11. How do you advise, support, and assist your students?
    Probe for:
    a. Formal; b. Informal; c. Interpersonal;
    d. While in the program; and e. After graduation.

12. Are your students encouraged to join professional organizations? Which ones?

13. What coherence (if any) do you see in your teacher prep program?

APPENDIX 11

IMPPACT Project
Preservice Program Interview
Teacher Education Faculty Form

1. How would you describe the teacher education courses you teach?
   Probe for:
   d. Types of objectives, e.g., certain knowledge, specific skills, attitudes towards science.
   e. Typical instructional strategies, e.g., lecture, labs, projects, seminar discussion, independent research, cooperative learning, etc.
   f. Instructional resources, e.g., textbooks, instrumentation, technologies, etc.

2. How do you typically evaluate students in your courses?
   Probe for:
   a. Written tests; b. Essays; c. Projects;
   d. Oral presentations; e. Research performance; f. Homework assignments
   g. Evaluation by peers.

3. How often do you use cooperative learning techniques in your courses?

4. Do you teach courses only for students preparing to teach science?

5. How often do students work in schools and classrooms as part of your courses?
   Probe for: Nature and duration of field experiences

6. What philosophy of (a) science, and (b) teaching do you stress in your courses?

7. What role do you play in managing or evaluating your program?

8. What relationships exist between your department and those responsible for [science, teacher education in general]?
   Probe for:
   a. Formal; b. Informal; c. As facilitating reform;
   d. As obstacles to reform; and e. Internal politics.

9. How satisfied are you with your program and courses? Why?

APPENDIX 11 (cont.)

10. What are the procedures for changing courses of programs in your institution?
    Probe for:
    e. What changes have occurred in the past 5 years?
    f. What changes are in progress?
    g. Why did you make these changes?
    h. What prompts you (personally) to change?
    i.

11. How do you advise, support, and assist your students?

    Probe for:

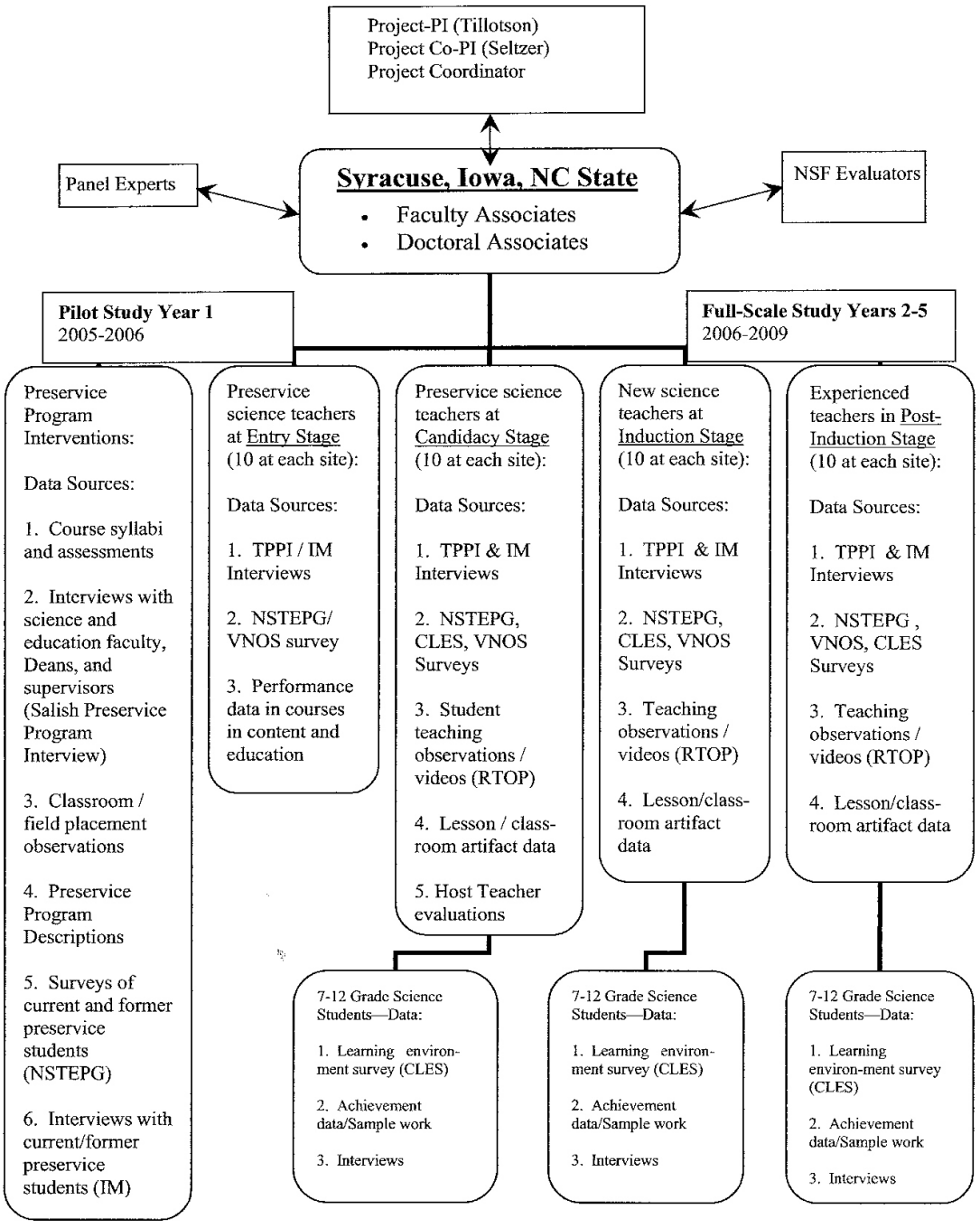
    a. Formal; b. Informal; c. Interpersonal;
    d. While in the program; and e. After graduation.

12. Are your students encouraged to join professional organizations? Which ones?

13. What coherence (if any) do you see in your teacher prep program?

APPENDIX 12

Figure 1. IMPPACT Project Research Design



APPENDIX 13

Middle Grades Science Education

Grades 6-9 Science Licensure (13MSS038)

FRESHMAN YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Orientation to Math & Sci Ed	0	Phys Geology/Lab	4
Molecular Chemistry	3	Quantitative Chemistry	3
Molecular Chemistry Lab	1	Quantitative Chemistry Lab	1
Elemental Calculus **OR**		Calc Life & Manage Science B **OR**	
Calc Life & Manage Science A	3	Intro to Statistics	3
Acad. Writing & Research	4	Phil/Rel/Arts Elective [5,6]	3
History Elective [1,2]	3	Social Science Elective [1,6,7]	3
Health & Physical Fitness	1		**17**
	15		

SOPHOMORE YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Public Speaking	3	Solar System Astronomy	3
Introductory Biology I	4	Introductory Biology II	4
Conceptual Physics	4	Intro to Teach Math & Science	3
Intro to Weather & Climate	3	Intro to Teach Ma & Sci Lab	0
Intro to Weather & Climate Lab	1	Literature Elective [1,6]	3
Physical Education Elective	1	Hum/Social Science Elective [1,6,7]	3
	16		**16**

JUNIOR YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Teaching in Middle Years	3	Intro to Ecology	3
Instr. Mat in Science	3	Ecology Laboratory	1
Genetics in Human Affairs	3	Principles of Teach Diverse Pop	3
School and Society	3	Methods of Teach Science I	3
Educational Psychology	3	Teach Except Students	3
Emergency Medicine **OR**		Orient to Math & Sci Ed	0
Personal Health	2	Biological Science Elective [10]	3
	18		**16**

SENIOR YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Methods of Teach Science II [3,8]	3	Free electives	4
Student Teach in Science [3]	8	Science Elective	3
Sr Sem in Math & Sci Ed [3]	2	Psych of Adol Develop	3
	13	Middle years Reading	3
		History/Phil of Sci Elect [2]	3
		Arts & Adolescents	2
			18

Minimum Credit Hours Required for Graduation 128 [4,9]

APPENDIX 14

Science Education: Middle Grades Education: Mathematics and Science Specialization

Grades 6-9 Licensure (13MSD038)

FRESHMAN YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Orientation to Math & Science Ed	0	Geology: Physical	3
Introductory Biology I	4	Geology I Laboratory	1
Calc Life & Manage Science A	4	Calc Life & Manage Science A	4
Academic Writing & Res.	4	Introductory Biology II	4
History Elective [1,6]	3	Speech Elective	3
Health & Physical Fitness	1	Physical Education Elective	1
	16		**16**

SOPHOMORE YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Molecular Chemistry I	3	Quantitative Chemistry	3
Molecular Chemistry Lab I	1	Quantitative Chemistry Lab	1
Hum/Social Science Elective [1,6,7]	3	Conceptual Physics	4
Intro to Computers	3	Statistics Course [11]	3
Intro to Finite Math	3	Intro to Teach Math & Science	3
Intro to Weather & Climate	3	Intro to Teach Ma & Sci Lab	0
Intro to Weather & Climate Lab	1	Mathematics Elective [10]	3
	17		**17**

JUNIOR YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Teaching in Middle Years	3	Teach Except Students	3
Educational Psychology	3	School and Society	3
Intro Teach Div Pop	3	Orient to Math & Science Ed	0
Found of Adv Math	3	History/Phil of Sci Elect [2]	3
Literature Elective [1,6]	3	College Geometry	3
Instr Mat in Science **OR**		Methods of Teach Science I	3
Teach Math w Microcomputers	3	Emergency Medicine **OR**	
	18	Personal Health	2
			17

SENIOR YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Methods of Teach Math [3,8]	3	Middle Years Reading	3
Student Teach in Math	4	Social Science Elective [1,6,7]	3
Teach Math Middle Years [3,8]	3	Free Elective	1
Student Teach in Science	4	Psych of Adolescent Development	3
	14		**13**

Minimum Credit Hours Required for Graduation 128 [4,9]

APPENDIX 15

Science Education: Biology Specialization

Grades 9-12 Licensure (13SED038Z)

FRESHMAN YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Introductory Biology I	4	Introductory Biology II	4
Chem - A Molecular Science	3	Chem- A Quantitative Science	3
General Chemistry Lab	1	Quantitative Chemistry Lab	1
Elements of Calculus **OR**		Calc Life & Mgmt Science B **OR**	
Calc Life & Mgmt Science A	3	Intro to Statistics	3
Acad. Writing & Research	4	History Elective [1,6]	3
Orientation to Math & Sci Ed	0	Literature Elective [1,6]	3
Health & Physical Fitness	1		**17**
	16		

SOPHOMORE YEAR

Fall Semester	Credits	Spring Semester	Credits
Animal Diversity	4	Genetics in Human Affairs **OR**	
Intro Org Chemistry **OR**		Principles of Genetics	3-4
Organic Chem I	4	Intro to Teach Ma & Sci	3
Public Speaking	3	Intro to Teach Ma & Sci Lab	0
College Physics I	4	College Physics II	4
Physical Education Elective	1	Social Science Elective [1,6,7]	3
	16		**16-17**

JUNIOR YEAR

Fall Semester	Credits	Spring Semester	Credits
Intro to Ecology	3	Plant Physiology **OR**	
Ecology Laboratory	1	Cell Biology **OR**	
Geology: Physical	3	Principles of Physiology	3-4
Geology I Laboratory	1	School and Society	3
Instr Materials in Science	3	Methods of Teach Science I	3
Educational Psychology	3	Teach Except Students	3
Prin. Teach Div. Pop.	3	Hum/Social Science Elective [1,6,7]	3
	17	Orient to Math & Sci Ed	0
			15-16

SENIOR YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Methods of Teach Science II [3,8]	3	Principles of Biochem **OR**	
Student Teach in Science [3]	8	Gen Microbiology Lab	4
Sr Sem in Math & Sci Ed [3]	2	Psych of Adol Develop	3
	13	Earth Science Elective	3
		Phil/Rel/Arts Elective [5,6]	3
		Free electives	5
			18

Minimum Credit Hours Required for Graduation 128

APPENDIX 16

Science Education: Chemistry Specialization

Grades 9-12 Licensure (13SED038C)

FRESHMAN YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
A Molecular Science	3	Chem- A Quantitative Science	3
General Chemistry Lab	1	Quantitative Chemistry Lab	1
Calculus I	4	Calculus II	4
Acad. Writing & Research	4	Geology; Physical	3
History Elective [1,6]	3	Geology I Laboratory	1
Health & Physical Fitness	1	Social Science Elective [1,6,7]	3
Orientation to Math & Sci Ed	0	Physical Education Elective	1
	16		**16**

SOPHOMORE YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Physics for Engrs and Sci I	4	Physics for Engrs & Sci II	4
History/Phil of Sci Elect [2]	3	Intro to Teach Ma & Sci	3
Organic Chem I	4	Intro to Teach Ma & Sci Lab	0
Public Speaking	3	Organic Chem II	4
Literature Elective [1,6]	3	Earth Science Elective	3-4
	17	Hum/Social Science Elective [1,6,7]	3
			17-18

JUNIOR YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Intro Phys Chem	4	Quantitative Analysis	3
System Inorg Chem I	3	Educational Psychology	3
Intro Biology I	4	Intro Biology II	4
Prin Teach Div Pop	3	School and Society	3
Instr Materials in Science	3	Methods of Teach Science I	3
	17	Orient to Math & Sci Ed	0
			16

SENIOR YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Methods of Teach Science II [3,8]	3	Principles of Biochem	4
Student Teach in Science [3]	8	Chemistry Elective [10]	3
Sr Sem in Math & Sci Ed [3]	2	Psych of Adol Develop	3
	13	Teach Except Students	3
		Phil/Rel/Arts Elective [5,6]	3
			16

Minimum Credit Hours Required for Graduation 128 [4,9]

APPENDIX 17

Science Education: Earth Science Specialization

Grades 9-12 Licensure (13SED038E)

FRESHMAN YEAR

Fall Semester	**Credits**	**Spring Semester**	**Credits**
Geology: Physical	3	Geology II: Historical	3
Geology I Laboratory	1	Geology II Laboratory	1
Chem - A Molecular Science	3	Chem- A Quantitative Science	3
General Chemistry Lab	1	Quantitative Chemistry Lab	1
Calc Life & Manage Sci A **OR**		Calc Life & Manage Sci B **OR**	
Calculus I	3-4	Calculus II	3-4
Acad. Writing & Research	4	History Elective [1,6]	3
Orientation to Math & Sci Ed	0	Health & Physical Fitness	1
	15-16		**15-16**

SOPHOMORE YEAR

Fall Semester	Credits	Spring Semester	Credits
lntro Weather & Climate		Intro to Teach Ma & Sci	3
OR The Global Atmosphere	3	Intro to Teach Ma & Sci Lab	0
College Physics I	4	College Physics II	4
Intro Biology I	4	Intro Biology II	4
Prin Teach Div Pop	3	Intro to Oceanography	3
Public Speaking	3	Literature Elective [1,6]	3
	17		**17**

JUNIOR YEAR

Fall Semester	Credits	Spring Semester	Credits
Earth Science elective [10]	3	Intro to Geologic Materials	4
Instr Materials in Science	3	Stellar & Galactic Astron **OR**	
School and Society	3	Solar System Astronomy	3
Educational Psychology	3	Teach Except Students	3
Hum/Social Science Elective [1,6,7]	3	Methods of Teach Science I	3
Physical Education Elective	1	Social Science Elective [1,6,7]	3
Free Electives	0-3	Orient to Math & Sci Ed	0
	16-19		**16**

SENIOR YEAR

Fall Semester	Credits	Spring Semester	Credits
Methods of Teach Science II [3,8]	3	Structural Geology	4
Student Teach in Science [3]	8	Earth Science Elective[10]	3
Sr Sem in Math & Sci Ed [3]	2	Psych of Adol Develop	3
	13	History/Phil of Sci Elect [2]	3
		Phil/Rel/Arts Elective [5,6]	3
			16-17

Minimum Credit Hours Required for Graduation 128

APPENDIX 18

Science Education: Physics Specialization
Grades 9-12 Licensure (13SED038P)

FRESHMAN YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
University Physics I **OR**		University Physics II **OR**	
Physics for Engrs and Sci I	4	Physics for Engrs & Sci II	4
Chem - A Molecular Science	3	Chem- A Quantitative Science	3
General Chemistry Lab	1	Quantitative Chemistry Lab	1
Calculus I	4	Calculus II	4
Acad. Writing & Research	4	History Elective [1,6]	3
Orientation to Math & Sci Ed	0	Health & Physical Fitness	1
	16		**16**

SOPHOMORE YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
University Physics III **OR**		Physics Elective	3
Intro to Modem Physics	3-4	App Diff Equations I	3
Intro Biology I	4	Intro Bio II	4
Calculus III	4	Intro to Teach Ma & Sci	3
Public Speaking	3	Intro to Teach Ma & Sci Lab	0
Prin Teach Div Pop	3	Literature Elective [1,6]	3
	17-18		**16**

JUNIOR YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Physics Elect (PY 411 recommended)	3	Physics Elect (PY 328 recom)	3
Physics Elect (PY 414 recommended)	3	Physics Elect (PY 413 recom)	3
Geology: Physical	3	School and Society	3
Geology I Laboratory	1	Teach Except Students	3
Instr Materials in Science	3	Methods of Teach Science I	3
Educational Psychology	3	Social Science Elective [1,6,7]	3
Physical Education Elective	1	Orient to Math & Sci Ed	0
	17		**18**

SENIOR YEAR

Fall Semester	***Credits***	***Spring Semester***	***Credits***
Methods of Teach Science II [3,8]	3	Hum/Social Science Elective [1,6,7]	3
Student Teach in Science [3]	8	Solar System Astronomy	3
Sr Sem in Math & Sci Ed [3]	2	Psych of Adol Develop	3
	13	History/Phil of Sci Elect [2]	3
		Phil/Rel/Arts Elective [5,6]	3
			15

Minimum Credit Hours Required for Graduation 128 [4,9] (Total)

APPENDIX 19

Overview of Project IMPPACT

The study is conducted simultaneously at three different universities: University of Iowa, North Carolina State University, and Syracuse University. The goal of the study is to see how science teacher's beliefs and practices change over time. The project has been presented at several different conferences:

(1) Paper presented at 2008 ASTE International Conference; St. Louis, MO.
(Preczewski, Tillotson, & Young, 2008)

(2) Themed Paper Set presented at 2008 ASTE International Conference; St. Louis, MO.
(Young et al., 2008)

(3) Paper presented at 2007 Annual NE-ASTE Meeting; Amherst, MA.
(Young & Preczewski, 2007)

(4) Paper presented at 2007 Annual NE-ASTE Meeting; Amherst, MA.
(Preczewski & Young, 2007)

(5) Poster presented at 2007 TPC PI Conference; Reston, VA.
(Tillotson & Young, 2007a)

(6) Paper presented at 2007 ESERA Conference; Malmo, Sweden.
(Tillotson & Young, 2007b)

(7) Paper presented at NARST Annual Meeting 2007; New Orleans, LA
(Tillotson, Young, Luft et al., 2007)

(8) Poster presented at Building a Scientifically Literate Population and Workforce for the 21st Century Conference; Uniondale, N.Y.
(Young & Tillotson, 2007).

(9) Paper presented at 2007 ASTE International Conference; Clearwater Beach, FL.
(Tillotson, Young, Yager et al., 2007)

APPENDIX 19 (cont.)

(10) Paper presented at 2006 Annual NE-ASTE Meeting; Amherst, MA.
(Young & Fidler, 2006)

(11) Paper presented at 2006 ASTE International Conference; Portland, OR.
(Tillotson & Young, 2006b)

(12) Poster presented at 2006 TPC PI Conference; Reston, VA.
(Tillotson & Young, 2006a)

(13) Poster presented at 4th Annual Hawaii International Conference on Education; Honolulu, HI.
(Tillotson & Young, 2006c)

(14) Paper presented at 2005 Annual NE-ASTE Meeting; Amherst, MA
(Tillotson & Young, 2005)

A paper detailing the project is due out later this year (2009). This will be the central article of the project and all future papers related to the project will reference back to this article. This will help authors working on the project avoid having to try and describe a very complicated study in each and every project related paper. This will also benefit the reader by referring them to a detail description of the project if they are unfamiliar or allowing those readers who are familiar with the project not labor through reading about a description of the project.

Instruments

A variety of instruments will be employed to collect data relevant to the research questions. Each of these will be reviewed and the actual instrument will be found in the appendices.

APPENDIX 19 (cont.)

Overview

Teacher Measures

- Introductory Interview – Appendix 1
- Preservice Program Interview – Appendix 2
- Teacher Beliefs Interview –Appendix 3
- Teacher Nature of Science Interview – Appendix 4
- Reformed Teaching Observation Protocol – Appendix 5
- National Survey of Teacher Education Program Graduates – Appendix 6
- Beliefs about Reformed Science Teaching and Learning – Appendix 7
- Survey of Enacted Curriculum – Appendix 8

Student Measures

- Student Attitudes about Science Teaching Questionnaire – Appendix 9
- Iowa Test of Educational Development –Proprietary

Faculty Measures

- Preservice Program Interview Science Faculty– Appendix 10
- Preservice Program Interview Science Education Faculty – Appendix 11
- Reformed Teaching Observation Protocol – Appendix 5

Quantitative Instruments

The instruments for project IMPPACT were selected based on their abilities to measure those qualities of exemplary teaching described in the NSES (National Committee on Science Education Standards and Assessment, 1996).

The National Survey of Teacher Education Program Graduates (NSTEPG) (Loadman, Freeman, & Brookhart, 1999). This survey instrument measures subjects' beliefs and self-reported classroom teaching practices as they relate to domain-specific

elements of their preservice preparation program. This survey was repeated each year to assess changes over time.

Interview Maps (IM) (Luft, Roehrig, & Patterson, 2002). Each year, the teachers in this project are interviewed to examine changes in their teaching beliefs regarding effective science instruction. The interview questions on this instrument reveal beliefs that are traditional, instructive, transitional, responsive, and reform-oriented. The interview maps will be scaled to show movement in the direction of either teacher or student-centered beliefs.

Reformed Teaching Observational Protocol (RTOP) (Pilburn et al., 2000*).* During each year data collection, the participating science teachers are contacted at random twice during the academic year and asked to videotape three consecutive days of lessons in the same class and to submit copies of all lesson plans, curriculum materials, and assessment tools used during those three lessons to the research assistants. In addition, samples of student work will also be submitted along with the materials from those classes. These videotapes will be evaluated using the RTOP instrument and the results will again be scaled to show movement in the direction of either teacher or student centered beliefs and practices. When the teacher is located near campus, actual classroom observations by a doctoral associate will be substituted for videotaping.

APPENDIX 19 (cont.)

Achievement Exam Scores for Middle and Secondary Science Students- pre and post assessments of 7-12 grade science achievement will be measured using available standardized exam results and samples of student work collected throughout the academic year. This test was selected to be the Iowa Test of Educational Development (ITED).

Views on the Nature of Science-Version C (VNOS-C) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). All participants in the study will complete the VNOS-C instrument during the first year of the project and then be interviewed concerning how they would modify their responses in each subsequent year of the study. The instrument will be scaled to reflect the participant's range of knowledge concerning views on science.

Science Teachers' Transcripts and Teacher Certification Exam Scores- These documents, along with other demographic information that will be collected on each study participant, will be used to determine knowledge attainment in science content and pedagogy throughout the preservice program.

APPENDIX 19 (cont.)

Qualitative Instruments

Preservice Program Interview (Salish, 1997). This comprehensive interview guide has versions for science content faculty, science education faculty and preservice science teachers to complete gathering information of the specific impact of program interventions on secondary science teachers' development. It will be administered annually to collect in-depth information about changes in the teachers' beliefs and. practices as they gain experience in the classroom

Classroom Observation Field Notes- Research assistants will visit the classrooms of teacher's located within a reasonable distance to campus and collect detailed observation notes on the practices exhibited by the teacher s participating in the study and the learning activities of their students during these lessons.

Teachers' Pedagogical Philosophy Interview (TPPI) (Richardson & Simmons, 1994) This comprehensive interview protocol asks participants' to describe their evolving beliefs about effective science instruction in a number of important categories related to instructional methods, curriculum decisions, assessment techniques, technology integration and diversity/inclusion issues. The interview also asks specific questions related to the role of preservice program experiences in influencing the pedagogical decisions that the teacher makes. The interview will be repeated annually during the spring semester to chart yearly changes.

APPENDIX 19 (cont.)

Program Descriptions- Both the electronic and print versions any of preservice program documents and in-service professional development program materials that are available will be examined qualitatively to determine the extent to which they describe the intended impact of these experiences on science teacher learning.

Time Table of Instrument Administration

In addition to numerous instruments being used in Project IMPPACT, the time table for administering these instruments was complex. As the reader will see in chapter 3, the project was fluid in it execution. That is to say that not all instruments were administered on the time table proposed to NSF. Some instruments were not administered and some items like the "Science Teachers' Transcripts and Teacher Certification Exam Scores" still have yet to be acquired. In addition, another interview titled "Reflections On Preservice Program Experiences" (ROPPE) is under development and is scheduled to be administered next semester. So even this most current table is not the final version.

APPENDIX 19 (cont.)

Project IMPPACT Administration of Instruments						
Instrument	Fall 2006	Spring 2007	Fall 2007	Spring 2008	Fall 2008	Spring 2009
Introductory Interview	I,II, III, IV					
Preservice Program Interview	III, IV		II	III, IV	I, II	III, IV
Teacher Beliefs Interview	I,II, III, IV		I,II, III, IV		I,II, III, IV	
Teacher Nature of Science Interview	I,II, III, IV		I,II, III, IV		I,II, III, IV	
Reformed Teaching Observation Protocol	I,II, III, IV	III, IV	I,II, III, IV	II, III, IV	I,II, III, IV	I,II, III, IV
National Survey of Teacher Education Program Graduates		III, IV		II, III, IV		I,II, III, IV
Beliefs about Reformed Science Teaching and Learning		III, IV		II, III, IV		I,II, III, IV
Survey of Enacted Curriculum		III, IV		II, III, IV		I,II, III, IV
Student Attitudes about Science Teaching Questionnaire			S	S	S	
Iowa Test of Educational Development			S	S	S	
Preservice Program Interview Science Faculty	F	F	F	F		
Preservice Program Interview Science Education Faculty	F	F	F	F		
Reformed Teaching Observation Protocol (faculty)	F	F	F	F		
I = Cohort One II = Cohort Two III = Cohort Three IV – Cohort Four F = Faculty S = Students						

APPENDIX 20

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Investigating the Meaningfulness of Pre-service Programs Across the Continuum of Teaching (IMPPACT) in Science Education

Principal Investigator: Dr. John Penick

We are asking you to participate in research study in order to improve pre-service teacher preparation.

INFORMATION
If you agree to participate in this study, you will be asked to complete survey(s). In addition, you may be observed teaching and interviewed while being digitally recorded. Some participants may be asked to provide samples of student work products.

RISKS
The risks to subjects in this research study are minimal and include those typical of social science research. Participants may experience inconvenience, discomfort, or annoyance at being audio and/or videotaped as part of the data collection process. Some participants may be inconvenienced by the time necessary to complete the surveys and interview sessions or be uncomfortable with someone observing their teaching practices.

BENEFITS
The subjects in this research study will likely benefit from being asked to reflect on their beliefs about effective teaching and from knowing that they are playing a role in helping to improve the preparation of future science teachers. Student participants may feel good about helping to prepare better science teachers.

CONFIDENTIALITY
The information in this study records will be kept strictly confidential. Data will be stored securely in restricted access servers at the Friday Institute. No reference will be made in oral or written reports which could link you to the study.

CONTACT
If you have questions at any time about the study or the procedures, you may contact the researcher, Dr. John Penick, at the Department of Mathematics, Science & Technology Education, North Carolina State University, Box 7801, Raleigh, NC 277695-7801 or (919) 515-6900 or John_Penick@ncsu.edu. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact
Dr. David Kaber, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee,, Box 7514, NCSU Camputs (919/515-3086) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148).

PARTICIPATION
Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

CONSENT
"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study wit the understanding that I may withdraw at any time."

Subject's signature_____ **Date**_____

Investigator's signature_____ **Date**_____

APPENDIX 21

PROJECT IMPPACT INFORMATION FORM

Name _____ **Code**_____
(Office use only)

Address_____

_____

Phone (H)_____ (Other)_____

e-mail _____

In the 2006-2007 academic year, how would you describe your current position in education?

_____ 2nd/3rd year preservice teacher (E)

_____ 4th/5th year preservice teacher (C)

_____ 1st/2nd year teacher (P)

_____ 3rd/4th year teacher (PI)

What is the highest degree or highest level of education you hope to attain?

1. BS degree
2. master's degree
3. specialist's degree/certification of advanced study
4. Ed.D., Ph.D., or other advanced degree

What is your ethnic background?

1. American Indian or Alaskan
2. Asian or Pacific Islander
3. Black, non-Hispanic
4. Hispanic
5. White, non-Hispanic
6. Other

How would you describe yourself?

1. Part-time student
2. Full-time student
3. Day to day substitute teacher
4. Part-time teacher
5. Full-time teacher
6. Other

APPENDIX 22



Contact Information Update Sheet

Participant's Name: _____

1. Have you completed your preservice program at NC State? If so, congratulations! Yes No.

I expect to complete it _____.

2. At what permanent address and phone number may we contact you? If this is the home of friends or family, please let us know that, too.

3. What is your permanent e-mail address?

4. Have you accepted a teaching job yet? If so, please tell us the school, district and subject(s) you'll teach. If not, please remember that you're not alone. Many of your classmates are still looking, too.

5. Do you have any reflections you wish to share about your preservice program at NC State?
   Yes—I've enclosed them on a separate sheet, or on the back of this sheet.
   No.

Additional Information Needed:

APPENDIX 23

General Studies

Public Speaking - Research skills, topic selection, speech organization, skills in speech delivery. Listening for analysis and evaluation of in-class speech presentation.

Educational Psychology - Students will explore how biological, cognitive, and social/emotional development affects children's learning and behavior. The course will focus on applying important theories and current findings in development to issues in education such as lesson planning, curriculum design, behavior management, motivation, an appropriate assessment. Students will also apply knowledge of development to issues such as creating actively engaging individuated experiences to deal with gifted students, students with diverse ethnic or cultural backgrounds, and students with exceptionalities or disabilities.

School and Society - The interrelationship between the school and other institutions, values, and patterns of thought in American society.

Teaching Exceptional Students - Provides classroom teachers in all disciplines and grade levels with a knowledge of various handicapping conditions, as well as with techniques to assist exceptional students within the mainstreamed classroom. Required for MSL majors.

Psychology of Adolescent Development - Theories, principles, and issues of human psychological development emphasizing adolescence. Cognitive, social, and physical changes; their interaction. Implications for teaching and parenting adolescents.

Math and Science Education

Orientation to Math and Science Education - Overview of departmental expectations and procedures and introduction to practical aspects of academic life. Opportunity for interaction of students with advisors and with other undergraduates who are nearing completion of programs. Open only to students in Math and Science Education

Introduction to Teaching Math and Science - Introduces prospective teachers to the teaching of mathematics and science in the middle school and high school. As an important part of the course, students serve as teacher assistants to a classroom teacher. Ideas and questions arising from this experience provide an integral part of the classroom instruction on campus.

Introduction to Teaching Math and Science Lab – No catalog description

Instructional Materials in Science - Development and selection of teaching materials that reflect concepts of content and emphasis in middle and secondary school science. Experimental and laboratory approaches, including use of microcomputer and video technologies.2 lecture hours and 6 lab hours per week for 7 weeks

Methods of Teaching Science I - Classroom, laboratory, and internship experiences for pre-service teachers to effectively prepare, plan and assess learning environments in the middle and secondary science classroom and instructional laboratory. Emphasis placed on knowledge, skills, and dispositions for inquire-based learning environments.

APPENDIX 23 (cont.)

Methods of Teaching Science II - Goals, methods, curricula, and evaluation practices in teaching the physical and biological sciences at the middle and secondary school levels. Taught during the first seven weeks of the semester.

Student Teaching in Science - Supervised classroom experience in developing the skills and techniques for teaching science in a selected middle or secondary school for 10 weeks.

Senior Semester in Science in Math Education - In-depth investigation of one or more teaching areas in mathematics or science education.

Science Content

Molecular Chemistry - A fundamental study of molecular bonding, structure, and reactivity. Principles of atomic structure, ionic and covalent bonding, reaction energetics, intermolecular forces, precipitation reactions, acid/base reactions, oxidation/reduction processes, and introductions to organic and inorganic chemistry.

Molecular Chemistry Lab - Laboratory experience to accompany CH 101. Introduction to basic laboratory equipment and skills.

A Quantitative Science - Detailed quantitative aspects of solutions, solution stoichiometry, thermodynamics, chemical equilibrium, acid-base equilibria, solubility equilibria, electrochemistry, chemical kinetics, and nuclear chemistry.

A Quantitative Science Lab - Laboratory experience to complement CH 201. Experimental exploration of thermodynamic, kinetic, and electrochemical behavior.

Introduction to Biology I - Emphasis on interactions of organisms with their environments, evolutionary change and role of natural selection in the evolution of life forms, biological diversity in the context of form and function of organisms, and on critical thinking, problem solving, and effective communication.

Introduction to Biology II - Basic concepts and principles of molecular, cellular, and developmental biology. Emphasis will be on the physical basis of life, the cell as the fundamental unit of life, the mechanisms involved in the development of multicellular organisms and on critical thinking, problem solving, experimental design, and effective communication.

Geology Physical - Systematic consideration of processes operating on and below the earth's surface and the resulting features of landscape, earth structures, and earth materials. Occurrences and utilization of the earth's physical resources.

Geology Lab - Scientific methodology applied to the study of common rock-forming minerals, common rocks, topographic maps, geologic structures and geological maps. Field trips.

APPENDIX 24

RTOP Spreadsheets

	FALL 2005						SPRING 2007						FALL 2007						SPRING 2009						FALL 2008					
Pseudonym	Q1-5 sum	Q6-10 sum	Q11-15 sum	Q16-20 sum	Q21-25 sum	Total	Q1-5 sum	Q6-10 sum	Q11-15 sum	Q16-20 sum	Q21-25 sum	Total	Q1-5 sum	Q6-10 sum	Q11-15 sum	Q16-20 sum	Q21-25 sum	Total	Q1-5 sum	Q6-10 sum	Q11-15 sum	Q16-20 sum	Q21-25 sum	Total	Q1-5 sum	Q6-10 sum	Q11-15 sum	Q16-20 sum	Q21-25 sum	Total
Kerry	13	15	14	14	13	69							4	12	6	6	8	36							6	14	4	13	14	51
Bella	10	16	12	9	13	60							0	7	0	3	6	16							2	12	0	5	5	24
Laurel	13	15	14	14	13	69							10	14	4	7	6	41							2	11	3	4	4	23
Averages	12	15	12	12	13	66							5	11	3	5	7	31							3	12	2	7	8	33
Mary Kate													2	9	0	2	2	15	1	10	0	5	6	22	1	12	0	3	5	21
Marcella	6	12	7	10	13	48							2	13	1	3	6	25	7	14	8	11	13	53	3	13	1	7	9	33
Rob	10	16	14	11	19	70							5	8	1	3	8	25	8	6	2	5	14	35	9	11	3	12	10	45
Shannon													6	20	6	8	9	49	6	16	1	7	7	37	3	15	0	3	6	27
Averages	8	14	10	10	16	59							4	13	2	4	6	29	6	12	3	7	10	38	4	13	1	8	8	35
Seth	5	13	4	7	5	34	1	13	3	8	8	33	1	12	2	5	3	23	1	10	0	6	6	23	6	18	7	10	13	54
Ronald	4	13	3	5	8	33	3	9	4	5	6	27	7	14	7	10	10	48	1	15	0	4	5	25	2	12	4	9	11	38
Nadia	8	15	5	10	10	48	8	15	5	10	10	40	8	16	6	11	8	49	1	13	0	3	3	20	1	12	3	6	4	26
Average	7	12	4	8	9	40	4	13	4	8	8	33	6	14	4	8	9	36	2	12	0	5	6	24	3	13	4	7	8	35
Mara	2	16	2	4	4	28	3	13	1	3	5	25	3	15	4	10	8	40	4	13	2	4	6	29	4	11	5	10	11	41
Peggy	3	14	1	6	6	30	1	10	1	3	4	19	4	14	3	6	8	35	1	13	0	1	6	21	3	15	5	9	13	45
Rose-Abby	9	14	10	9	12	54	15	20	9	14	13	71	1	12	0	8	8	29	4	11	1	8	8	32						
Average	5	15	4	7	7	37	6	14	4	7	7	38	3	14	7	8	8	35	3	12	1	4	7	27	4	13	5	10	12	43

Pre-service

Student Teaching

First Year

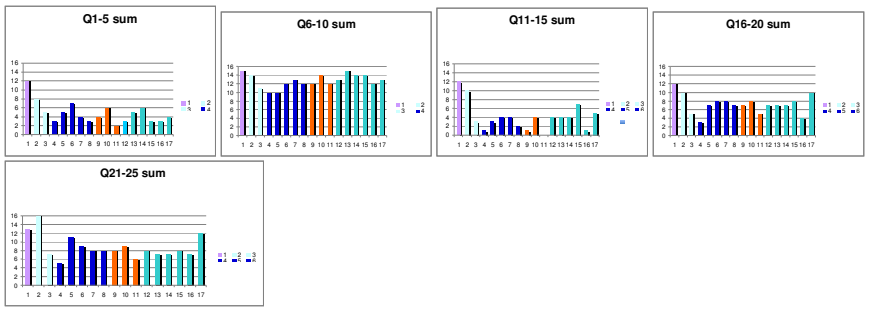
Second Year

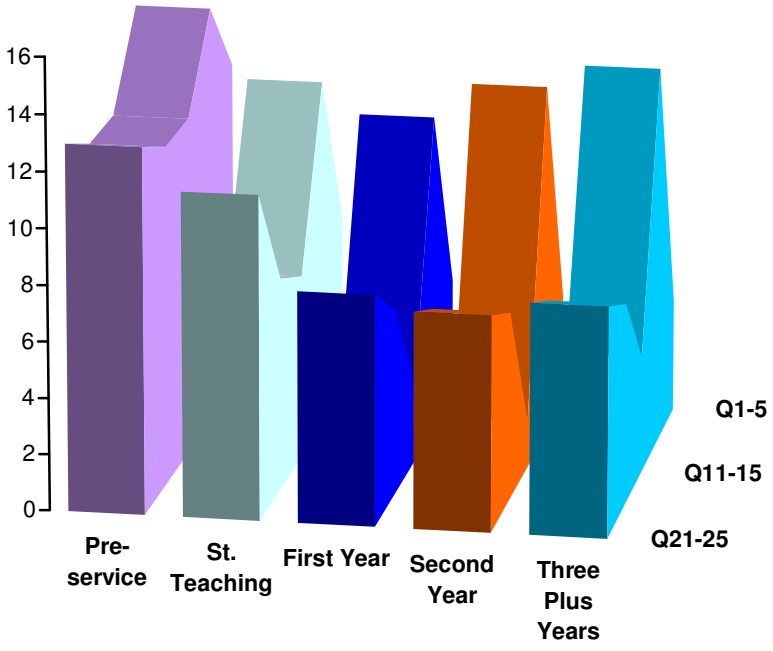
3+

Professional Developme	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Average
Preservice	69	60	69															66
Student Teaching	36	16	41	48	70													42
First Year Teaching	51	24	23	15	25	25	49	22	53	35	37	34	33	48	33	27	40	34
Second Year Teaching	21	33	45	27	23	48	49	23	25	20								29
Three + Years Teaching	54	38	26	28	30	54	25	19	71	40	35	29	29	21	32	41	45	36

APPENDIX 25

Charts of RTOP Sub-scale sums from Table 4.14





APPENDIX 26

Participant Quotes Related to Belief in using Inquiry-based Teaching Practices

Participant	Quotes
Kerry	*How do students learn best?* I think, just to get students sort of **interactive in their learning** is probably the best thing you can do. I like **a lot of lab stuff. Not so much the lecture**. Just getting them to experience the stuff, and trying it out. It makes a lot more impact if **they figure it out instead of me just telling that it works**. Application. I mean, it makes students kind of, I guess**, discover things for themselves, and then be able to apply it**,
Bella	Like I said before. More activities. **More hands-on activities**. We'll see how that goes when I have to teach Academic Earth Science. Do more cooperative learning. I **put students in groups**. And, what else do I do? Let's see. I ask a **lot of questions and allow students to talk amongst themselves—sometimes too much. [They learn best] by helping each other.**
Laurel	I don't like the idea of being lectured at for the entire lesson, and while I know that sometimes it's going to be unavoidable--there's just a lot of information to cover and not necessarily an activity to with it, but I like the idea of maybe engaging the students right away. **Maybe starting with a demo or a little lab or little activity.** I guess it depends on what kind of scheduling you're on; if you're on blocked scheduling, obviously you have more time to start something like that. Then, lecture—I think it's good to **let them explore**. And then have time for questions. Well, I'd like to incorporate **many inquiry-based activities and group learning**. I know **kids would rather be touching things and doing things** [miming this process]. And, physics lends itself to those activities, so. I think they're harder to plan. It's easier to figure out what you want to tell them, than to figure out what they can learn themselves. But, I think that to increase student learning and to, just increase their participation and engagement in class, which would, therefore, increase the learning. I want them to be **active and involved in their learning process**. I think of science as a **super-open-ended Inquiry subject**. I need to teach latitude and longitude today, but I could teach it through this activity, or it just seems that it's very, very open-ended. Which is what I love about science [She places her hand over her heart.] but, it's what makes it difficult for me to teach it, as well.

APPENDIX 26 (cont.)

Participant Quotes Related to Belief in using Inquiry-based Teaching Practices

Misty Kate	I like to do a lot of labs. **A lot of labs**. They hate it, at first. But, afterwards, they think its fun. And, evidently it works. I try to make it very, **very hands on**, very, very visual. **Letting them figure things out for themselves** and then, maybe helping them out when they can't get it. I think science is, you're presented with some problem, some observation, something to figure out [and] through whatever method you can, whatever test you have for it. And I force them to do a lot of that. Like, just thinking, figuring things out on their own.
Marcella	I kind of see myself as a guide, rather than as an authoritarian. I don't want them to think that I'm a dictator or anything like that. I think that, in a lot of ways, students learn the most **when they are responsible for teaching their classmates.** So, any time that I can get them to share information with each other [nodding] that probably works the best. I think science skills will probably serve them well, later in life. **Knowing how to analyze, and how to collect data, and how to think critically about something, how to do the explanation by yourself,** basically. Something that I try to impart on all of my students. I try to **let my children learn things by discovery** as much as possible. Or, **by inquiry**. I try to let them ask questions and **be scientists**. 'Cause, **more than just learning science, they get to be a part of science. They get to find things out the way that scientists find things out.**

APPENDIX 26 (cont.)

Participant Quotes Related to Belief in using Inquiry-based Teaching Practices

Rob	I'd like to have **a mentor relationship with my students**. I'd like to be able to inspire them. How do they learn best? In a variety of ways. Different kids, different styles. Building models, for some. I think it's easier to say how they don't learn. So. [get] them **talking to each other**. I know that they're not learning [when their chattering off topic]. **Science would be a way of looking at the world with kind of a curiosity as to what is occurring.** I can bond with this kid as an authority figure. I can spend time catching them doing things right. Acknowledge them for doing things right. Give them the public approval. We're not doing the worksheets. They're a waste of time! I can lecture them daily [waving his hand in the air, then bringing his finger to his temple] but they won't get anything out of it, I don't think. And, I want them [sweeping both hands laterally] to engage and [spreading his arms, palms up] run with the activities. So, my job is to try and figure out how to **engage them and motivate them**. [His expression brightens as he refers to the group he just taught in the activity observed by the interviewer.] Last group? Pretty easy to motivate! Can we really do science in ninth grade biology?" We talk about science, just some concepts that they have to learn. Yes. The third quarter projects, **I would like them to do science** [miming the process], make some observations, learn something, do the background research, the entire shebang. This year, we're boldly going into paper mâché and making large cells [extending his arms to form a large horizontal circle]. We're going to make 3-D cells [raising his arms to form a large vertical circle]. We're gonna hang nucleuses and their ribosomes and their mitochondria and all these things in there [miming each structure]. But, the point is, **I'll give them all these things and they've got to get 'em in there gotta make your mitochondria. What does it do?**

APPENDIX 26 (cont.)

Participant Quotes Related to Belief in using Inquiry-based Teaching Practices

Shannon	As far as science is concerned, my high school anatomy and AP biology was probably my best experience. Because, we did **a lot of hands on**. It was very . . . It wasn't just copy down notes every day or fill out a lot of definitions every day. **We used what we were learning**. And, I think that's how a lot of kids learn better to use what you are talking about. You know? As a student, you don't want to hear somebody up there drone to you all period. You want it to be **fun, and interactive**. And, I think that's kind of what led me [gesturing toward herself] to be the kind of teacher that I am now. I am a big proponent for **inquiry learning**, and, you know, **hands-on, lab-based, instruction**. Because, I think kids do get more out of that, just, than taking notes and making pictures. They retain more. And, I think it's more meaningful for them. With anatomy, you know, kids really like this class. Because, we're talking about their bodies. We're talking about things that they can actually see going on and that they feel. And so, **when you make it personal for somebody, it makes it more interesting. It makes it more fun. [She smiles and nods.] And, more meaningful.** I want to be a facilitator, and I want to be a source of information. I expect them to **think critically**. And, I expect them to take what little bit I tell them [using her fingers to indicate a small amount] and take it beyond [extending her arm broadly]. I would hate to stand up there and just talk, and talk and talk! And, not have them talk back to me. You know, I want some response, and have them raise their hands and ask questions. I think **they do learn best by doing.** I think they do learn a lot by doing the activities by **acting out the processes [and] being a part of it.** I try to stress to my students that all of theses sciences are very much so all **interconnected**! They teach them as separate entities, but they all rely on one another to work. I have a Smart Board, a brand new Smart Board. So I use a lot of technology. And, **I use a lot of hands-on**. And, you know, a lot of things in my class are—I think—they're just interesting. That gets them more involved and wanting to know stuff. , I enjoy teaching, and I want them to come in here and enjoy learning.

APPENDIX 26 (cont.)

Participant Quotes Related to Belief in using Inquiry-based Teaching Practices

Seth	Most of the students learn best by **actually doing it . . . whether it be by them working a problem or by them doing a lab activity.** If I just stand up in front of the class and work it through for them . . . all I do is three or five problems and don't give them a chance to try any . . . they don't learn as well as when they have the chance to actually try it on their own and see whether they can do it or not and then ask questions. You can talk about all sorts of scientific concepts. But, until you see something for yourself, then what you're doing on paper doesn't really make sense [shaking his head]. And, I've even tried doing it with computer simulations. And, computer simulations don't really help you to understand it. And, you don't gain the necessary skills that you need, either. If you just do your labs all on a computer, it doesn't let you make mistakes. Computer software never lets you knock over a bottle of hydrochloric acid, or drop a beaker and have it break. It just doesn't break on a computer [smiling]. So, **they need the actually experience of seeing how tough some of this stuff was and, so they can see how actually tough the scientific process actually works.**
Ronald	I think when you provide them with a variety – like for example if we take speed and velocity, and we're talking about that, I think if you provide them with multiple ways for them to get the information – like we'll do a lab, we'll do an activity, we'll do notes, we'll do stuff online. How do you know when learning is occurring in your classroom? Students are engaged. And, I know they're engaged when they're asking questions, interacting with me, interacting with each other and completing the tasks that I ask them to complete.

APPENDIX 26 (cont.)

Quotes on Barriers to Inquiry Created by Limitations of Students or Teachers

Nadia	It's one of those that we're…[This state] is moving to **the inquiry-based which I think is wonderful** and I think it's great but it's just one of those – it's really hard if students aren't used to it to sit there and go here's your material. They don't want to listen to me for an hour and a half. I don't want to stand up there and talk to them for an hour and a half. Not because I don't want to speak to them, but because I get tired of standing up there for an hour and a half. They're given an introduction. They're given a question. And, in one it was, "Here are your materials. Figure out," you know, "Make your question based off of," I think they had it was, "10 or 11 chemicals." And, the question they asked was, "**How do you test the reactivity?"** So, they had **to try to figure out a way to set up an experiment**, use all the materials and try to figure out how to notice which substances are the most reactive. *What is your role as a teacher?* Facilitator. I'm slowly, slowly trying to get to that point where it's more **inquiry-based** where it's they find the solution or they model it after something else just to see if they can find a new discovery or, just to verify what's there. I'm getting better at finding ways of answering their questions without giving them the answer. And so, I just need to find more ways of doing that with **inquiry-based labs**. Because, I really think that would help their depth of understanding, if they physically put something together and they go through and **even if they fail.**
Mara	**Any type of lab or manipulative where they're using their hands**, to me, is an indication that they're learning the material. When I see them asking me questions. When I see them, **helping each other**. When I see them [waving her hands] doing the task that I've asked them to do, correctly. Then, I know that they're learning. In order to make it, not just biology, but in general, This is the process of science, and, how science relates to everyday things [waving her hand to indicate general applications]. If I make an observation and that leads me to asking a question, I'm going through the process of answering the question . . . to me, is science. It **[science] encourages the students to think and to look at things from different angles.** Because there's more than one angle to look at everything from a science point-of-view [nodding].
Peggy	I try to do as many labs as I can.

APPENDIX 26 (cont.)

Participant Quotes Related to Belief in using Inquiry-based Teaching Practices

Rose-Abby	"Why?" or **inquiring** about what is happening in a situation . . . if they are able to go through and try. And, this is something that's very hard for me! I love it. I think it's a great way of teaching. But, some students are so geared to a cookbook method, "I need this," or spoon-fed, "I need to know what's happening, what's going on," instead of just getting in there. I have question upon question. In science, it can never end! **People can have questions which have, which provokes, another question to be asked, which provokes another, and [gesturing to indicate and endless stream of questions] and so forth and so on! They learn by participation**. They have got to do something in order for it to stay in their mind. So, **engagement**. Things having them **stay active**. And, they almost, in a sense, kind of decide as to what, how I teach. How things are brought into the lesson. It **makes it more personal for them** when I allow them to set up. *When you think of science, what do you think of?* [smiling] I think of **inquiry**. Trying to figure out why it works the way it does. Or, "Why is it that this is happening?" **Science is based on observation and inquiry**! And, that's what, to me, makes it different. Because, actually all of the other disciplines are mixed into science. It's a founding point for everything else. And, that's what makes it's a good connector. Science is basically, to me it's based on an observation, and from that, an **inquiry**. In order for you to answer that question, you've got to have some sort of experiment. I mean, it doesn't mean that you have to be in the lab with beakers, and equipment, and stuff like that.
Kerry	How we find a way to **apply to understand** I think is a better assessment than filling in multiple choice tests. **Use it.** *How do your students learn best?* **By doing.** I think it's really hard to get away from regurgitation in education. You have to have a lot of imagination and understanding to be able to read a book and have an understanding in your head. But, in science, you don't have to imagine it.
Bella	*How do your students learn best?* I'd like to do more **hands-on things**, rather then just taking notes, doing worksheets. I know kids hate worksheets. I know you can't do those every single day. Just **activities**, I think, with discussion. Asking questions.

APPENDIX 26 (cont.)

Participant Quotes Related to Belief in using Inquiry-based Teaching Practices

Laurel	**(student teaching)** Allow the students to be **actively involved** instead of just sitting and listening. I think the best classroom environments that I've been in have been ones of **mutual respect**, where, like I said with the administration. I think students will **live up to expectations** if you let them know that this is what you expect from them and you see no reason why they can't accomplish this, and just showing support for the students.
Misty Kate	**We do a lot of work in pairs, work in groups, and especially with labs.** Almost everyday, we do some sort of lab, mini-lab, or some sort of **activity**, where they're working with their partners. They know they can ask other students for help. *How do your students learn best?* When I give them a problem, and they're forced to work it out [bring down her hand forcefully]. Like, you have to force them **to think for themselves**.
Marcella	**I really try to foster curiosity in my classroom. Also with labs, I try to not always tell them what's going to happen. I try to leave as much as I can open-ended so they can seek answers themselves. Everyday we do some sort of group activity. One of the ways that they learn best is by teaching each other, because then they are responsible for some information. They're responsible for making sure that they are conveying the correct information.**

APPENDIX 27

Participant Quotes Related to use of inquiry in Their Practice

Rob	I really prefer to keep the class as loose as possible. I want to promote kids going [raises his hand and waves it vigorously], interrupting and asking questions. **I want to promote them talking to each other** [smiles] **about the topic.** And, so I really prefer that loose-knit flow. I tend to really **let my classes struggle with their problems and their solutions**. …**Can I create an environment for them where they can be engaged and curious and play with things and so forth**. They could do a CSI scene. You know, we could even set it up. I take clips out of CSI. You know, here's the CSI mystery. Who did it? Here's the sample from the murder scene. We can do paternity. We can do crime scene analysis. We can do, releasing people from prison. We can do family pedigree DNA analysis [expanding his arms broadly]**. I could eliminate my budget for textbooks. 'Cause, I hate 'em!** [He uses his fingers to count off the problems.] They cost too much. The definitions are horrible. They have all this extraneous information. There's no reason all my kids can't graph out the darn cell cycle. So, I don't need them. We have Madagascar hissing cockroaches [gesturing toward his classroom]. One of my student's dad is a researcher, and he had some. So, he's given to us. And, they're now reproducing, so we've got more. And**, we're gonna become experts on Madagascar hissing cockroaches** [extending his arm, then gesturing throughout the rest of the description] or, some different critters. But, the general gist of what we're going to do third quarter is: on Fridays, which we generally do the odd activities the Science Fridays, the **presentations.** The first Friday in the third quarter, we're gonna dump our animals out on a table. And, the first week, they have to come up with 20 **observations**. Then, the second week, from their 20 observations, they're going to have to come up with some **questions**. From their questions, they're going to need to develop a **hypothesis**. From their hypothesis, they're going to have to **develop an experiment**. And, they're going to have to write up an experimental design, figure out how to **do it ethically**, with the critters that we have. And, at the end of the quarter, they're gonna have to turn in an **independent research** statement, where they made observations, come up with a problem, developed a hypothesis, **figured out their variables, figured out their control groups, did their experiment, collected data, analyses data, supported or defended their hypothosis-es, and write a statement of what's right or wrong with our experimental design and how would we change it in the future**. Doing it, instead of just talking about it.

APPENDIX 27 (cont.)

Participant Quotes Related to use of inquiry in Their Practice

Shannon	Even when I'm lecturing, or just giving direct instruction, I try to make it as **interactive** as possible. You know, we get up, and we act things out. We do things. **I try to make it meaningful for them**. I try to not stay at the front of the classroom [gesturing toward that area and laughing]. I have ordered a clicker [miming the clicking], so that I can move around more. I try to get out from the front, you know, get out in the center aisle. Because, that helps me not only monitor what they're doing [smiles], but you know [shrugs] makes them aware that I'm comin'. **Like I say, we do a lot of labs. We do a lot of activities to try to drive things home. So, you know, I try to change things up**. I try to not be just lecturing 90 minutes. Sometimes we do more **inquiry** stuff and have them looking, and thinking about things, and just answering questions before we even, like, get to the meat of things to **help them be responsible for their own learning**.
Seth	I do a lot of labs. I do at least one lab every week. A lot of time, I'll do two or three. I'll include **demonstrations**. There's time for **independent work, there's time for them to work on problems in groups**, and some other things like that. Very rarely do I tell them to open up their books and work the 10 problems on page whatever [smiling]. 'Cause I don't think that's a very effective [way to learn]. We'll either do some sort of lab activity, or sometimes **we'll do the lab first, before we do the lecture, so that they have to figure it out for themselves.** And then we work problems. And then, by the end of class, they should be able to work the problems on their own. We definitely use all the steps of the scientific method in my class. They have to keep a **lab notebook in everyone of the classes where they have to write down what the problem is, what their hypotheses is, the materials [etc.].** Most of the time, I don't tell the students what the answer is. [He pauses briefly and looks upward.] Actually, I can't think of a situation where I tell the students what's going to happen before they do it. **They have to do the experiment and find out for themselves what's happening.**

APPENDIX 27 (cont.)

It should be noted (once again) that the term "inquiry" does not appear in any of the interview questions posed to the participants. Hence, the idea that the participants were some how "tipped off" that this was an area of interest of the researchers and the participants were some how trying to appease the investigators is disputable. Project IMPPACT's research questions focused on the beliefs and practices of teachers across the continuum of teaching.

Hence, the questions asked during the interviews for the project did not focus on inquiry. In essence, it was a double blind study with respect to inquiry. Both participants and field researchers were unaware that inquiry would become a focus of the study.

These five pages of single spaced quotes were distilled from over 1,000 pages of transcripts. An effort was made to select quotes that demonstrated various elements of inquiry, like: cooperative learning, commitment to laboratory and hands-on activities as evidence for the belief in inquiry-based teaching.

The following six pages contain quotes presenting evidence that teachers believe they are using inquiry in their practice. Some participants are much more expressive about this belief then others. Once again, there are many more quotes that can be presented. But six pages of single space quotes that show a variety of Inquiry elements is evidence enough to reach a conclusion for this research question.

APPENDIX 27 (cont.)

Participant Quotes Related to use of inquiry in Their Practice

Ronald	I tend to try to just make questions for them so that they are – **open-ended questions for them - so that they can do their thing.** I group the students into pods, small groups so that it can build some **cooperative learning** [and] some **social learning** there [bringing his hands toward each other to reflect interaction]. Additionally, I encourage [smiling wryly] less-academically-able students to work with more-academically-able students in the chemistry class, to allow them to talk things over and **work things out**. And, a lot of times, if I'm walking around helping students, I will suggest that they talk to one of the students who maybe know a little bit more, **first, see if they can help one another** first see if they can answer. One, it helps me [laughing slightly] to kind of be able to answer questions for students. But, two, **allows the students to teach each other and learn that way.**
Nadia	They work well together with each other. And so, they know one person's weaknesses, and they help bring that up. And, that person knows the person's weaknesses. We're doing it more off of an **Inquiry-based**. Because, you don't always know the answer to the question that you're asking. And so, **finding different ways to investigate that problem.** And, knowing that fact that you can investigate it completely different [then] that the person next to you and still go toward the same answer. In physics we do a lot more very easily **real world applications**.
Mara	I have them drawing and creating. So [raising her shoulders] . . . If it comes from them, it tells me what they know, and I feel like they're learning. When I see students engaged. Sometimes**, I'll have them come up with their own procedure**. Sometimes, I'll have the procedure and they collect data and draw conclusions and make graphs. So . . . It's [scientific method] incorporated with every single lab activity that we do.

APPENDIX 27 (cont.)

Participant Quotes Related to use of inquiry in Their Practice

Peggy	**We make molecules with marshmallows and gum drops** just because I'm not going to give them the sticks and balls because they have mastered the marshmallows and then we make bigger molecules. And then I'll say ok, now take your molecule and we'll start to build a single bond and then we'll do a double bond. Diet coke floats, regular coke sinks. Well what about Pepsi and diet Pepsi? What about mountain dew and diet mountain dew? Well that became this whole project where I just wanted to teach them about density. And it became this battle of the soft drinks. You know they can't bring a pencil but they can bring in 87 different types of soft drinks.
Rose-Abby	My classroom looks kind of chaotic [smiling] 'cause there are lots of things all over the walls. I have some other things that kind of make them question, and make them wonder about the world around us. *Describe the instructional strategies you're using to maximize students' learning.* Oh, sometimes I have something that just lets them question. That's what I like to do. First, we'll have our observation. Then, we'll use **do inquiry** on our question. So, I might bring in something, like maybe an aquarium with, maybe, a Coke, a Diet Coke, and water. "Which one floats or sinks?" Something just to trigger them wanting to know what's going on, and then trying to tie it in to the purpose, or the goal, of the lesson that day.

APPENDIX 28

Quotes on Barriers to Inquiry Created by Limitations of Students or Teachers

Participant	Quote
Laurel	**(First year of teaching)** If I make it through getting them notes during the day, I feel like that's a success. Some of these classes . . . [again, shaking her head disgustedly] . . . I mean, there's no way for me to maximize student learning! I have kids that I didn't talk to all day—that I didn't reach all day—because they . . . [shaking her head]. I mean, I try to talk. I try to teach. **They talk over me**. But, I don't know how to fix it. I've tried. I've asked for help. And, it seems like everybody wants to help, but . . . **It's been very hard to get help in this school** as well. *How about how the students have changed your beliefs and practice?* Well, I'm not sure if it's just this age group that's turned me off, and whether I don't see myself in a high school setting at all or whether I see myself at a smaller high school setting, maybe a more rural high school setting. I think even if I was teaching physics here…I mean, I was a little bit nervous to teach physics at first, thinking that I wanted the support of other teachers, you know, teachers who were teaching the same subject? But now, if I had it to do over again . . . [She nods with certainty] I would have held out and tried to demand a physics job somewhere. Because I think [with] my confidence in that content, I would have been fine by myself. **I just didn't trust myself enough**. And, I ended up making a worse decision.

APPENDIX 28 (cont.)

Quotes on Barriers to Inquiry Created by Limitations of Students or Teachers

Marcella	**(Second year of teaching).** Science is a subject that you could basically teach yourself with a little bit of guidance. Because, it's all about discovery and Inquiry . . . finding things out for yourself. But, I've learned that it has to be more structured, especially at this school, than it does at the ideal classroom in my head. I think this school is different from other schools, in terms of the population that it serves. I've learned that it is o.k. to have a more structured science class, and not to give them so much freedom to think of things on their own. '**Cause, some students don't need the freedom.** They can't think of things on their own. Even if you give them the opportunity to. So, um [shrugging and pausing for a while]. I don't know**. I used to think science was a bit more hands-off for the teacher, and hands-on for the students. And now, I think it's the other way around.** *How do your students learn best?* **My students can't read** [and therefore] don't make very good grades. I can only imagine how hard it is to complete an assignment if you can't read a word [shaking her head sadly]. I really don't know. If I'm gonna be honest, I feel like they learn better from notes and getting the information, and having the information with them, having the reference with them . . . [pausing] than from labs. **Sometimes, I think they have no idea what's going on. They don't want to think about what's going on. They don't want to have to process the information. They just want to receive it. They've never had to think before [shaking her head]. So, they don't know how to think now.** So, it's easier to teach them with notes. I haven't really figured out how they learn better [shaking her head].

APPENDIX 28 (cont.)

Quotes on Barriers to Inquiry Created by Limitations of Students or Teachers

Nadia	**(Fourth year of teaching)** *How is the discipline of science represented in your teaching?* [sighs] Not as well as it should be. "Here's a problem, or here's a past experiment. Verify it. Or, see if you can explore and find a way to answer the question." Um, I'm still very much into the cookbook, um, labs. [smiling] I'm slowly, slowly trying to get to that point where it's more Inquiry-based where it's they find the solution or they model it after something else . . . just to see if they can find a new discovery . . . or, just to verify what's there. But, I haven't found a good way of preparing my students to do it. Because**, they literally freak out! They have no idea of how to do it. I've even found in problems, where I right directions where they should be able to follow it and go through it. And, honestly, I expect them to be able to read it and complete the stuff. They can't** [shaking her head]. Even though they come up to me and ask me a question, and I'll go, "Have you done this, this, and this?" "Well, no." "Well go do it, and then come and ask me." They'll still come up and ask me. **Because, they haven't learned . . . before . . . to think. And just, to think through a process, and take more than two seconds of reading it and saying, "Well, I don't understand it, so you need to explain it to me again."** I've got to find a way where I can keep my sanity. Because, I know I'm going to be asked questions whenever we do that stuff. And, that's fine. I'm getting better at finding ways of answering their questions without giving them the answer. And so, I just need to find more ways of doing that with Inquiry-based labs. Because, I really think that would help their depth of understanding, if they physically put something together and they go through and . . . even if they fail. Because, that's the thing I'm finding with students here. And, I'm guessing it's probably true across the board. They feel like . . . **Especially when it's higher achieving students; usually . . . They think that, if they're ever wrong . . . that it's going to be the worst thing that's ever happened. Even if it doesn't necessarily correlate with a bad grade. They hate being wrong.** This is one of the reasons I had issues with homework. Because, they felt, "Oh, I can't understand this question." So, instead of being wrong, and trying something . . . they don't try at all. And so, that's [the] behavior that I'm trying to discourage. Because, sometimes, they really need to learn to fail before they can succeed. So, that's just behavior that I'm attempting to get through. It's so frustrating because I need to see where they screw up

APPENDIX 28 (cont.)

Quotes on Barriers to Inquiry Created by Limitations of Students or Teachers

Peggy	**(Fifth year of teaching)** My students [claim they] learn best, and they tell me this . . . by me talking to them. They don't learn by notes. **They don't learn by labs**. **They actually told me they don't like labs.** Which—I don't understand. They don't like worksheets. They learn by me talking to them. That's what they told me. *Do they take their own notes?* Some do [nodding]. About a third [of the students] write their own notes. Yeah. They all do the labs because it's not a choice [shaking her head]. I tell them if I'm here and I'm setting up the lab, spend my free time making the solutions and setting everything up . . . that they have no choice [shaking her head]. So, they do the labs**. I don't feel in academic chemistry, that they always understand the lab.** Some do [nodding]. Some of them go through the motions of the lab and have absolutely no idea what we did in the lab. **They don't listen to the prep. They don't listen to why we're doing the lab. They don't read the labs.** But, it gets them out of their seat and gets them at lest talking a little bit about chemistry. So, I feel like it's worth it to . . . you know, for them to see what's going on [nodding].

APPENDIX 29

Participant
Quotes

Kerry

(First year of teaching) It takes much more planning to do an Inquiry-based activity. I have a hard time even coming up with things like that. So, it takes a lot more figuring out and seeing if this would actually make them think more about things.

Laurel

(First year of teaching) I think they're [Inquiry-based lessons] harder to plan. It's easier to figure out what you want to tell them, than to figure out what they can learn themselves. [As she speaks, the interviewer pans the camera around to show the classroom. It seems fairly sterile. It is filled with two-person tables, all facing the front of the classroom. A lab bench stands empty at the back of the room.] That's been a challenge here. **There's not a lot of equipment or supplies here.** One thing I bought is little white boards. I sometimes let the students do their work on little whiteboards. 'Cause, everybody likes to write at the board, and that's why they have their own little board at their desk. But, **they don't have textbooks they can take home.** So, we end up [shaking her head in disgust] . . . doing a lot of worksheets. Because, sometimes that seems the best way to let them have the information to take home.

(First year of teaching) The science department at [this high school], there are at least something like seven that are either first year teachers or who are brand new to [this high school]. There are only four or five veteran teachers. And, even those veteran teachers are not super-veteran teachers. So, it's been a shared experience with some of my peers. But, it's also made it difficult to get help, because there are so few experienced teachers, sort of trying to help all of us that it's been hard to get the support that I've needed. I mean, everybody's been wonderful! It's just been difficult for me to get them to help me in the right way.

Is this just your science department you have that high of a turnover? [nodding vigorously, even before he finishes the question] Yeah! I didn't know that when I accepted the job. Several teachers have left since then. That's part of the reason I picked [this school], is because it has a big science department. And, it seemed like, from what they told me, they did lots of group planning and lots of all these things. And, I thought, "Hey. That'll be great, to step into this big team." Well, the team is almost all new. This is sort of nice, because we're all in the same boat, but we can't really help each other that much. **We just don't have the resources to share. We don't have the big box of, "Hey, this has worked for me in the past.**

Rob

(First year of teaching) Well, I've started hoarding slides [laughs]. Because, if I put 'em in the storeroom, someone's gonna mess 'em up and put them in other places. Um, they get broken . . . they get lost . . . so we don't have enough. No one knows where to get 'em. And, I've decided that with most of the biology ones, the other biology teachers know that I will have them in the back of my room. In my opinion, my room and the other rooms, we should have a certain amount of supplies, kind of the general equipment we should have within that group and then you share with teachers. **But then, our budget doesn't call for it. And then, we end up with this little, itty-bitty, dinky budget.** Which almost leads you to: O.k., we're gonna cut out paper blocks and say, "This is a sugar . . . We're gonna make a dumb DNA molecule." Because we don't have the budget. We don't have the supplies we need to make the budget. This is why I'm applying for grants to do this other stuff**. This is why I'm going to buy, on my own, this digital video microscope next fall** [He extends his arms and shrugs].

(**Second year of teaching**) I learn different styles of going after learning disabled kids. I can try to overcome gaps in past knowledge, basic life skills. And so, I'm completely into doing that. One hundred percent. But, what I absolutely cannot deal with **is the [district] bureaucracy** and, like, the administration." In college we had your learning cycle. We had "The Five E's". We had practice presentations. We had all that, which is certainly fine! They had to be done. Um, but there was nothing on how to deal with the crap that was coming. So, all of the sudden you're thrown into this thing. And it's like you're barraged [sweeping his hands across, almost like a flood]. And, **you've got to figure out how to sink and swim in an environment that's very, can be very, very hostile.** I don't know. There's a certain amount you just have to get in and start doing.

Our governor comes out and says, "Oh! We want these happy working conditions, and you're not supposed to do **extra duty**." Right? And, they're like [using his fingers to count off orders], "**You've got to come in on your lunch period and do duty. You've gotta donate all this time after school. You've got to do this work on the weekends. You've got to do all this stuff so that, you can do all these projects for people that, they're not even going to read!"**

Yeah. We were talking the other day that we were under this illusion . . . [laughing very briefly] . . . That is teachers . . . Within the school, there'd be a certain amount of **respect** and, there would be a certain amount of, "O.k. You're an adult professional, working in . . . in an environment?" And [pausing] . . . I have found it to be completely hostile. From the top down. **Strong-arm tactics**. Divide and conquer. Don't care about your time. That's not even slightly a concern. Because, "We have this project we want you to do. And, you must do it. And, it doesn't have anything to

do with running your class. “So, we want you to dedicate this huge amount of time.” And, they can double your workload.

APPENDIX 29 (cont.)

Rob (cont.)

Heck. Next week [He starts counting off on his fingers the extra activities coming up just in the following week.] Monday, we have admin-, faculty meeting coming up after school, followed by training [class]. Tuesday, we have a beginning teachers' training after school, we have to attend. Wednesday, I have a doctor's appointment. Thursday, I've got to go to training, plus we've got teachers' open house. Next thing you know, **I'm working a 70 hour week. 80 hour week.**

I have to do this for three years! Get my licensure thing stamped and the like, all gold. And, I'm not at all certain that I'll stay in [this state] after that**. I think the working conditions can be absolutely horrendous!** Oh! Tuesday, we're supposed to come in early. So, instead of 7:25, we have to come in, be in my room, actually for our PLC meeting at 7:00. I worry about the **stress levels.** I worry about Sunday morning, being grumpy at my wife and kids and having to take a *Xanax* on Sunday morning. I am the father of a four year old disabled kid. And, I head out the door at 4:30, 5:00. And, when I leave, it's not getting done. Because, when I finally put him to bed at 8:30 . . . I'm too tired [laughing sharply].

I guess the crux of it is, could you put pressure on the administrations at schools . . . like, if you can't get teachers to teach at these schools . . . Because [throwing up his arms] . . . **Work conditions suck. Because, there's a certain amount of blindsiding.** You don't know. **But the amount of stress is absolutely insane! Absolutely. The funny thing about it is, none of it is from the kids. I mean, there's a certain amount of fights. You've got to, like, learn how to hang out with a 16 year old. Who doesn't like you.** O.k.? Let's get around that. There's things you can learn. This year's going way better with the kids. All of them. 'Cause, I think my skill set's a little different at being able to deal with it. But, you learn to deal with that, and it's fine! **There's so much b.s. pressure on top of that.**

Seth

(Second year of teaching) Every year it's some new program and some thing they want us to try. But, they do have this new push, coming from the board and some administrators "Preparing Students for 21st Century Learning," is their new slogan. That's the new slogan in North Carolina. I think it is. "21st Century Schools. 21st Century Students" or something like that. So, we're trying to implement some of these technologies, I'm sure you've heard this before! [He smiles and gestures toward the interviewer.] And so, that's what they keep telling us! And so, with some of **the grants we have to write**, we have to keep asking, "How will this support '21st Century Learning?" Yet, we still have not been sat down and told what exactly this "21st Century Learning" is. We just keep hearing this phrase over and over again [laughing].

APPENDIX 29 (cont.)

Mara

(Eighth year of teaching). The negative, with my school culture, is really the **discipline and the lack of enforcement of the rules.** The school says that, after the first tardy they get Saturday school. If they don't attend Saturday school, they get suspended. But, I write a kid up for Saturday school. They don't go. They don't get the suspension. **So there's no enforcement of tardy policy, essentially.** So, what prevents them from being tardy? Nothing. So, they're tardy all the time. Same thing for a student walking out of my classroom [gesturing toward the door]. **I just don't feel supported when I write someone up for discipline.** And, 99% of my discipline, I handle within the classroom. It's when there's a major school issue that I write someone up. Because, **the students are now empowered, 'cause they know there's no consequences. So, if they're empowered. They're basically taking my power!** [She says this emphatically and uses her hand to mime students pulling power away from her.] If they're taking my power [repeating this gesture] What does that leave me? And, I think that's the biggest issue we are finding. I mean our student population is one of the most unique in this county. We have a high percentage of low SES (socioeconomic status). **We have a lot of high-needs kids. And, they really need the structure.** And, they're not getting it. They're falling through the cracks. So that just makes my job all the more challenging because it's hard to enforce the rules. The current administration doesn't make me not want to teach anymore. **They [administration] don't get to e-mails quickly**. And so, when I ask them for things or for disciple problems, it's maybe a week before they see the student if they see the student at all. And, it makes the biggest difference in my classroom [emphasizing these words]. In eight years of teaching, the last two years I've seen the most discipline problems. Ever! [She shakes her head.] And it's very disheartening. It makes me not want to teach. Because, I feel that my job is to try and teach them. But, at the same time, **I have several kids that are disrespectful**. And, there's nothing I can do about it [shaking her head]. Kids that get up and walk out of the classroom [gesturing toward the door] and, I write them up, and there's nothing I can do about it. I had a student get up and walk out of the class [swallowing hard] and, I looked at her record and she'd been written up for getting up and walking out of class five times! She was not once seen by an administrator. Every other day I e-mailed that administrator until she finally did something about it. Last year, I had an administrator, the same one, actually. I had a student I wrote up for talking on a cell phone in my class [miming this act]. He went and told her a story. **She believed him over me, and didn't give him a punishment at all**. **If I'm getting it from the kids, and the parents and from them [administration] it's a losing battle!** So, discipline problems, it's a big deal! It's a big deal. And, how the administration carries out that discipline process is also a big deal. I also feel like this administration cares a lot about the reputation of the school.

APPENDIX 29 (cont.)

Mara (cont.)

So much so that other things are being forgotten! You know? They're not suspending the children as much, because they don't want the school to look as bad. [She gestures with her arms to indicate her frustration.] And, it's all about the numbers. They're not involving the school resource officers like I believe they should because they don't want the school to look bad. They don't let those school resource officers park their cars in front of the school, because they don't like the idea of the police officer school. That's ridiculous! That's absurd! So [sighing deeply] . . . That, to me, has made the biggest impact into why I want to leave teaching. [She shrugs and shakes her head.] I don't enjoy it anymore

How 'bout relationships among teachers . . . among staff?

We had a teacher that would copy my things every day. [At the] beginning of the day come by, "What are you doing?" …take a copy and that's what he did that day. And, that got old very quickly. I let him know that. And, that stopped. And then he went to another teacher [laughing] and copied other teacher's stuff. So, that was annoying. But, now we all get together. And, we all get along. [She emphasizes this pint by bringing her hands together.] And, that's great. But, there are people who are hired that shouldn't have been hired to begin with. And then, the other teachers in that department have to pick up the slack. And it really makes me wonder why people are being hired and whether it has to do with sex and race. I really question the hiring of certain people. It really makes everyone else's job a lot harder. **Because, people with more experience or, with people who are lateral entry, who get credit for their previous experience in previous jobs. So, these are people that are making more than me, who are incompetent and can't do their job**. And, I'm doing it for them, making my life more difficult [smiling ironically] and, for what? So, we have another male in are department? [Its] absolutely ridiculous [shaking her head]! It can be overwhelming and disheartening. [She closes her eyes and shakes her head].

APPENDIX 29 (cont.)

Peggy

(Eighth year of teaching) I try to do as many labs as I can. As a matter of fact, I was in line to teach anatomy and physiology next, because that's one of the classes I wanted to teach. **It's very difficult with chemistry to do as many Inquiry-based labs as you can do with the dissecting labs because our class sizes are so big, and because we rotate rooms.** It's very difficult because everything has to be set up and torn down twice, and there's only so many minutes in the day, and I spend a lot of time tutoring and we make up work, that I can't do as many as I would like to**. Budgets [and] money are huge issue, too. So, I do what I can. I do as much as I physically can, but most of the time what limits me is the tearing up and cleaning up time.**

Like I did a lab today, and I've got stuff in the oven cooking, and I've got all these chemicals in the problem is that I share a room with another teacher who's not teaching the same thing I am, so she did another lab today. And my lab was interfering with her lab. She's in here first and fourth periods, and I'm in here in the middle of the day, so it's not even convenient for her to teach half the day, and then me to teach half the day. Her stuff has to be here in the beginning of the day and then the end of the day, so it's VERY difficult to accommodate the way I want to teach. And I tried, and I tried. Oh, yeah. **There's nothing they can do because our school is so overcrowded. Every room is utilized every period. We run our school like a college, basically, and it's very difficult to teach Inquiry base**, because e.g., I needed foil last period and my foil wasn't here. So I can't leave my kids, so I couldn't do what I wanted to do. So lots of times I find myself getting to the point, like, 'oh, no! I left it in the other room, and I can't leave my kids', so I don't do a lot of these things in similar classes, because if I set it up once the person that it really gets physically is myself, because I'm setting up and tearing down**. I pretty much do all my own set up and tear down of everything I do, and mixing chemicals and solutions, and I'm in charge of the chemistry department, so I order everything for the chemistry lab. I do all my planning and all my grading at home, which is very difficult to do.**

I think block is difficult on these kids, because 90 minutes is a long time to hear chemistry—they don't want to hear it for 90 minutes—but if I don't keep them busy for 90 minutes, it becomes a zoo, because my classes are big. So I can't, it doesn't work, I'm still working on this. They won't work on their homework if I have 15 minutes at the end of the period. They won't do it, they won't do it. **I don't like to do too many topics in one day, but sometimes I run out of ideas of how to teach something. I'm always looking for ideas. I don't have that much time to do research on ideas as I would like to. That's what I do in the summer**.

APPENDIX 29 (cont.)

Peggy (cont.)

Because, they keep saying, in No Child Left Behind, they're gonna lower the **class sizes**." I just kept thinking that in my head, because of the No Child Left Behind. It's so much easier to teach 25 than to teach 35. Those 10 extra kids in the classroom really hurts us instruction-wise. We're not talking one class. We're talking three classes. So, if you put 10 kids in three classes, that's 30 extra papers to grade, that is my entire weekend, when I do the class. **It takes my entire weekend to grade the exams.** When you have that many kids, you can't talk to everybody everyday. You can't make sure they understand the concepts. You can't get to know them. You can't be personal with them. If you are personal with them they [don't] know you care. They're gonna work harder, even if the material's very hard for them [nodding]. But, they do nothing to help us. Even though we talk about it. They've done nothing to help us, in that sense. I think **we don't want more money [shaking her head firmly]. We really are teaching because we want to help the kids.** They need to listen to us when we say, "Please don't put more than 25 kids in the classroom." When I'm running 11 Bunsen burners, and I have 33 kids and somebody is going to burn their pen cap and I don't know who it is because we've got 33 kids, and their backs are to me the way the lab spaces are set up. I'm disappointed in them [administration]. I've been here eight years. I have never seen the Superintendent in this school [her expression still wide-eyed and serious]. In eight years. I've never seen him. He's never been in the auditorium, talking to us. He's never been in my classroom. I don't expect him to be in my classroom. But, I would expect him to come to the school, maybe once a year [shaking her head] . . . and talk to us. I don't really feel that they have listened to what we say. They ask us. And, we tell them every year, "Will you please lower class sizes?" Couple things, "Will you give us more time?" Stuff like that. But, they don't really listen to the class size, thing [shaking her head]. I think the class size thing. If you can lower the class size at the high school level, there would be no child left behind. [She repeats this louder, firmer and even more passionately to make her point

The role of experimentation in my classroom is to reinforce the concept only. Um**, I can't give them free reign for two reasons: One . . . is they don't hurt themselves, and I'm liable for them . . . and two, 'cause I have too many kids. I can't monitor it.** I can't run the experimentation for 35 the way I would for 25 or 20. If I had 20 kids in my classroom we'd do an experiment almost every day. It'd be very open-ended. It would take forever 'cause they wouldn't know what they were doing, and I'd say, "No. This is how you do it." But, I physically cannot get around to that many students to direct them. **So, I cannot give them open-ended labs.**

APPENDIX 29 (cont.)

Peggy (cont.)

Now if I had smaller classes, I could [nodding]. I would [nodding]. I would give them stuff and say, "O.k. We're gonna make a battery out of this," and say, "And, here's your equipment. Go for it." And, I would walk around and say, "Oh, no. You can't have that with that. It won't work." But I can't physically do that. Somebody will be burning something in the corner and setting the school on fire [and] I would go to jail. So, I have to guide them. Were my classes smaller, I'd do more with them. **When my classes are larger, I have kids who miss 45 days of class.** And, I'm told to catch them up. My question is, I teach a lab science. How can I teach them a lab science, with labs, when they're not here? **No one cares about labs other than the teachers teaching them,** If I'm going to teach a student who has missed 45 days of my class chemistry, do they expect me to come in and set every single lab that I've done up again? No. **They [students and administrators] expect me to teach it out of a book.** So, can we teach chemistry without a lab? [She raises one finger, then points it toward the camera.] You bet! You bet that we can! [She points again.] It happens every day! And, I'm told to do it! So. Is experimentation important? [She pauses as if considering her answer. Then, her voice and her gestures soften. She places her hand on her chest.] It is to me. Because, I'm a medical technologist by heart. I love lab. That's why I teach science. In meeting the curriculum in North Carolina, the Department of Public Instruction, is it important to them? No. If it was important to them, they would not put 35 kids in the classroom. And, they would be buying me all kinds of equipment. We would have everything we need. We don't**. My probes are eight years old. Everything I have is very outdated. And, there is no money to buy me new things. So. I'm told to write a grant.** Well, I've written two grants. I didn't get either one of them. They both took me, pretty much, about a month to write. I did it in the summer. I tried. I'm not an English major [shrugging]. I'm not a good writer [shaking her head]. I will never get a grant, no matter how much time I spend. Unless I pay someone to do it, I'm not gonna get a grant. So, I'm not gonna get the equipment that I want. [Her expression becomes agonized. She clasps both hands together and closes her eyes. Her voice is filled with frustration.] It tears my up that other schools have better equipment than we do. 'Cause, I love equipment [pointing both hands toward herself.] Kids would all be touching the equipment! But, I don't have what I need. I don't have what I need to do the lab [her voice changes to a frustrated whisper] because, **lab is not important to people who are not scientists.** So. experimentation is important to me. I think labs are important. But, they have to reinforce concepts. They can't be the only way I teach something. Because, I'm gonna have six kids absent that day that have to know that material. And I don't have time to do the lab with them. **I have had to accommodate my teaching to the school environment.**

APPENDIX 29 (cont.)

Peggy (cont.)

I don't see the school environment affecting my teaching or what I believe in teaching. But, how I want to teach definitely changes with class size and abilities of my students. Students that are not at the right level that I have to teach limits what I do because they can waiver into any class, even if they're not at the right level, I have to teach the class to the majority level of the students. So, sometimes that affects it. **Class size is probably my biggest thing.** I don't have the time to set up and tear down labs. So, as the years go on and my class sizes get bigger and bigger, **I probably do less and less hands-on activities.** Just because, I'll have three labs back there that I'll have to clean up, and I'm not sure when I'll do it yet. That's the environment of the school. Plus, **lots of us switch rooms. I have a teacher that comes in here next period and wants to do a totally different lab** [shrugging slightly **I can see myself taking the labs and doing some a little bit more Inquiry base extensions with them but I sometimes feel like I don't have the knowledge to do that.**

APPENDIX 30

Participant
Quotes II

Kerry

(Student teaching) *So, from the district's perspective, what do you think is the most important priority to them that the students need?* Test scores.
Yeah. Biology teachers met at the beginning of the year and we talked to the guy who's in charge of [the district]'s science programs and pretty much they basically gave us a sheet of paper that tells us something to the effect of, **"statistics have shown that students do better on tests when they have no labs, and no activities, and sit in lecture the entire time."** And, all of us were like, "Huh?" 'Cause, like, the students at [this school] do labs at least once or twice a week. This is their lab set up. And, instead of seeing the bench set up with nice glassware or other stuff, we find the countertop full of paper. We find these handouts. *[The video reflects this, showing that nearly every inch of countertop is covered with stacks of papers.]*

Laurel

(Pre-service) *So, you'd feel comfortable at the end of the year if you didn't complete the book, you didn't make it cover to cover? That wouldn't bother you?* It wouldn't bother me personally. I mean, I guess **with the end of year exams and things like that, you do have to worry about covering certain things. I guess maybe at the end, then unfortunately you'd maybe skip a chapter that wasn't going to be covered on the end of the year exam, even if it was one that I really wanted to teach; some things I want to provide my students the opportunity to be successful by whatever standards they were measured.** But I don't know. I guess that's kind of a tough question. I mean, I wouldn't necessarily be worried that I had to cover the entire book. I don't think it would bother me.
As long as you covered all the topics they would be tested on?
I guess that what you HAVE to do, but I don't know. I don't necessarily think that tests like that are super reliable sources of how students are doing. I don't know, I mean I guess, yes **I would teach to what was going to be tested at the end of the year test if it was coming down to it, just because I feel like getting in less trouble. (Student teaching) We go by the Standard Course of Study. So, it's a guideline of what will be on the End-of-Course exams that are state-mandated for the classes.** So, I guess we present the material that will be tested. We're teaching to the test I guess [smiling slightly] that's [what it] ends up being [nodding].
(First year of teaching) You have to teach for the test to a certain extent, at least. **But, if they're going to be tested on certain things, you try to make sure you've covered those things in class.**

APPENDIX 30 (cont.)

Misty Kate

(First year of teaching) *In your school setting, how do you decide what to teach and what not to teach?* A lot of it's the Standard Course of Study and that dictates most of it.

(Second year of teaching) *In your school setting, how do you decide what to teach and what not to teach?* A lot of it's based on what the Standard Course of Study says. A lot of it's just thinking, "What can a kid answer, be expected to answer, in a multiple choice question [on the EOC exam] in the time they're allotted?"

Marcella

(**Student teaching)** *In your school setting, how do you decide what to teach and what not to teach?* So far, I've been looking to my cooperating teacher for that. I use the standard course of study as a guideline. I make sure to hit on everything that's in the standard course of study. But then, usually I reflect back on science courses that I've taken, to think of the things that were stressed in those courses. So, I think back to my biology courses I took in college and biology courses I took in high school. And, I try to remember how certain topics were emphasized. **The test does sort of govern how quickly you move through topics 'cause I have to have everything done in the unit, before the test date.**

How do you decide when to move on to a new topic? With regard to an entire unit, **I'm sort of schedule-driven. There's a certain day of the week for each subject to give their tests. Ours is Wednesday. So, we pick out the test day well in advance, for the unit, and we plan out the topics we're going to cover each day.** And then, I mean, in that sense, I am kind of schedule-driven.

How do your students learn best? Well, I have a hard time telling that so far. I know that some of them have expressed to me that they work best when they have some sort of notes to work off of, a sort of framework. This kind of surprised me, because I thought that they would feel that they were learning better when they do a lab or something hands-on. Because that makes sense to me**. I think that the curriculum's so rigorous sometimes, and so fast-paced** that they might feel that they're lost if they don't have sort of an outline, something to look at, so that they know.

(First year of teaching) *How would you characterize your district's philosophy toward science education reform and the extent to which it influences your beliefs and actions?* Well, I think they're probably pretty serious about science education reform . . . about having the newest . . . science education methods employed in their classrooms. Because, they've taken on this program, to offer incentives to young teachers. That's the only reason I can think of to get young science teachers. [Her face brightens.] is that, they have just come through college and university, and they're on board with, you know, the Inquiry and self-guided learning.

APPENDIX 30 (cont.)

Marcella (cont.)

I guess they think young teachers wouldn't be as inclined to "lecture as much' [miming the quotation marks] to old teaching, I guess. So, I feel like, they seem to be pretty serious about science education. But, at the same time, if you throw the teacher into the classroom, and you want them to perform, you've got to provide a little guidance. We want the scores turned around. We don't really know how to do it. Because, Ms. [the teacher across the hall] and I, we both teach biology. That's an EOC course for us. We've kind of developed our own plan for getting our scores up by having our students take a lot of practice EOC tests. **If we're being paid to turn around test scores, you have to teach to the test** [nodding adamantly]. So, I teach exactly what is in the Standard Course of Study, exactly what is suggested in the support documents, and nothing else.
(Second year of teaching) How do I decide what to teach and what not to teach? **Well, ideally, I would teach everything on the Standard Course of Study.** And, I did in biology, when I was teaching biology [last year]. I taught every single objective on the Standard Course of Study. I feel like the earth science Standard Course of Study is a little more comprehensive. It's a little bigger. And, it's kind of daunting. I'm not going to teach everything on the Standard Course of Study. It's not a state-tested subject. And, I know that I should teach everything on the Standard Course of Study, But, it's not going to happen. I would rather have my students master something than to master nothing because we ran through the whole thing.

Rob

(Student teaching) *In your school setting, how do they decide what to teach and what not to teach?* Standards. [The following comments in Rob's interview were almost identical to Kerry, Laurel, Misty Kate, and Marcella's comments during their student teaching experience and therefore were not included here].
(First year of teaching) The great state of North Carolina, in its great wisdom, has made biology an EOC-passed requirement for graduation class. There's a fair number of kids who fail. And, the end result is our academic classes are becoming more and more concentrated with kids that have failed, back again, failed, back again [using his hands to go back and forth]. And, so, this year, my academic classes seem to be maybe a notch more academically deficient than they did last year. So, that said, it's relatively similar. I've got the same number of classes [with] roughly the same number of kids but the concentrations of abilities in my academic classes seems to be a little worse.

APPENDIX 30 (cont.)

Rob (cont.)

Do you think it's possibly with these labels, they think, "I'm already a failure in science? And, they're just trying; it's hard for them to change that perception of themselves? At [this high school], we have two base populations. We have the magnet kids that are coming in, that are bright, bright, bright kids. They're generally pretty academically proficient, anyways, coming in. And, their family support networks are really, really, really pretty strong. I had parents coming in for an intervention because their daughter got a 92 [twisting his face in astonishment]. And then, you had to figure out why she needed a 93 to get the A. And, it's just like a big family thing. I had Mom and Dad coming in a suit and tie. And, I'm like . [Exaggeratedly shrugging and shaking his head in disbelief]. **[The] other population is very, very poor African-American, from a very bad socioeconomic thing. Now, I realize that's like a stereotype. And, I try to be away from that [extending both hands and turning them]. But, classes, you might look at the demographics and say, "How can I address that?" [He holds up one hand and starts counting off issues on his fingers.] They may have parents who are in prison. They may have no jobs. I've got parents that are living with their boyfriends, girlfriends, drug usage and there's a growing thing with gangs, in the area. I noticed the other day that one of my girls, a good student, has a great big fingernail on her pinkie [gesturing to indicate about an inch-and-a-half long nail that I think is a coke thing [bringing the fingernail up to his nose].** Don't know. I would never accuse her of it or, maybe I might confront her on it, or not. She's a pretty decent student. But, their needs are so completely different.

So, you don't like this "one size fits all"? Oh, no. It poses a lot of obstacles with that. They don't really envision themselves as good students, academically. Not necessarily just in biology, but in other classes as well. Because it is an EOC course, they've gotta pass it. If they fail it, they get shipped back. Its' so many abstract things built on top of each other. They don't understand it. They get bored [laughs]. It becomes a frustration. So yeah, the needs are different. So, my reward systems need to be different. The type of approvals I give them need to be different. The need to give them approval as individuals is way different.

How do you decide when to move on to a new topic in your class?

This year, we have a new EOC. And no, they don't tell us. They say, "No. Teach all of the entire spectrum of biology [extending his arms widely]. So it's really a matter of what the state literature trying to emphasize on the EOC. We have a feeling it's more cells and genetics this year. Last year, it was heavily ecology. I was really kind of mad because, the core curriculum we're supposed to do this entire, extensive, study of all the kingdoms, and phylums or animals and they're supposed to know all of the eating habits and digestion, reproduction, and all

these different things. And, we did a phenomenal job of studying that. [He shakes his head.] Not a single question on the EOC dealing with any of that. It made me mad. Because, in looking at it, we could have cut off half the year. They don't want to tell us because, we're supposed to teach it all! [He throws both arms into the air.] But I would have been much better off and my students would have done much, much better if we had focused more on ecology. (Rob started teaching mid year, so he had taught a semester of the year before and that is what he is referring to).
(Second year of teaching) *In what way, if any, have your beliefs and actions been influenced by your district's philosophy about science education reform?* Somehow, I became the school representative for "Blue Diamond" in the science department. So, I had to go to these five or six meetings throughout the year. Where, they got a sub, and I had to go to the [district] office and talk to them. And, I was really pretty mad. And, I was mad, not because we were giving this common assessment [holding his hands to represent the test], but, because they had no problem throwing an extra 25 or 30 hours of work on top of teachers' mid-year. I was telling [naming someone] our district guy, "This is not worth the cost [moving his hands forcefully]! I cannot grade papers. I'd get calls from parents, "How's my daughter doing?" Look over this huge pile [miming a pile of ungraded papers several feet high]. I don't know! I haven't graded anything in a month! Because of this! He [the district administrator] kind of got mad and was like, "Don't you believe in common assessments?" And, I was like, "I have no problem with common assessments! I have . . . This doesn't work!" [then] he kind of threatened me. He goes, "**Well, at least teachers keep their jobs right now in this economy.**" Last year I kick butt on the EOC's and the principal gets kind of kudos for having an awesome biology teacher and I can influence my co-teachers in that way. **In the views of my principal, my students, and everybody else is in how well did they do on the End-of-Course test in biology**. The state's written this completely vague document [and on it is] everything that you could possibly study in biology. [Therefore] it is on our curriculum. Grilled 'em on vocabulary.
This year, I've kind of taken the opposite approach. Where, I'm becoming much more of a minimalist. And, can I just teach, and get them to get, only the things on the EOC? Not as necessarily a way of limiting them to studying only those items but as a way of making sure that I'm hitting the core things that they have to have to pass. And then, if I can add on to that or, add enrichment activities more for my honors kids or make sure that I get those down, or at least I know **that I'm covering the absolute, bare-boned basics.**

APPENDIX 30 (cont.)

Shannon (cont.)

(First year of teaching) *In what way, if any, have your beliefs and actions been influenced by the district philosophy about science education reform?*
for all of the EOC classes. Like, real, true**, pacing guides** that all of the teachers for that certain class follow [sweeping her hand broadly through the air]. So, we designed those last year.
(Second year of teaching) If I taught it the way that the curriculum is designed, to the degree that the curriculum is designed, it would be miserable because, it's just so much information [shaking her head]. You know, you can't cram everything that they want you to know into this class. It's tough because, you can't weed out. But, **the [we] way have set up biology, and the way that we have made that pacing guide, you know, given the Standard Course of Study. We can fit everything in, but it's tight! [laughing again and nodding] It's tight! Because, there's just so much more accountability with biology.** I am graded with biology. You know [smiling slightly]? Essentially, at the end of the semester. It's not just them that's taking that test. I [gesturing toward herself] it's a reflection of the job that I'm doing, too. And, they do not like Inquiry. They like to be told! Which [smiling] is just the nature of school. But I like them to teach themselves [smiling]! But, sometimes I think that they get aggravated when I won't just tell them the answer
How do you decide when to move on to a new topic in your class? With biology, **the pacing guide has to be fairly quick** [nodding]. They do not like to teach themselves [smiling]! I want them to try to figure it out. Because [nodding and smiling], I think that they learn best when they teach themselves. But, they don't like to learn that way. And so, it's a balance. You know, I have to balance it between the things that I give them directly and then, the things that I let them figure out on their own.

Seth

(Fourth year of teaching) *How do you maximize student learning in your classroom?*
Department of Public Instruction. They require us to do all these other extensions. But, I try to fit as many of those in there as I can.
How has the school environment or culture influenced your beliefs and actions as a teacher? Well, our school has very, very high expectations of the students. **It's expected that every student makes high scores on their end-of-year tests**.
Because, in years past, we've been one of the highest-scoring schools. It's just always been expected that students will learn when they are in class. It's just sort of expected of that. And so, that carries over into my classroom. I expect that all of my students will pass the state testing at the end of the semester, and work towards that goal. And, I design all of my tests so that they're not allowed to slack off.

APPENDIX 30 (cont.)

Seth (cont.)

They can't forget what they've learned [using his hands to mime setting certain information aside]. Because, I'll include questions from the material they learned at the very first test on every single test, throughout. So, it makes sure that they are staying on top of things [nodding].
In your school setting, how do you decide what to teach and what not to teach? Well, if it's in **the "North Carolina Standard Course of Study",** I teach it [laughing]. I absolutely make certain I teach everything in there!
How do you decide when to move on to a new topic in your classes? Well, I created a pacing guide, based on how things have gone the past couple of years, where I know about how many days I need to spend on what topic. Most major topics, I try to spend about four or five days on. And, the last day, they get a test. And, if their grades on the tests are absolutely horrible, I'll say, "O.k. We have to go back and spend a couple more days on this, and then we'll move on." If they all did well, or if most of the class did well, then we'll move on. **And, those who didn't, you'll come in either before school or after school or during lunch. But, I can't hold up the whole class if it's three or four students that don't understand it.** But, if it's over half the class that doesn't understand it, then obviously I need to go back and spend more time on the topic.

Ronald

(Third year of teaching) *How do you decide when to move on to the next topic?* Unfortunately in the EOC class, **I have a very rigid, set schedule. These are the things I have to cover. And this sounds terrible** - I know it sounds terrible- but if the student has it, great. If they don't, maybe we'll pick it up in review. It's time driven. It's not student-achievement driven.
(Fifth year of teaching) How would you describe the district's philosophies about education reforms. I think the district's policy is terrible! I think that the district only looks at success in science as based on test scores and doesn't look at how well we're preparing students to work in the sciences, be scientists, or even, just function in a scientifically literate community. I think there's absolutely zero focus on that. I think **a lot of it is driven by our End-of-Course testing. Because, the only thing that the administration's concerned about, or that the teachers are concerned about is,** "Do my kids do well on this EOC or not?" Everything else is secondary. If they don't remember stoichiometry two years from now, or the basics of chemistry two years from now, it doesn't matter as long as they do well on the EOC. I think it's a terrible injustice, what they've done at the elementary level **essentially taking science out of the curriculum! Because, the EOG's [End-of-Grade tests] don't test the sciences**

APPENDIX 30 (cont.)

Ronald (cont.)

at that level. So, it's just the district's policy's absolutely horrible! I would never send my child to public school, because of that. Or, that's part of the reason.

Nadia

(Fourth year of teaching) We have our Standard Course of Study. And, it takes away from our professionalism. And, I feel that that's an insult!

Mara

(Eighth year of teaching) Everything I teach is in the North Carolina Standard Course of Study. We are given the North Carolina End-of-Course Exam. At the end of the semester, they have to pass the exam to pass the class. Everything I teach is based off that.

Peggy

(Fifth year of teaching) *How has the school environment, or culture, influenced your beliefs and actions as a teacher?* Scores are very important, contrary to what everybody says. [As she says this, her eyes widen, and she seems very intent and very serious.] It drives pretty much, academically, that goes on is the scores. **My scores will be shined, on an overhead in front of the entire faculty. And, they'll be talked about as needing for improvement or not needing improvement. So every day I am judged on those scores.** So, that environment makes it critical [firmly emphasizing that word] to me, to keep the environment of this school, which is driven by scores to make sure my kids understand it [nodding seriously]. So, I guess that I would be teaching ionic bonding anyway. I would be teaching what I'm teaching in the classroom anyway. But, I'm judged on it. So, I need to make sure that every single student understands it. Because, according to No Child Left Behind even a student who missed the entire lesson, or missed the entire week needs to know about bonding. So that will be done on my free time. That will be before school, after school or during my lunch. So, I usually come in at seven. And, I leave at four. And, I will tutor before school. And, **I have students making up the lab that they missed yesterday before school or even in lunch they can come in to make sure that they understand. So, the environment is No Child Left Behind. Everyone needs to understand. And, even though I worked very hard yesterday, teaching a lesson, I had six students absent [nodding]. So, those six need to be taught that material.** So, the environment is to create I guess, repeat, what I did yesterday, today . . . along with the new material.

APPENDIX 30 (cont.)

Peggy (cont.)

(Sixth year of teaching) *Describe the school/community relationship in your district.* I don't really think that the parents understand, academically, what goes on here. I don't think they realize the intensity of the classes. **This high school is not like high school was when they were in high school.** And, I think that they're constantly comparing our high school to their high school experience. And, they don't understand **that it's harder to get into colleges. High schools are harder now. The bar has been raised and so they are constantly criticizing the instruction if their child is not doing well, because they are thinking that we're not teaching.**
How do you decide when to move on to a new topic? Well, we have a **pacing guide** that tells us. I have all of the topics that I need to cover. And, I have what I call "no frills". I have the bare minimum, what I need to cover.

Rose-Abby

(Fifth year of teaching) For example, this year I've had two students who have lost a family member to two different types of cancer who were their classmates as well as themselves, inquisitive about how this works. Well, because there might be one or two questions about cancer on the end-of-course test, I could not go into and help, which, I would say, would be very helpful to those two children, not alone the class which have questions that have questions, "I have a grandma," or "a cousin", or, "I know of somebody else that has had this "What has happened to their body? [She brings her hand to her heart.] **I couldn't have time to go into that, because it is not in my curriculum. So, that's one thing that I feel really against the standardized test. I understand it's important to keep people accountable: "Are you doing what you're supposed to be doing?" But, I wish that there was some other way that students could receive credit.** That I could have a little more freedom and still cover some important goals, but allow students to take some ownership in the classroom. And, that is very hard for me. I have no time. Absolutely no time [emphasizing each word]! And, that is something that I struggle with.
(Sixth year of teaching) *In your school setting, how do you decide what to teach and what not to teach?* Well, first thing, I go by that **Standard Course of Study. Unfortunately, my hands are tied a lot of times.** It's the first time that biology, we're teaching on a new curriculum, in six years that I know how to pace myself, and, I feel comfortable as to what's important to cover. If I have extra time, then I can get into the students interests. But, I try to make them interested in what's important. And, that's the main thing, is trying to engage them in the points that are required to study. So, when I do a lecture, I'll throw a banana peel on the floor and, I pretend to fall and say, "Schleiden! Schleiden discovered that all plants are made of cells."

APPENDIX 30 (cont.)

Rose Abby (cont.)

How do you maximize student learning in your classroom? The first step is building a relationship. And then, I have to engage a child. So, when I engage by building a relationship, I can figure out the learning style of the child. And then, I need to have some form of engagement, so that I can connect with them, I can differentiate my instruction so that it appeals the best towards their learning style, and then I can maximize their learning.

My classroom is organized in a u-shape. I like the kids not necessarily sitting in rows. I want them all to kind of have the focal point.

[note: Rose-Abby gives little discussion to EOC and has the highest RTOP scores of anybody in her cohort]