# TEACHERS' INQUIRY EFFICACY AND IMPLEMENTATION FOLLOWING A FIELD AND LABORATORY BASED SCIENCE EDUCATOR PROGRAM: A MIXED METHODS INVESTIGATION

by

AMY TERA PARLO

(Under the Direction of Malcolm B. Butler)

## ABSTRACT

There is an increasing body of research providing evidence that inquiry-oriented teaching results in improved student content knowledge and critical thinking skills (Hurd, 1998; Narode, 1987; Weinstein et al., 1982; Bredderman, 1982). Inquiry instruction has also been found to enhance learning in underrepresented and underserved populations (Rosebery et al., 1992; Scruggs et al., 1993). It is argued that educators often teach in the way in which they learned (Loucks-Horsely, 1998) If teachers are to implement inquiry in their classrooms, as outlined by the National Science Education Standards, it is important that are provided with experiences that engage them in inquiry learning. This study investigated teachers' inquiry efficacy and their implementation of inquiry in classroom instruction following participation in a two-week, residential program that immersed teachers in intensive field and laboratory experiences. Using the Teaching Science as Inquiry instrument (Dira-Smolleck, 2004), it was determined that following the program, there were positive gains in teachers' inquiry efficacy and that these increases were consistent over the course of the year following the program. Case studies of six of the participants revealed that although efficacy had increased, changes in inquiry instructional methods were modest. Although participants expressed their feelings that inquiry was an essential element of science and science education, competing responsibilities and the limitations of the traditional classroom were perceived to hinder their ability to increase their implementation of inquiry. Implications of this study emphasize that purported changes in teacher beliefs do not necessarily result in changes in practice. While research should continue to identify perceived obstacles to implementing reform, teacher education programs and inservice need to offer teachers an opportunity to confront their beliefs about reform and how it may fit into the context of their teaching.

INDEX WORDS: Inquiry, Professional development, Inquiry efficacy, Science education

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# DEDICATION

I dedicate this work to my father who instilled in me his love for nature, science and exploration and to my mother for giving me the moxie and confidence to pursue my every goal.

# ACKNOWLEDGEMENTS

No task this great could have been accomplished alone. Isaac Newton, in a 1676 letter to Robert Hooke stated “If I have seen a little further it is by standing on the shoulders of Giants.” My achievement was only possible with the encouragement and support of the giants around me. They provided needed boosts, both emotional and intellectual, and at times of great duress, have even carried me the few steps needed to continue on.

I would like to thank my doctoral committee. Much like Dorothy’s companions on the trip to Oz, each of them offered their unique expertise, perspectives and experience to guide my progress through this program. A special thank you is needed to acknowledge Dr. Mary Atwater for volunteering to step in as my major professor during Dr. Butler’s transitional period. Her assistance and input was invaluable. I would also like to thank Dr. Butler especially for all of his support, which always included inquiring about my well being beyond the scope of the paper. As the “rainmaker”, he always managed to do whatever was necessary to help me reach the sometimes foolishly optimistic deadlines I set for myself.

The quantitative portion of this study would not have been possible without the tireless work of Carter Betz. His assistance in running the data helped me to gain a firmer understanding of statistical analysis in practice than did three semesters of coursework. Additionally, Dr. Olejnik was instrumental in helping me to understand aspects of the quantitative portion one can only really confront when knee deep in analyzing data and trying to establish results.

The honors/gifted Biology classes of 2010 at Berkmar High School deserve a special, heartfelt thank you for their support. Dedicating my daytime to teaching Biology and then

spending most of my evening hours at the computer writing was exceedingly taxing. Continuing to make my classroom a pleasant place to engage in discovery would not have been possible without the one hundred and fourteen smiling faces that greeted me each day. They were my biggest cheerleaders, sometimes literally, and were so understanding and supportive on days when it was all weighing too heavily.

To my brother Patrick, I am also greatly indebted. His unwitting computer hotline allowed me a reliable and ever present source for help on all technical aspects of this research. If not for him, I would have never gotten past numbering the pages appropriately.

This research would also not have been possible without the participation of the teachers from the R2R program. Their openness in sharing their experiences and their classrooms with me is what made this research possible and provided meaningful insight into challenges even the best teachers face. I am grateful for the opportunity to have gotten to work with them. Each is a remarkable teacher and I gleaned far more from our interactions than simply the data for my study.

I would be remiss if I did not thank my husband Larry who has given up four years of any meaningful time with me in the evenings. I'm grateful for his efforts to keep the house in order and to make himself scarce when I was attempting to find my writing zone. His belief that I would succeed was unwavering and frequently voiced.

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# CHAPTER ONE

## The Research Problem

### *Introduction*

In the summer of 2001, I was selected to participate in the Coastlines program offered by the University of Georgia. The program was/is intended to increase teacher content knowledge of Georgia environmental issues and provide opportunities for preservice and inservice teachers to apply these topics to their current or prospective curriculum.

The two weeks spent on Skidaway Island and Sapelo Island on the south coast of Georgia marked a turning point in my entire approach to science education. Reflecting on the experience with a fellow participant of the program, we identified the most valuable aspect of the program to be the experience of enjoying nature and science in an atmosphere of exploration and discovery. Surprisingly, with an endless list of memorable and remarkable events from which to choose, we both noted one moment in particular as our favorite. At the end of a long day of island mapping, several of us went to the dock to relax. Under the light of the moon, we each lay on the splintered wood of the dock on our bellies, running our hands in the water beneath us. With each pass, bursts of lime green bioluminescence dotted the dark water. It was then that my colleague said, “It’s the kind of thing that makes you love science in the first place”. This is precisely the type of experience I would want to share with my students in developing their love of science.

Concurrent to the time I was formulating a research topic, I had read an unpublished dissertation regarding the concept of inquiry efficacy, by Lori Dira Smolleck, and was intrigued by teachers’ beliefs about their ability to implement inquiry in their classes. Referred to as the

"I-word" by one of my professors, Dr. Wallace, inquiry received a great deal of attention in my graduate coursework. I had researched the historical foundation of inquiry and been informed of its importance as a teaching and learning strategy through the National Science Education Standards. However, it wasn't until I experienced inquiry in action through the Rivers to Reefs program that I began to personally see value in it. It is with the experiences of my participation in the program in mind that I decided to investigate this newly developing concept of inquiry efficacy and how experiences in inquiry may effect teacher beliefs about the use of inquiry in their classroom and how these beliefs may translate to its use as an instructional strategy.

## *Statement of the Problem*

In the 1980s, educational reform began to refocus on the concept of standards. This movement was initiated by a report in 1983 by the National Commission on Excellence in Education entitled *A Nation at Risk: The Imperative for Educational Reform*. The authors of *A Nation at Risk* expressed their concern that the United States' preeminence as a global leader in commerce, industry, science and technological innovation was being challenged due to a "rising tide of mediocrity" in our schools. They went on to state that our gains in student achievement in the wake of Sputnik have been squandered through a "cafeteria-style curriculum" that fails to value high expectations and the discipline needed to meet them. Their recommendations were that education become more uniform and that schools should adopt "more rigorous and measurable standards, and higher expectations for academic achievement" (NCEE, 1983, p. 27). From a patriotic call to maintain the nation's security and safety, the movement towards standards-based reform was launched.

Following the publication of *A Nation at Risk*, several professional organizations began establishing standards of practice. The first standards appeared in two publications addressing mathematics education standards: *Curriculum and Evaluation Standards for School Mathematics*, by the National Council of Teaches of Mathematics (1989); and *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, by the National Research Council (1989). Science education curricula were also being constructed by numerous science organizations such as The American Chemical Society, The Biological Sciences Curriculum Study, the Education Development Center, the Lawrence Hall of Science, the National Science Resource Center and the Technical Education Resources Center among others (NRC, 1996). In 1985, the American Association for the Advancement of Science founded project 2061 in an effort to increase science, mathematics and technological literacy for all Americans. The AAAS 1989 publication of *Science for All Americans* (AAAS) outlined what knowledge and skills all students should possess upon their high school graduation. These recommendations would serve as the foundation for the science standards movement. *Benchmarks for Science Literacy*, published in 1993 by AAAS, translated the goals of *Science for All Americans* into learning objectives or benchmarks to measure progress toward literacy when students reach grades 2, 5, 8 and 12. The National Science Teacher Association (NSTA) followed, with their own publication of *The Content Core: A Guide for Curriculum Designers* (1992). Similarly to the *Benchmarks* and *Science for All Americans*, the focus of the NSTA publication was on science skills and concepts rather than memorization and minutia. In December 1995, the National Research Council released its final draft of the National Science Education Standards (NSES) outlining its guidelines for achieving scientific literacy for all students, drawing heavily on the benchmarks laid out by the AAAS (NRC, 1996). A prominent feature of the NSES is the focus on the role of inquiry in science education. The standards propose using inquiry as a method for students to learn science, learn how to do science and learn about science (NRC, 2000).

In 2002, President George W. Bush signed the No Child Left Behind Act (NCLB) into law. One of the pillars of the NCLB is to increase school and teacher accountability for student achievement. Under the act's accountability provisions, schools must demonstrate through standardized testing that yearly progress has been achieved. To meet yearly progress, schools must demonstrate that students meet or exceeds statewide annual objectives or that the number of students below proficient levels is reduced by ten percent. Failure to meet yearly progress marks results in serious consequences for schools ranging from voluntary relocation of students to higher performing schools, the addition of supplemental programs to improve performance, to complete restructuring of school administration and turnover of school staff (NCLB, 2002).

Teachers and schools are now being held accountable for the achievement of their students. This achievement is measured against state standards of student abilities. With the increased focus on measurable gains in achievement, educators are eager to find and employ methods that will best enhance their students' learning. The literature is rife with research indicating the value of inquiry in positively influencing many dimensions of student learning. If teacher practice is to reflect current educational standards-based reforms as well as current understandings of effective teaching strategies, studies directed at identifying factors that may increase teachers' use of inquiry should be conducted.

### *Purpose and Rationale*

Although an abundant amount of research on various aspects of inquiry teaching and learning exists, there is a deficiency focusing on teacher attitudes and beliefs regarding inquiry and inquiry practice (Keys & Bryan, 2001; Pajares, 1997). Additionally, there is little research investigating the impacts of teacher professional development experiences on changes in inquiry-related practice in the classroom (Blanchard et al., 2005; Crawford, 2000; Frechtling et al., 1995). In light of this dearth of research, this purpose of this study is to analyze teachers' inquiry beliefs and inquiry-related practice following their participation in the Rivers to Reefs/Coastlines (R2R) teacher workshops.

Three research questions were developed to investigate teachers' inquiry efficacy beliefs and inquiry-based practice after completion of the Rivers to Reefs/Coastlines program. These questions are: Following participation in the Rivers to Reefs/Coastlines program,

1. What changes in inquiry efficacy can be measured?
2. What changes in inquiry-based science teaching practice are reported by participants?
3. What factors, as perceived by the participating teachers, facilitated or restricted their use of inquiry-based instructional practices in their classrooms?

Loucks-Horsley et al. (1998) has argued that it "is difficult if not impossible to teach in ways in which one has not learned" (p.1). However, professional development opportunities tend not to employ this approach when instructing educators. Lieberman (1995) stated

> What everyone appears to want for students – a wide array of learning opportunities that engage students in experiencing, creating and solving real world problems, using their own experiences, and working with others – is for some reason denied to teachers when they are learners. (p. 591)

The R2R program is structured to provide teachers with valuable experiences as inquiry learners. As emphasized in the standards, participants are able to learn science topics while also learning about science and how scientific inquiry is conducted. The results of this study will add to the small but developing research base regarding the effects of professional development on teacher inquiry practice.

## *Overview of the Methods*

To address the research questions, participants of the 2005 R2R workshop were administered a pre-test, post-test and delayed post-test inquiry efficacy measurement instrument. The survey was administered at the beginning of the program, at the conclusion and again at the end of the following school year. The Teaching Science as Inquiry instrument (TSI), which is discussed further in Chapter 3, provided the quantitative measurement of any changes in inquiry efficacy after participation in the program. Qualitative data were obtained through the framework of case studies of six participants to ascertain their current interpretations of inquiry and its value as an instructional method. Analysis of teacher implementation of inquiry after participation in R2R was conducted by the researcher through participant interviews, participant reflection and collection of artifacts such as lesson plans.

### *Introduction to Rivers to Reefs/Coastlines*

Since 1999, the University has conducted a summer, coastal marine, teacher workshop. Located on the coast of Georgia, R2R is a fifteen-day, residential program that engages participants in scientific investigations regarding environmental issues. The program rotates yearly between the Rivers to Reefs and Coastlines format. Each addresses coastal issues with essentially the same activity structure but brings a unique approach to highlight the program. The Coastlines institute supplements the program with a literature element by incorporating relevant readings. Rivers to Reefs, in contrast, focuses on the connection of coastal issues to activities conducted upstream. Within each program, lessons constructed to enhance teacher content knowledge are also directly connected to teacher practice through participants' development of activities for use in their own classrooms.  For the purposes of this study, we used the Rivers to Reefs (R2R) title to represent the program for simplicity.  Elaboration regarding the structure of the summer institute is provided in Chapter 3.

### *Conceptual and Theoretical Framework*

This investigation was designed to identify any change in teachers' beliefs about their ability to use inquiry in the classroom subsequent to their experience in the R2R program. Furthermore, the study addresses changes in teachers' inquiry practices or limitations hindering such changes, following participation in the R2R program. The theory base providing structure for this research includes professional development and teachers' beliefs, specifically those regarding efficacy and inquiry.

#### *Teacher Beliefs.*

There is a vast literature base supporting the idea that teacher beliefs are a significant influence on teacher practice (Parajes, 1992; Nespar, 1987; Richardson, 1996; Bryan & Abell, 1999).  Teacher beliefs may also be context specific (Brickhouse & Bodner 1992).  Ford (1992), asserts that the context in which one teaches is fundamental in shaping a person's beliefs and subsequently influencing their actions.  This whole of this research, is grounded in the measuring of teacher beliefs and their possible alignment to teacher practice following a professional development course.  It is important, then, to clarify what is meant by the term belief.  Pajares (1992) illustrated the challenge of pinning down an exact definition as well as an exact term. Literature commonly uses a sundry of terms to address the construct, such as concepts, conceptions, perspectives, and attitudes.  Informing my definition of teacher beliefs are the research of and literature summaries compiled by Pajares (1992) and Gess-Newsome (2003).

Beliefs are cognitive constructs of internal truths built upon experiences and knowledge that guide behavior.

Consistent with research, the model depicted in Figure 1.1 illustrates my conception of the factors that work to influence and affect teacher practice. This model demonstrates the interactive nature of experiences to influence beliefs, which in turn affect practice. Practice can also be viewed as experiences that lend themselves to further modification or reinforcement of beliefs. In a model of the process of teacher change provided by Guskey (1986), change in teacher beliefs comes as a result of changes in classroom practice. Ideas and principles about teaching are believed to be true by teachers "only when they give rise to actions that 'work'" (Bolster, 1983, p. 298). This understanding is also reflected in my model where experiences can affect practices before lasting changes in belief occur. Also influencing teacher practices are mitigating factors, specifically, external factors that may cause a teachers to act in contrast with existing belief structures or that create coexisting beliefs that have greater predominance on decision making. These factors include teachers' beliefs about the presence or absence of support of administration for implementing certain teaching strategies as well as teachers' beliefs regarding other contextual circumstances that may facilitate or prohibit certain teaching practices.

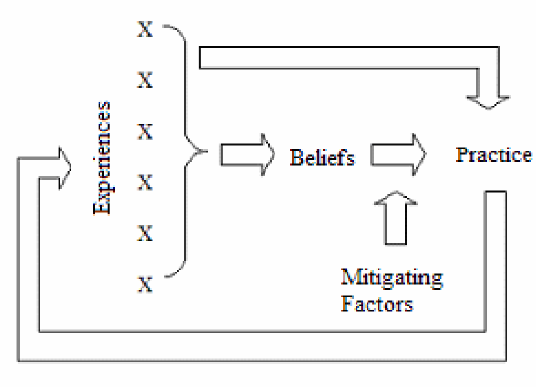

Figure 1.1. Interaction of factors that determine teacher practice.

*Self Efficacy.*

Defined by Bandura (1977), self-efficacy is “beliefs in one’s capabilities to organize and execute the course of action required to produce given attainments” (p.3). Teacher efficacy is an important construct in teacher education (Pajares, 1997). Tschannen –Moran and Woolfolk Hoy (2001), define teacher efficacy beliefs as a teacher’s “judgement of his or her capabilities to bring about desired outcomes of student engagement and learning, even among those students who may be difficult or unmotivated”. Research has indicated a consistent relationship between a teacher’s sense of efficacy and the behavior and learning of students (Woolfolk and Hoy, 1990). Therefore determining ways in which to enhance teacher efficacy is a worthy pursuit (Henson, 2001).

Studies regarding inquiry efficacy of teachers is just beginning to be developed. If general and personal teacher efficacy is related to student achievement, investigations in relation to teachers’ sense of their ability to use inquiry might also provide a valuable insight into teachers’ use of inquiry practices and any measurable gains in student achievement as a result.

*What is Inquiry?*

This research investigated teachers’ beliefs about inquiry and their use of inquiry in their classroom practice. It would therefore seem necessary to establish a working definition of inquiry. The National Research Council defines inquiry as:

> …a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze and interpret data; proposing answers, explanations and predictions and communicating the results. Inquiry requires identification of assumptions,

> use of critical and logical thinking and consideration of alternative explanations.
>
> (NSES, 1996 p.23)

The definition provided by NSES is merely one of many that exist. However, since the standards are used to guide current teacher practices, this is the definition that will be used for the purpose of this study.

### *Summary*

This chapter illustrated the need for research to address teachers' beliefs about inquiry and teachers' practice of inquiry. The stated purpose of this study is to investigate this topic and add to the developing body of research. An abbreviated outline of the methods used to conduct this research has been presented. In addition, the conceptual and theoretical frameworks grounding this research have been summarized. In the following chapter, the relevant literature regarding the theory base of this study will be further examined.

# *CHAPTER TWO*

# The Literature Review

## *Inquiry*

### *The History of Inquiry*

Inquiry has had a sinuous role in science education over the past century. Typically attributed to the works of noted educator and researcher, John Dewey, inquiry began to emerge as an important science teaching method early in the 1900's. Dewey (1909) stated, "Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject matter of fact and law, rather than as the effective method of inquiry into any subject matter". Dewey's early interpretation of scientific inquiry focused on science education as a rigid set of problem solving steps, similar to today's textbooks outline of the scientific method (Barrow, 2006). Later modifications to this model include an understanding that students must be reflective and active learners (Dewey, 1938).

In the 1960's, a shift began from teacher-centered, behaviorist to learner-driven, constructivist views of learning. Behavioralism focuses on learning from the perspective of observable behaviors, without regard to mental processes. Through conditioning and positive reinforcement, students can be taught to repeat desired behaviors. Constructivism, in contrast, states that learning is a process of knowledge building though one's individual experiences, beliefs and preexisting mental structures (Schuman, 1996). These developments in our understanding of how individuals learn have facilitated the resurgence of inquiry into the spotlight of educational reform. Leaders of the constructivist movement supported the use of inquiry to foster student construction of knowledge. Jerome Bruner (1960), in his book *The Process of Education* stated that*:*

> Master of the fundamental ideas of a field involves not only the grasping of general principles, but also the development of an attitude toward learning and inquiry, toward guesses and hunches, toward the possibility of solving problems on one's own. To instill such attitudes by teaching requires something more than mere presentation of fundamental ideas. Just what it takes to bring off such teaching is something on which a great deal of research is needed, but it would seem that an important ingredient is a sense of excitement about discovery – discovery of regularities of previously unrecognised relations and similarities between ideas, with a resulting sense of self-confidence in one's abilities. Various people who have worked on curricula in science and mathematics have argued that it is possible to present the fundamental structure of a discipline in such a way as to preserve some of the exciting sequences that lead a student to discover for himself. (p. 20)

The call for inquiry in science instruction began to build momentum through the support of additional researchers and educators such as Schwab, Dewey, and Piaget (NRC, 2000). Inquiry would become the underlying focus of educational reform for the decades to follow (DeBoer, 1991). Although curriculum materials developed during this time were largely guided by these men to include inquiry, most teachers continued to practice traditional methods of instruction (Harms and Kahl, 1980; Harms and Yager, 1981; Stake and Easley, 1978).

Following *A Nation at Risk* (1983), educational reform has centered on the use of standards to guide practice and student outcomes. As aforementioned in Chapter One, publications such as *Science for All Americans* (SFAA; Rutherford & Ahlgren, 1989) and the

*Benchmarks for Scientific Literacy* (AAAS, 1993) established goals for the use of inquiry in instruction. Also designed to guide science instruction, the National Research Council established the *National Science Education Standards* (NRC, 1996). These standards place a heavy emphasis on the use of inquiry.

*Defining Inquiry*

Inquiry has been defined in various ways since the works of Dewey (DeBoer, 1991; Rakow, 1986). Jerome Bruner (1973) described inquiry as "discovery learning". In 1964, Novak offered his definition of inquiry: "Inquiry is the [set] of behaviors involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious." Another definition describes inquiry as a "cycle of engagement, exploration, explanation, application and evaluation" (Bybee, et al., 1989). Regardless of the various wording, inquiry has typically been associated with constructivist models of learning and is often characterized as a component of high quality teaching. Since current reforms are currently the driving force for inquiry use in classroom, this study will focus on inquiry as it is defined by the NSES:

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

The National Science Education Standards address inquiry in three distinct ways. They address inquiry as learning about inquiry, learning to do inquiry, and inquiry teaching. Within the content standards for Science as Inquiry, students are expected to develop both skill in inquiry practice as well as an understanding of the process of inquiry. To *do* science, the Standards state that students should be able to pose a question, plan and implement an experiment, critically analyze data, form a conclusion and communicate their findings. In contrast, learning *about* inquiry refers more to the understanding of the nature of science. NRC (2000) describes this as "understandings of scientific inquiry represent how and why scientific knowledge changes in response to new evidence, logical analysis, and modified explanations debated within a community of scientists".

### *Characteristics of Inquiry Teaching*

Several science teaching standards are provided in the NSES, most of which stress inquiry as a major component of science instruction. However, these standards do not provide an operational definition of inquiry teaching. Instead, five essential features of classroom inquiry are outlined and examples are provided elaborating each. These features are:

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

(NRC, 2000).

The NRC (1996), provides an outline within the NSES illustrating the desired shift of emphasis of classroom instruction to promote inquiry (Table 2.1).

Table 2.1

*Changing Emphases to Promote Inquiry*

| Less Emphasis On | More Emphasis On |
|---|---|
| Knowing scientific facts and information | Understanding of concepts and developing abilities |
| Studying subject matter disciplines for their own sake | Learning science content through inquiry in a personal, social and historical context |
| Covering many science topics | Focusing on a few concepts at greater depth |
| Activities that demonstrate and verify science content in one class period | Investigate and analyze questions over an extended period of time. |
| Providing answers to questions about science content. | Using evidence and strategies for developing or revising explanations |
| Individual groups of students analyzing and synthesizing data without defending conclusions | Collaborate with peers in analysis and synthesis of data, communicate and defend explanations |

Modified from NRC, 1996

Just as the term inquiry has many different definitions, inquiry teaching is defined in multiple ways by various researchers. Inquiry teaching can be viewed as existing on a continuum (Jarrett 1997). Varying from highly structured, teacher led activities as in guided inquiry (Igelsrud & Leonard, 1988) to the less guided approaches of open inquiry (Tinnesand & Chan, 1987). The NSES illustrates this continuum in a chart showing their five identified essential features of inquiry and where each exists on the spectrum from teacher centered to student centered (Table 2.2).

Table 2.2

*Essential Features of Classroom Inquiry and Their Variations*

| Essential Feature | Variations | | | |
|---|---|---|---|---|
| 1. Learner engages in scientifically oriented questions | Learner poses a question | Learner selects among questions, poses new questions | Learner sharpens or clarifies question provided by teacher, materials, or other source | Learner engages in question provided by teacher, materials, or other source |
| 2. Learner gives priority to evidence in responding to questions | Learner determines what constitutes evidence and collects it | Learner directed to collect certain data | Learner given data and asked to analyze | Learner given data and told how to analyze |
| 3. Learner formulates explanations from evidence | Learner formulates explanation after summarizing evidence | Learner guided in process of formulating explanations from evidence | Learner given possible ways to use evidence to formulate explanation | Learner provided with evidence and how to use evidence to formulate explanation |
| 4. Learner connects explanations to scientific knowledge | Learner independently examines other resources and forms the links to explanations | Learner directed toward areas and sources of scientific knowledge | Learner given possible connections | |
| 5. Learner communicates and justifies explanations | Learner forms reasonable and logical argument to communicate explanations | Learner coached in development of communication | Learner provided broad guidelines to use sharpen communication | Learner given steps and procedures for communication |

More --------------Amount of Learner Self-Direction -------------- Less
Less -----Amount of Direction from Teacher or Material ----- More

(NRC, 2000 p. 13)

Further literature delineates between these variations of inquiry instruction. Herron (1971) created a rubric based on the writings of Schwab, (1964) describing four levels of inquiry ranging from instruction that was significantly scaffolded by the teacher to instruction where the teacher served as a resource for student generated inquiries. These levels range from zero to three with level zero representing the most structured instruction. This type of instruction is commonly referred to as “cookbook labs” where students conduct a confirmation activity where the results are known in advance. Chinn and Malhotra (2002) refer to this as simple school inquiry. Level one, or structured inquiry, allows the student to participate in an investigation, however they are following a prescribed procedure outlined by the instructor. Herron’s second level, guided inquiry is somewhat more loosely structured. Although the teacher still provides the questions of interest, students are aided in designing their own solutions and experiments to formulate a conclusion. Level three is characterized as open inquiry. Students formulate their own questions and design their own procedures for answering those questions. Chinn & Malhotra (2002) refer to this as authentic inquiry, also referred to as scientific inquiry by Schwartz & Lederman (2004).

### *Research on Inquiry Teaching*

Studies of inquiry teaching approaches have generally indicated positive results. Inquiry teaching methods have been associated with increased scientific literacy and understanding of scientific processes (Haury, 1993; Lindberg, 1990), critical thinking (Haury, 1993;Narode et al., 1987), vocabulary and conceptual understanding (Haury, 1993; Lloyd & Contreras, 1985). There have also been studies that demonstrate that inquiry based instruction improves student attitudes toward science (Chang & Mao, 1999; Haury, 1993; Kyle et al., 1985; Rakow, 1986). Increases in laboratory skills, graphing skills and data interpretation were demonstrated in a study of middle school students in inquiry based programs (Mattheis & Nakayama, 1988).

Inquiry teaching has also been associated with gains in underserved and underrepresented student populations. A study conducted by Taylor (1988) revealed that inquiry practices were considered to be more compatible with the viewpoints of Native American students than traditional text-based instruction. In another study, English language learners were found to benefit from inquiry instruction, increasing their ability to think and write in scientific ways (Rodriguez & Bethel, 1983; Rosebery et al., 1990). Students with learning disabilities have been found to perform better on assessments when involved in inquiry science (Dalton, Morocco & Tivnan, 1997; Scruggs, Mastropieri, Bakken, & Brigham, 1993). In addition, inquiry approaches have been advocated for deaf students as well (Chira, 1990). As student populations become more and more diverse it is important that teachers utilize instructional strategies that are linked to improved performance.

Despite the overwhelming literature base touting the benefits of inquiry instruction, a limited amount of research has been conducted to study the effects of professional development on teachers' use of inquiry in the classroom (Blanchard, 2006). A majority of the studies that have been conducted have focused on preservice teachers (Crawford, 1999; Lemberger, Hewson & Park, 1999; Schwartz, Lederman, Crawford, 2004; Seymour, Hunter, Laursen, & Deantoni, 2004). Several studies conducted by Blanchard et al. appear to comprise the bulk of the research regarding aspects of inquiry following a teacher workshop (Blanchard, Diagle, & Malcom, 2005, April; Blanchard, Hancock, & Stallins, 2007; Blanchard, Muire, Davis, & Granger, 2007; Blanchard & Southerland, 2006, January; Blanchard & Southerland, 2006, March). Furthermore, the concept of inquiry efficacy is one that is only recently being developed.

### *Roadblocks to Inquiry Teaching*

Research has indicated that current inquiry practices do not reflect visions of inquiry illustrated in reform documents (Anderson, 2002; Rutherford, 1964, Welch et al., 1981). One explanation may be that inquiry methods of teaching and learning do not usually represent prior experiences of teachers. Loucks-Horsely et al., (1998) state that “it is difficult if not impossible to teach in ways in which one has not learned”. Granger and Hernkind (1999) state that:

> Teachers teach science the way they learned science; through college courses based on lecture, textbook learning, memorization, and “cookbook” experimentation. Their lack of experience with scientific inquiry makes them extremely uncomfortable in the uncharted waters that inquiry-based instructional methods employ, and as a result, they do not use them (p. 9).

Learning to teach through inquiry is much more than simply learning new skills (Anderson, 2002). Anderson (2002) asserts that science educators cannot agree on a working definition of inquiry and therefore, many teachers are unfamiliar with inquiry or how it can be used in the classroom.

Anderson (1996) identified three barriers that inhibit teacher use of inquiry practice: the technical dimension, the political dimension and the cultural dimension. The technical dimension encompasses teachers’ beliefs of their inability to adequately teach constructively and their concern with commitments to other teaching responsibilities, which may include mandated testing and local science objectives. Teachers may also feel challenged by engaging students in a new, active learning role (Barrow, 2006). The political dimension refers to the general support of inquiry teaching by the school and parents. Conflict over teaching strategies may exist within the school and teachers may be limited financially in terms of available resources and equipment. The cultural issue, which Anderson claims to be the most important, deals with teachers’ beliefs of the value of inquiry in a school culture that may focus on content coverage in an effort to prepare students for testing and the next level of schooling.

Other hurdles to inquiry teaching have been identified by researchers. In a 1986 study, Costenson and Lawson investigated reasons that teachers were not using inquiry in their classrooms. Their study revealed a myriad of reasons including teachers' reports that inquiry lessons were too time consuming, too expensive and required too much energy to plan and conduct. Magnusson & Palincsar (1995) suggest that inquiry teaching requires adequate content knowledge, while Flick (1995) stresses the importance of strong pedagogical content knowledge and skills. Perceived inadequacies in either or both of these areas may inhibit a teacher's use of inquiry in their practice. Each of these findings is further reinforced by additional research which reiterates a lack of support, lack of time and materials, an emphasis only on content as mandated by state documents and the difficulty in using inquiry as additional roadblocks to implementing inquiry in the classroom (Welch et al., 1981; Eltinge & Roberts, 1993). These impediments will be addressed further in regards to teacher beliefs in the following segment.

### *Teacher Beliefs*

This study identified changes in inquiry practice and teacher beliefs about their use of inquiry following participation in the R2R program. Research literature is rife with connections between teacher beliefs and teacher practice. Therefore, it seems valuable to address the framework of teacher beliefs as it applies to this study.

Defining the construct of beliefs is somewhat complicated whereas its meaning seems to vary with the intent of its user. The term is also commonly used interchangeably with countless other terms such as concepts, attitudes and perspectives further complicating identification of a operational definition and blending its overlap in meaning with closely related terms (Pajares, 1992). There have been distinctions made between the construct of beliefs and other concepts such as attitudes and knowledge. Koballa and Crawley (1985) as well as Fishbein (1967) differentiate between the two by asserting that beliefs are information that a person accepts to be true whereas attitudes posses an affective component about such information. This affective component is also what Pajares (1992) identifies as the difference between beliefs and knowledge. Southerland et al., (2001) proposes that whereas knowledge is built from more formal school-based experiences, beliefs tend to be formed from everyday experiences. Beliefs are also of a more personal nature than knowledge. Knowledge requires an agreement among a community of people whereas a belief may be more individual, varying from person to person (Gess-Newsome, 2003; Richardson, 1996).

Beliefs are described by Tobin et al., (1994) as "a form of knowledge that is personally viable in the sense that it enables a person to meet his or her goals that be undertaken only in a social setting" (p.55). Kagan (1992) defines beliefs as "often unconsciously held assumptions about students, classrooms, and academic material to be taught" (p.65). These overlapping definitions have contributed to my interpretation of beliefs and may be combined with the statement by Tabachnick & Zeichner (1984) defining beliefs as "opinions with a disposition to act" (as cited in Pajares, 1992), in that beliefs are an impetus behind decisions that are enacted in the classroom.

In regards to beliefs about science teaching, prior science learning experiences appear to have a strong influence on teachers' beliefs about the nature of their role in instruction and how students learn and these beliefs are resistant to change (Lumpe, Haney & Czerniak, 2000). These beliefs were formed though what Lortie (1975) describes as an "apprenticeship of observation".

### *Beliefs and Practice*

In a review of the literature, Pajares (1992) stated that beliefs serve as the "best indicators of the decisions individuals make" (p. 307). Beliefs are closely tied to the understanding of teacher practice, choices and changes in practice (Bryan, 2003; Bryan & Abell, 1999; Keys & Bryan, 2001; Nespor, 1987; Pajares, 1992). Nespor (1987) asserts that:

> ….teachers' beliefs play a major role in defining teaching tasks and organizing the knowledge and information relevant to those tasks. But why should this be so? Why wouldn't research-based knowledge or academic theory serve this purpose just as well? The answer suggested here is that the context and environments within which teachers work, and many of the problems they encounter, are ill-defined and deeply entangled, and that beliefs are peculiarly suited for making sense of such contexts (p. 324)

However, despite the foundation of research linking teacher beliefs to subsequent practice, discrepancies and conflicts between the two have often been identified (Brickhouse, 1990; Brickhouse & Bodner, 1992; Bryan, 2003; Gardiner & Farrangher, 1997; Luft, 2001; Simmons et al, 1999; Thomas et al., 2001; Yerrick et al., 1997). One possible source of the discrepancy between beliefs and practice may be related to the social context of teaching (Ernest, 1989; Lumpe et al., 2000). Gess-Newsome (2003) asserts that another source of the discrepancy between beliefs and practice can result from a lack of knowledge. Teachers may possess particular beliefs about their practice but lack the knowledge to enact them. This explanation may apply with the implementation of inquiry in instruction as a result of few teachers having experienced learning in methods in their own educational background in addition to the lack of a single operational definition of inquiry in regards to teaching.

### *Beliefs about Inquiry*

Research investigating teachers' beliefs about inquiry also illustrate a disconnect between the beliefs and their practice. A study conducted by Cronin-Jones (1991),found that middle-grade teachers found that teachers possessed firm beliefs that science was a body of factual knowledge and that their students did not have the needed skills to perform more loosely structured inquiry activities. Perhaps built upon their own experiences as students in a traditionally structured classroom, these beliefs limited teachers' use of inquiry-based instruction. Tobin & McRobbie (1996) refer to teacher beliefs in this regard as impediments to reform. They identified four pervasive beliefs: the transmission myth which places the teacher as the source of knowledge, the efficiency myth which focuses on the perceived amount of content needed to be covered, the rigor myth and the myth of preparing students for examination. Further studies regarding beliefs about inquiry portray a discrepancy between the conceptions of inquiry held by teachers and that held by teacher educators and educational reform policy (Carnes, 1997; Crawford, 1998; Flick, 1995; Fradd & Lee, 1999; Keys & Bryan, 2001; Keys & Kennedy, 1999).

This study focused primarily on the beliefs secondary science teachers have regarding their ability to use inquiry in their classroom as well as how these beliefs translate to actual practice. Therefore, central to this review is the construct of efficacy.

### *Self Efficacy*

The concept of self-efficacy is grounded in Bandura's (1977,1986, 1997), social cognitive theory which assumes that individuals are capable of maintaining a measure of control over their thoughts, motivation and actions. This "agency" operates in a process Bandura refers to as triadic reciprocal causation. Triadic reciprocal causation describes the interactive relationship between behavior, environmental factors and one's personal factors, such as cognition and affect. These three factors interact to effect future behavior. Central to the social cognitive theory is the construct of self-efficacy. Bandura (1977) defines self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p.3). Bandura (1986) believed that how people behave is directly related to what people think, believe and feel.

Bandura's social cognitive theory also incorporated the construct of outcome expectancy. Theoretically independent from self-efficacy, outcome expectancy refers to the judgements of the likely consequence that specific behavior will produce (Bandura, 1986). Bandura argued that outcomes people expect are somewhat dependent upon their efficacy. In addition, outcome expectancy is similarly instrumental in influencing motivation and predicting behavior.

Self-efficacy is derived from four sources: mastery experiences, vicarious experiences, verbal persuasions, and physiological states (Bandura, 1997). The most influential of these is mastery experiences. Mastery experiences, simply stated, are experiences in which an individual can assess the effects of their actions. Their interpretation of the subsequent success or failure as a result of their actions helps to form their efficacy. Positive experiences promote higher efficacy and negative experiences lower it, respectively.

The second source involves social modeling to provide vicarious experiences in which one is able to see someone similar to themselves succeed by sustained effort. By seeing someone that is perceived to be similar to oneself succeed, an individual may feel that they too can also succeed. Modeling as an influence on efficacy is most effective when the comparisons between model and self are most closely aligned. Models also provide examples of competencies and abilities that people may aspire to. Bandura states that "through their behavior and expressed ways of thinking, competent models transmit knowledge and teach observers effective skills and strategies for managing environmental demands" (1994, p.2). Attainment of these abilities then serves to raise perceived efficacy.

Verbal persuasion is the third way in which efficacy can be developed. It is easier to diminish one's efficacy beliefs through verbal persuasion than to build it (Bandura, 1994). However, verbal persuasion is not effective when the praise is perceived as hollow or insincere (Erikson, 1980; Bandura, 1997). Increasing efficacy through persuasion requires the persuader to supplement verbal praise with situations that allow the person to experience successes that reinforce that praise.

The last source of efficacy development identified by Bandura involves physiological states such as stress, fatigue, anxiety and mood. Individuals oftentimes measure their confidence in relation to the emotional state they have experienced while approaching a task. For example, when a person perceived themselves as a poor test taker, their thoughts and fears about their test taking abilities may ultimately increase their anxiety and result in actual poorer performance on the exam. Mood can also affect perceptions of ability. Positive moods serve to increase efficacy while negative moods can lower it. It is not only the presence of a physiological state that can influence efficacy, but also how that state is interpreted by the individual. Anxiety for some can be debilitating while for others it energizes them for the task ahead.

Research has demonstrated that efficacy is a powerful predictor of behavior with clinical issues such as addiction (Marlatt, Baer, & Quigley, 1995) and depression (Davis & Yates, 1982) as well as with educational behavior such as motivation (Maehr & Pintrich, 1997; Pintrich & Schunk, 1996) and academic performance (Pajares, 1996; Schunk, 1991; Zimmerman, 1995). It is in the realm of educational behavior that this review will now turn.

## *Teacher Efficacy*

In 1976, RAND researchers published a study analyzing various reading programs and interventions (Armor et al., 1976). Influenced by the work of Rotter (1966), RAND researchers added two items to their study. Item number 1 stated, "When it comes right down to it, a teacher really can't do much because most of a student's motivation and performance depends on his or her home environment". Item 2 stated, "If I really try hard, I can get through to even the most difficult or unmotivated students." Based on Rotter's (1966) locus of control theory, these items were designed to measure whether a teacher's ability to impact student learning was perceived to be within their control or not. Their study produced powerful results and thus created the concept base of teacher efficacy (Tschannen-Moran, et al., 1998).

Tschannen-Moran and Woolfolk Hoy (2001) define teacher efficacy as a teachers' "judgement of his or her capabilities to bring about desired outcomes of student engagement and learning, even among those students who may be difficult or unmotivated" (p. 783) Teacher efficacy can be broken down into two uncorrelated constructs that are reflective somewhat of Bandura's personal self-efficacy and outcome expectancy; these are general teaching efficacy (GTE) and personal teaching efficacy (PTE). General teaching efficacy refers to teachers' beliefs about the strength of external factors as compared to the influence of teachers and school in regard to student learning (Ashton, Olejnik, Crocker, & McAuliffe, 1982). GTE is reflected in item 1 of the RAND study. Item 2 reflects PTE, which is a more individualized view of the power of the teacher to influence student learning (Tschannen-Moran et al., 1998). These two constructs are typically measured together in one instrument with further analysis discriminating between the levels of the two.

Teacher efficacy has been correlated with several variables of student performance such as achievement (Anderson et al, 1988; Armor et. al., 1976; Ashton & Webb, 1986; Moore & Esselman, 1992; Ross, 1992), student motivation (Midgley, Fedlaufer, & Eccles, 1989) and a students' own sense of efficacy (Anderson et al., 1988). These increases in student achievement as a correlation with high efficacy teachers are also evident in populations that are underserved and underrepresented (Watson, 1991).

Efficacy has also been related to teacher behaviors. Teachers will high efficacy are more likely to help struggling students and less likely to criticize students for incorrect answers (Gibson & Dembo, 1984; Ashton & Webb, 1986). In addition, highly efficacious teachers are less likely to refer a student to special education (Meijer & Foster, 1988; Podell & Soodak, 1993). Studies have also indicated that teachers with high efficacy are more likely to experiment with teaching strategies to enhance instruction (Berman et al., 1977; Guskey, 1988; Stein & Wang, 1988) and spend greater amounts of time in lesson preparation, planning and organization (Allinder, 1994).

Teacher retention rates benefit from high efficacy levels as well. Teachers with high efficacy report greater enthusiasm for teaching (Allinder, 1994; Guskey, 1984; Hall, Burley, Villeme & Brockmeier, 1992), a greater commitment to teaching (Coladarci, 1992; Evans & Tribble, 1986; Trentham et al., 1985), and a desire to stay in teaching (Burley et al., 1993; Glickman & Tamashiro, 1982). It is clear from the collection of supporting literature that the construct of teacher efficacy holds many promising avenues for further research investigating ways to improve teacher practice and possibly increase student achievement.

### *Measuring Teacher Self-Efficacy*

Initial efforts to measure teacher efficacy have been developed from the two RAND items originally used in 1976. In fact, first efforts used only those two items (Tschannen-Moran, et al., 1998). Concern over the reliability of a two-item scale resulted in the development of several longer, more comprehensive instruments. The first of these was the Teacher Locus of Control (TLC), developed in 1981 by Rose and Medway. The TCL was quickly followed by two other RAND-based instruments:  the Responsibility for Student Achievement (RSA) developed by Guskey (1981) and the Webb Efficacy Scale developed by Ashton et al. (1982).

Initial research efforts in teacher efficacy stemmed from the RAND (1966) work and utilized measurement instruments such as the ones listed above.  However, while this avenue of research was developing, another based on Bandura's social cognitive theory and his construct of self-efficacy was evolving.  Bringing in the theoretical base of Bandura, Gibson and Dembo (1984) developed the Teacher Efficacy Scale.  Although used extensively in the study of teacher efficacy, inconsistencies in items began to emerge (Tschannen-Moran, 1998).  As a result, the instrument has been shortened to various degrees by researchers as a modification to eliminate questionable items  (Hoy & Woolfolk, 1993; Soodak & Podell, 1993; Woolfolk & Hoy, 1990)

These examples of efficacy measurement have been attempts to measure a general sense of efficacy.  Bandura has argued that self-efficacy is a context specific construct that cannot adequately be assessed by these general self-efficacy instruments.  Instead Bandura recommends measuring efficacy in terms of "particularized judgements of capability that may vary across realms of activity, different levels of task demands within a given activity domain, and under different situational circumstances" (1997, p. 6).  In general, teacher efficacy beliefs will provide the most predictive power when the measurement closely reflects the specific behavior desired.  Instruments developed following the TES have attempted to address this issue.  One such example is the development of the Science Teaching Efficacy Belief Instrument (STEBI) designed by Enochs and Riggs (1990).  The STEBI also identifies the two subconstructs of personal science teaching efficacy and science teaching outcome expectancy, reflecting Bandura's efficacy concept.  The STEBI has two different forms, A and B, designed to measure the science teaching efficacy of preservice and inservice teachers respectively.  Instruments have become even more specified. Rubeck and Enochs (1991) examined chemistry teaching efficacy distinguishing it from science teaching efficacy.

The Teaching Science as Inquiry Instrument, developed by Lori Dira-Smolleck (2004), has been designed to measure both teacher personal efficacy and outcome expectancy with special regard to inquiry teaching. This domain specific assessment will better reflect teachers' beliefs about inquiry practices for classroom instruction. The structure of the TSI and its development are discussed in greater detail in chapter 3.

### *Influencing Teacher Efficacy*

Little research has been conducted to measure effects of interventions on teacher efficacy although that which has been conducted yields promising results (Henson, 2001; Ross, 1994). Research indicates that although efficacy is malleable in preservice teachers (Housego, 1990; Hoy & Woolfolk, 1990), it tends to be fairly stable and resistant to change for inservice teachers (Anderson et al., 1988; Ohmart, 1992; Tschannen-Moran et al., 1998). Bandura (1997) has stated that changes in efficacy must be through the result of "compelling feedback that forcefully disrupts the preexisting disbelief in one's capabilities" (p. 82). However, further research involving experimental and long-term intervention is merited (Henson, 2001; Ross, 1994).

## *Professional Development*

In 1983, *Nation at Risk* illustrated a perceived need to greatly increase student achievement. The educational reforms that followed this report have emphasized standards as guidelines for desired teaching practices and student outcomes. These standards emphasize teaching strategies and learning environments that do not reflect teachers' prior experiences or current practices. Fullan (1996) argued, "You cannot improve student learning for all or most students without improving teacher learning for all or most teachers" (p. 41). Within many of the proposed standards lies the call for high quality professional development to meet this need.

Despite the goals to improve teacher practices, there is a history of criticisms regarding the shortcomings of professional development programs in the past. Guskey (1986) outlined these criticisms and cites one author as stating that professional development programs have been "uninspiring and ineffective". These findings are further supported by a 1985 national survey that reports that inservice professional development ranked as the least effective source of learning for teachers (Smylie, 1989). Guskey (1986) suggests that these shortcomings are a result of a lack of understanding of teachers' motivation and the process of change needed to occur to alter practices. The National Joint Committee on Learning Disabilities (2000) describes these inadequate professional development opportunities as "too linear or top-down in approach" and employing "sit and get" teaching strategies where teacher learners are treated as passive recipients of knowledge. Inservices were also considered to be too brief in duration and too shallow in content to provide any substantive change in teacher practices (Abbott, Walton, Tapia, & Greenwood, 1999; Malouf & Schiller, 1995; NJCLD, 2000). Several researchers have proposed necessary elements of effective professional development. A consensus of six has been outlined by Supovitz and Turner (2000) and will be highlighted in the following paragraphs.

High quality professional development must immerse participants in inquiry, questioning and experimentation through modeling of the inquiry process (Arons, 1989; McDermott, 1990; Bybee, 1993). Such programs have been found to have a significant effect on student achievement (Marek & Mathaven, 1991). Loucks-Horsley et al., (1998) has argued that teachers must experience learning opportunities that they are expected to use in their own classrooms.

However, these types of experiences are commonly denied to teachers in their own learning experiences (Liebermann, 1995). Darling, Hammond and McLaughin (1995) stated:

> Teachers learn by doing, reading, and reflecting (just as students do); by collaborating with other teachers; by looking closely at students and their work; and by sharing what they see…To understand deeply, teachers must learn about, see, and experience successful learning-centered and learner-centered teaching. (p. 598)

Studies that have implemented intensive inquiry based professional development have found that on average, the teachers who participated in such inservice opportunities were statistically associated with greater use of inquiry based teaching practices in their classrooms (Supovitz & Turner, 2000).

Professional development must also be intensive and sustained (Smylie, Bilcer, Greenber, & Harris, 1998; Hawley & Valli, 1999). Research conducted by Supovitz and Turner (2000) supports this finding that both teaching practices and classroom cultures were "affected most deeply after intensive and sustained staff development activities" (p. 976). Their study revealed that teachers participating in more than 80 hours of professional development experienced the greatest amount of change.

Teacher inservice must engage teachers in concrete tasks and be based on teachers' experiences with students (Darlin-Hammond & McLaughlin, 1995). In fact, teachers likely participate in staff development opportunities because they envision them as avenues in which to improve their teaching. However, they often approach inservice with the expectation that the program will offer specific and concrete applications that they can directly relate to their everyday teaching practices (Doyle & Ponder, 1977; Zigarmi, Betz, & Jensen, 1977).

Inservice programs must also focus on subject matter knowledge and enhance teachers' content skills (Cohen & Hill, 1998). The literature indicates that the substance of professional development activities is more important than the structure in impacting teachers' beliefs and practices (Cohen & Hill, 2000; Garet, Porter, Desimone, Birman, & Yoon, 2001; Kennedy, 1999). Professional develop that addresses general pedagogies or generic teaching strategies are relatively unsuccessful as compared to those offering specific content matter and accompanying strategies use to teach it (Cohen & Hill, 2000; Garet et al., 2001; Kahle, Meece, & Scantlebury, 2000; Kennedy, 1999).

Professional development must be grounded in a common set of professional development standards and illustrate how teachers can connect their work to standards of student performance (NRC, 1996; Hawley & Valli, 1999). The National Science Education Standards (NRC, 1996), have developed standards to guide the professional development of science teachers. These standards are focused on four areas:

1. The learning of science content through inquiry.
2. The integration of knowledge about science with knowledge about learning, pedagogy, and students.
3. The development of the understanding and ability for lifelong learning.
4. The coherence and integration of professional development programs.

The NRC states that the first three of these goals may be summed up as "learning science, learning to teach science, and learning to learn". The final goal illustrates the need for local and state organizations to share common visions of high quality professional development and that those visions ideally are based on the National Science Education Standards.

Finally, reform strategies must be connected to other aspects of school change (Fullan, 1991). There must be coherence between the professional development and school policy for the transfer of knowledge to effect teacher practice (Birman et al., 2000; Darling-Hammond & McLaughlin, 1995; Loucks-Horsley, Stiles & Hewson, 1996). Sparks (2002) states that the structure and culture of the school environment are critical to enhancing the impact of professional learning. "True reform that results in real change and improvement requires changing the organizational structure, the established procedures, the way decisions are made and resources allocated and the relationships between central office personnel and school staff." (Duttweiler, 2000). Inquiry practice is often associated with hands-on learning that may not always be quiet. If teachers feel that quiet, controlled classrooms are valued by those that monitor their performance, they may feel compelled to abandon new practices in favor of more traditional ones. For change to take hold, the teacher must feel comfortable implementing the new strategies and this may require a new outlook from administrators.

### *Summary*

This chapter has provided an inclusive review of the literature that frames the theory base of this study. The following chapter will provide a detailed description of the philosophical framework used to guide this study and the methods that will be employed. The context of the Rivers to Reefs workshop is outlined and the demographic data of the participants is provided. A portion of the methods addresses the quantitative component with reference to the TSI instrument and the statistical analysis used to interpret the results. The qualitative component of the study employs a case study of six participants. The chapter concludes with a discussion of the limitations of the study, including subjectivities, error and bias.

# CHAPTER 3

# Methods and Methodology

## *The Purpose and Research Questions*

The purpose of this study was to examine the impact of the Rivers to Reefs/Coastlines program on teachers' science inquiry efficacy and subsequent classroom practice. The following depicts the research questions that were studied through this research:

### *The Research Questions*

Following participation in the Rivers to Reefs/Coastlines program:

1. What changes in inquiry efficacy can be measured?
2. What changes in inquiry-based science teaching practice are reported by participants?
3. What factors, as perceived by the participating teachers, facilitated or restricted their use of inquiry-based instructional practices in their classrooms?

## *Description of the Summer Workshop*

The Rivers to Reefs program is a fifteen-day residential program held at the University of Georgia's Marine Education Center and Aquarium (MECA) on Skidaway Island in Georgia. Participants are involved in intensive field and laboratory experiences dealing with water quality and topics related to Georgia's coastal marine environments. Instructors for the class include education faculty from MECA and the UGA College of Education as well as scientists from the Marine Technology & Outreach Center and the Shellfish Research Lab, research faculty from the

Skidaway Institute of Oceanography, and personnel from the Gray's Reef National Marine Sanctuary (NOAA) office. The scientific activities designed for the program are infused with pedagogy appropriate for the science instruction of middle and high school students.

The location of the Rivers to Reefs program on the Georgia coast offers a unique classroom for environmental studies. Opportunities are available to study Georgia's salt marshes, tidal estuaries, sounds, barrier islands and offshore reef systems. The biological communities that reside in these areas are living in a natural state of dynamic equilibrium. The learning opportunities afforded by this environment are exceptionally diverse. Participants are engaged in a multitude of inquiry experiences throughout the program that reflect each of the essential features of inquiry as defined by the NSES (Table 2.2). These experiences vary in the level of guidance and formality, allowing participants to experience a range of scientific inquiry. For example, participants create a transect of a nearby marsh. Participants are responsible for all data collection, including organism identification, population counts, and mud depth. Following the data collection, participants organize their findings and then communicate the identified trends in a visual representation of the transect. Other activities involve participants in authentic scientific research that is currently ongoing through the Institute of Oceanography or the Marine Sanctuary. Aboard the R/V Savannah, a vessel of the University National Oceanographic Laboratory System, participants collect data alongside scientists researching biological, chemical, physical and geographical characteristics of the estuarine and continental shelf waters off the coast of Georgia. Throughout the program, participants are engaged in or creating their own scientific questions. From these, they are given opportunities to gather and analyze data, or in some cases, analyze data that have been previously collected, and formulate explanations and conclusions. A syllabus and itinerary detailing the program can be found in Appendix A.

## *Philosophical Framework*

Crotty (1998) outlines four elements necessary for developing research: the epistemology, theoretical perspective, methodology and methods. Each element serves to inform the other to build the philosophical framework of the study. This section serves to illustrate the philosophy that guided this research study, each element addressed in turn.

### *Epistemology*

Maynard (1994) states that the epistemology provides the philosophical grounding that determines the kinds of knowledge that are possible (as cited in Crotty, 1998). This study is built upon two distinct epistemologies. As a life-long student of science, I believe that there is a Truth (capital T) that exists regarding natural and physical phenomenon. Our role as scientists and researchers is to attempt to discover this Truth. Regardless of our ability to uncover it at any point or declare its discovery as absolute, the Truth still exists in one indisputable, objective form. However, another truth (lowercase t) exists through our interactions and life experiences. Each individual constructs her/his own truth through the understandings she/he has come to acquire. Wilson (1997), illustrates truth as a "dynamic, changing truth bounded by time, space and perspective" (p.2). From my understanding that truth is an interpretation of information as it is filtered through our experiences and social interactions, the additional epistemology contributing to this study is constructivism.

Although many types of constructivism have been identified, (e.g., radical, social, physical, postmodern and evolutionary), this study specifically draws from social constructivism. Littlejohn (1992) states, "People communicate to interpret events and to share those with others. For this reason it is believed that reality is constructed socially as a product of communication…. Our meanings and understandings arise from our communication with others" (p.190-191).

It is through this lens that I approached the study of teachers' construction of the definition of inquiry and its usefulness to classroom practice. I believe that the understanding of the concept of inquiry, in the case of educators, is built upon their experiences as a student. It is through the social act of learning that they first construct these understandings and apply value to its use. And through the act of teaching, they may reconstruct them. Due to the social nature of both the Rivers to Reefs/Coastlines program and the structure of teaching, it seems appropriate to address the social component of the teachers' interpretations of inquiry and the application of it in their classroom.

### *Theoretical Perspective*

The theoretical perspective is the philosophical stance that informs the methodology (Crotty, 1998). The theoretical perspective that framed this study is interpretivism. Crotty (1998) states that interpretivism "looks for culturally derived and historically situated interpretations of the social life-world" (p, 67). Rooted in the works of Max Weber (1864-1920), interpretivism takes the research perspective of Verstehen, or understanding.

Within the perspective of interpretivism, this research is guided by symbolic interactionism. Based on the constructionist views of George Hebert Mead, Hebert Blumer developed the term symbolic interactionism (McClelland, 2000). Blumer outlined three basic assumptions of symbolic interactionism:

1. Humans act toward things on the basis that these things have for them
2. The meaning of such things is derived from and arises out of the social interaction that one has with one's fellows
3. These meanings are handled in and modified through an interpretive process by the person dealing with the things he encounters

(as cited in Crotty, 1998, pp. 72)

Viewed as a subset of social constructivism by the researcher, the three core concepts of symbolic interactionism- meaning, language and thought, provide the basis for the research into teachers' interpretation and use of inquiry in their classrooms.

### *Methodological Perspective*

This research employed a mixed methods design to add depth and breadth to the study. Five general purposes of using mixed methods have been identified: triangulation, complementarity, development, initiation, and expansion (Greene et al., 1989; Rossman & Wilson, 1985). Greene et al. (1989) has stated that every mixed methods study can utilize one or more of these purposes. This study used the mixed methods approach as a means of triangulation, complementarity, and expansion. Denzin (1978) offered the principle of triangulation because he felt "no single method ever adequately solves the problem of rival causal factors….Because each method reveals different aspects of empirical reality, multiple methods of observations must be employed." In the case of this study, findings are triangulated through a use of multiple methods as well as mixed methodologies. Furthermore, the additional sources of data served to elaborate and enhance findings from each method used. Complementarity is achieved by the overlapping results from the TSI and the case studies to address teachers' beliefs about their ability effectively utilize inquiry strategies in their classroom. The combination of quantitative and qualitative measures allowed a comparison of professed beliefs of inquiry as a construct and inquiry in the practice of their classroom.

## *Methodology*

This study aimed to measure teachers' beliefs regarding their use of inquiry in the classroom and how their beliefs are related to the usage of inquiry as a result of participation in the River to Reefs/Coastlines program. In order to investigate this complex issue in its natural setting, a case study approach will be used. Yin (1994) defines a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 13). This approach will be appropriate for this study in that it will allow me to take into consideration the contextual conditions of the teacher’s instruction through an in-depth, holistic investigation rather than simply observing their practice (Feagin, Orum, Sjoberg, 1991). Using case study as the research strategy, I was able to draw upon multiple sources of data. In addition, case studies allow easy infusion of both qualitative and quantitative methods (Yin, 1994).

### *The Methods*

#### *The participants.*

Enrollment for the program will consisted of 32 inservice and preservice teachers from throughout Georgia for the summers of 2005 and 2006, with 16 each summer session. Recruitment for participants of the R2R program relied mainly on past participant referrals and posted fliers within the College of Education. Presentations advertising the program were given at a conference for a state teacher association and an informative letter sent out through the association’s listserv. Participants for the program were selected by a university professor associated with R2R as well as instructors of the program. Selection of teacher participants for the program was structured to allot one half of the class to current graduate students that may or may not be currently teaching and the other half to practicing teachers not enrolled in classes. Careful attention was also paid to create a population that represents the elementary, middle and high school levels as well as diverse disciplines of science instruction, years of experience and various geographical areas of Georgia. Participants are eligible to receive either six graduate credits or twelve staff development units upon completion of the fifteen-day workshop. Demographic information regarding the participants is illustrated in Table 3.1.

For the qualitative portion of the study, case studies of six of the participants were conducted. Participants were purposefully selected by soliciting teachers in the R2R program that were secondary science instructors representing middle school and high school instruction. Extensive interaction with participants during the program also aided in identifying those who would be amenable to participation in a year long research project. Initial research had intended to sample elementary teachers, as well. However, current reform efforts have impacted the elementary school teachers who participated in the R2R program in that the whole of their instruction was reported to focus almost entirely on reading and mathematics. An additional elementary teacher who initially volunteered for the study taught at a private school where a science specialist was employed to instruct science. Due to this lack of applicability of the program in terms of science instruction, specifically use of inquiry for science instruction, as well as the requirement of elementary teachers to teach most, if not all of the core classes, the decision to refocus solely on secondary instructors for the qualitative portion of the study was made.

Table 3.1

Demographic Information of Participants

| Participant # | Male Female | Years Experience | Grade Level | Science Course | Education Level |
|---|---|---|---|---|---|
| 1 | F | 1 | 9 | Biology | MEd* |
| 2 | M | 16 | 11 & 12 | AP Physics | PhD* |
| 3 | F | 3 | N/A | N/A | PhD* |
| 4 | M | 5 | 2 | Elementary | MEd* |
| 5 | F | 2 | 10 | Biology | MEd* |
| 6 | F | 0 | 7 | Life Science | MEd* |
| 7 | M | 4 | N/A | N/A | MEd* |
| 8 | F | 0 | 7 | Life Science | MEd* |
| 9 | F | 17 | 9-12 | Biology | MEd |
| 10 | F | 12 | 8 | Earth Science | PhD* |
| 11 | F | 0 | 9-12 | Physics | MEd* |
| 12 | F | 3 | 8 | Earth Science | MEd |
| 13 | F | 1 | 10 | Biology | MEd* |
| 14 | F | 8 | N/A | N/A | PhD* |
| 15 | M | 1 | 9 | Physical Science | MEd* |
| 16 | M | 0 | 9 | Physical Science | MEd* |
| 17 | F | 4 | Elementary | Elementary | MEd* |
| 18 | F | 5 | 7 | Life science | MEd* |
| 19 | F | 1 | NA | NA | MEd* |
| 20 | M | 12 | NA | NA | PhD* |
| 21 | F | 2 | Elementary | elementary | MEd* |
| 22 | F | 1 | NA | NA | MEd* |
| 23 | F | 9 | Elementary | Elementary | EdS* |
| 24 | M | 13 | 8 | Social studies | MEd |
| 25 | M | 3 | 9-12 | Chem Bio and Physical Sci | MEd |
| 26 | F | 30 | 9-12 | ESOL Environmental Sci, Bio and Physical Science | MEd |
| 27 | F | 12 | 8 | Earth Science | MEd |
| 28 | F | 1 | 9 & 10 | Physical Science & Biology | MEd* |
| 29 | F | 27 | 8 | Earth Science | MEd |
| 30 | F | 10 | NA | Ed Coordinator | MEd* |
| 31 | M | 10 | 12 | Human Bio and AP Bio | PhD* |
| 32 | F | 5 | NA | NA | PhD* |

* degree in progress at time of study

Further selectivity of participants was made to not include first year teachers. First year teachers commonly have to struggle with learning the routines of a new school and may lack in pedagogical content knowledge (PCK). First described by Shulman, PCK includes the "most useful forms of representation of these ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others…. Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons." (Shulman, 1987, p. 9). The pedagogical knowledge base for teachers is developed over years of preparation and teaching experience in the classroom (Clermont, Borko, & Krajcik, 1994). New teachers have few of their own teaching experiences to draw upon (Tippins, Kagan, & Jackson, 1993). For this reason, I felt that the impact of the program would be easier to measure in experienced teachers who may be more comfortable in school routines and with their current resources to make changes. In addition, the beginning teacher has no real point of reference to compare the impact of the program. Demographics for the participants in the qualitative portion of the study are summarized in Table 3.2.

Table 3.2

*Teacher Participant Overview*

| Pseudonym Ethnicity Degree | Years Experience | Grade Level | Science Course Currently Teaching | School Context |
|---|---|---|---|---|
| Gina<br>White<br>M.Ed. completed | 30 | High school | Environmental Ed, Biology, Physical Science | Public Suburban<br>49% White<br>8% Black<br>40 % Hispanic<br>2% Asian |
| Sally<br>White<br>M.Ed. in progress | 1 | High school | Physical Science and Biology | Private Parochial Suburban<br>75% White<br>10% Black<br>8% Hispanic<br>7% Asian |
| Jeff<br>Male<br>Ph.D. in progress | 16 | High school | AP Physics | Public Suburban<br>64% White<br>19% Black<br>11% Hispanic<br>4% Asian |
| Rosie<br>A.A.*<br>Ph.D. in progress | 12 | Middle school | Earth Science | Public Suburban<br>46% White<br>20% Black<br>10% Hispanic<br>22% Asian |
| Rachel<br>White<br>M.Ed. in progress | 3 | Middle school | Earth Science | Public Suburban<br>27% White<br>40% Black<br>22% Hispanic<br>6% Asian |
| Carolyn<br>White<br>M.Ed. completed | 17 | High School | Biology | Public Magnet for Fine Arts<br>47% White<br>41% Black<br>2% Hispanic<br>6% Asian |

*African American

*Science inquiry efficacy.*

The foundation of this study is centered on the effects of the River to Reefs/Coastlines teacher workshop on teachers' inquiry efficacy. The quantitative data were collected through the use of the Teaching Science as Inquiry instrument (TSI) (Dira-Smolleck, 2004) in a pretest, post-test and delayed post-test format to ascertain any measurable changes in inquiry efficacy as a result of participation in the program. The instrument can be found in Appendix B. This instrument was chosen because of its specific focus on efficacy in regards to the use of inquiry in classroom practice as opposed to alternative general efficacy scales such as the Science Teaching Efficacy Belief Instrument Form A (STEBI Form A, Riggs, 1988) and Gibson and Dembo's Teacher Efficacy Scale. Although designed and tested specifically for elementary level teachers, review of the survey questions found no individual questions to be specific only to elementary level teachers.

The TSI was designed by Lori Dira Smolleck based upon the work of Bandura (1977), and Enochs and Riggs (1990). Using Bandura's theoretical framework of self-efficacy, the TSI aims to analyze the two dimensions of self efficacy beliefs as defined by Bandura: personal self-efficacy and outcome expectancy. The instrument consists of 69 Likert scale items which were modeled after those used in the STEBI A and STEBI B (Riggs, 1988; Enochs & Riggs, 1990). Possible responses for each item included (1) Strongly disagree, (2) Disagree, (3) uncertain, (4) agree, (5) strongly agree. Survey questions are also categorized based on the essential elements of inquiry as outlined by the NSES (1996) and illustrated in Chapter 2, Table 2.2. In creating the TSI, Coefficient Alpha values for the TSI subscales, used to measure internal consistency, ranged from .6034 to a .7833. Specific internal consistency data is provided in Appendix C. This range meets the requirements established by Nunnally (1978) with most results also meeting the more rigorous standards set forth by Anastasi and Urbina (1997). The TSI was determined to be a construct and content valid instrument through multiple reviews and revisions of nine versions of the survey (Dira-Smolleck, 2006).

The study consisted of two separate groups participating in R2R over two consecutive summers. Therefore, it was important to determine if any significant differences existed between the two groups in the pretest before combining them for further analysis. The composite variable was determined for group 1 to be 251.5 and group 2 to be 234.4. This difference was not significant: $t(24.4) = 0.94$, $p = .3540$. Reliability for the TSI was also analyzed using standardized values to account for the wide variability of some of the variables. Standard alpha values ranged from .977 for the full 69-item survey to a low of .870 for Essential Feature 3. Exceeding the value of .70 established by Nunnally and Bernstein (1994), the TSI can be considered internally consistent. Complete analysis of internal consistency for each variable may be located in Appendix D. The high value determined for internal consistency for the full 69 item survey allowed the researcher to analyze mean differences in the scope of a unifying concept of inquiry efficacy even though consistency values determined by Dira-Smolleck (2004) were intended for analyses of the subcomponents in particular.

On the initial day of the workshop, the purpose of the study was explained and volunteers for participation were solicited. Initially, all participants agreed to participate in the survey portion of the study and were then administered a consent form outlining the expectations of their participation and explaining their rights to withdraw at any time. It was disclosed that participation or refusal would have no effect on teachers' grades or staff development units (SDUs) for the workshop. The TSI was administered to all willing participants on the first day of the program and again on their final day. Data collected were analyzed through two-tailed, dependent group t-tests using SAS.

*Theory to practice translation.*

Data collection and management for the qualitative portion of this study was conducted under the guidance of a data collection matrix (LeCompte & Preissle, 1993). Table 3.3 illustrates the planning matrix that was used, outlining and expanding upon the research questions, the data needed to address these questions, the source of the data and analysis methods to be employed.

Table 3.3

*Data Collection Planning Matix*

| Guiding Question | Needed Data | Source of Data | Data Analysis Method |
|---|---|---|---|
| What is the teacher's interpretation of inquiry? | Interviews, lesson plans, artifacts | Teacher | Interviews, observations, field notes. Constant comparative analysis. |
| What are the teacher's prior learning experiences? | Interview | Teacher | Interview. Constant comparative analysis. |
| How are teachers using inquiry in their classrooms? | Interview, observations, artifacts | Teacher | Interviews, field notes from observations and notes on artifacts. Reflection with STIR instrument. Constant comparative analysis. |
| What factors within the school structure facilitate or prohibit | Interviews, documents | Teacher | Interviews. Constant comparative |

| | | |
|---|---|---|
| use of inquiry in their classroom? | | analysis |

(Adapted from LeCompte & Preissle, 1993, pp. 51-53)

*Interviews.*

Interviews supplied the main source of qualitative data for this research. All interviews were audio recorded and transcribed. Transcriptions were coded using constant comparative analysis methods to identify themes and patterns. Further explanation of analysis is given in the Data Analysis section.

Each of the six teachers selected for the case studies participated in two to three separate interviews. The first interview for each teacher was conducted late in the fall following participation in the R2R program. The second interview was conducted in the spring semester as a follow-up to gather further information, clarify responses from the previous interview and to collect additional artifacts. These interviews followed a semi-structured format and sought to identify the participants' interpretation of inquiry and how they understood it to be implemented in the program. In addition, questions were guided to glean an understanding of classroom practices prior to participant enrollment in R2R as well as any use of inquiry activities or anticipated use of inquiry activities in the upcoming school year.

The final interview with each participant was conducted using the Science Teacher Inquiry Rubric (STIR) as a reflective tool. Developed by Beerer & Bodzin (2004), the STIR was designed to assist teachers in understanding and implementing inquiry based science instruction. The STIR was derived from Web-based Inquiry for Learning Science (Bodzin & Cates, 2002) and outlines the five essential features of inquiry instruction and their variations as provided by the NSES (2000). The STIR varies in that the language is "simplistic" and translates the features given by the NSES and translates them into teaching descriptors (Beerer & Bodzin, 2004).

Lesson plans that were provided as artifacts or discussed were revisited and the participant was asked to place these items within the rubric as they deemed most appropriate. Discussion continued regarding their current teaching practices and where they felt they most often fit within this rubric. Participants were asked to explain reasons for choosing, or feeling restricted to their placement on the rubric. Within the case studies, their choices are compared to their scores on the similar variations of the essential features for elaboration and triangulation.

*Artifact collection.*

During the course of the school year, artifacts were collected to further illustrate the teachers' interpretation of inquiry and their use of it in their classrooms. Artifacts that were collected included lesson plans, project assignments, class assessments and examples of student work. Each artifact collected was tagged with an identifier indicating the teacher and date of collection. These artifacts were selected by the participating teacher as evidence of lessons they either created or modified as a result of participation in the R2R program. These artifacts were used as a tool of reflection in a subsequent interview.

*Data analysis.*

Interviews were transcribed and coded, using constant comparative analysis (Glaser & Strauss, 1967) Bogdan & Biklin (1982), stated that in data analysis, " certain words, phrases, patterns of behavior, subjects ways of thinking, and event stand out" (p.166). These ideas or events that stood out were coded using Strauss and Corbin's (1990) open coding method. The resulting codes were then organized into themes.

Themes uncovered during the coding and analysis process were verified through dissemination of themes with participants via email correspondence. Participants were asked to review the themes and provide feedback. Once each teacher's data were analyzed, cross case analysis was conducted to identify themes shared by all the participants.

## *Subjectivities*

As an experienced practicing teacher and a doctoral student at the university where many of the participants have some type of affiliation (e.g., current student, alumni, employment, etc.), it is important to address my subjectivies in association with this research. Almost every teacher in public school has had his/her classroom practice observed and critiqued by an administrator or mentor teacher. Having experienced this myself, I can attest to the sense of being judged by someone that doesn't see my class on a daily basis and may only see a very small and possibly misrepresentative portion of my classroom practice. Many of the participants in the R2R program are in their earlier years of teaching and may have felt intimidated by my presence in their classroom or by the line of questioning about their practices. It was important for me to assure them that in no way was I there to assess the quality of their work. In contrast, I was merely taking note as to the type of instruction used and to get their valuable insight into their interpretations of inquiry as a result of the R2R program. I feel that my participation in the portion of the program along with them gave them an opportunity to view me more as a student and peer, increasing their comfort level with me.

In addition, through my experiences as a science teacher and graduate student, I have formulated my own constructs of inquiry teaching. Keeping my personal conceptions from influencing the participants or my analysis of their interpretations was an important aspect of this study.

## *Ethical Considerations*

Approval for research was obtained by the Institutional Review Board of the Human Subjects Office at the University of Georgia. Signed consent was also obtained by each participating teacher. Confidentiality of each participant and interviewee was carefully protected through the use of pseudonyms. In addition, all data were privately kept in the researcher's possession.

## *Limitations of the Study*

This study did not examine participant classroom practice prior to taking part in the R2R program. Therefore, modifications to practice as a result of the program are measured solely on self-reporting by teachers.

One of the major voids in inquiry research is in the domain of student science learning from teacher-designed, inquiry based instruction (Keys & Bryan, 2001). Although the program aimed to ultimately improve student achievement as a result of participation in the program, this study does not address this facet.

The TSI, although a construct and content valid instrument with high internal reliability, was designed to measure inquiry efficacy of prospective elementary teachers specifically. Additional norming and/or the development of supplemental forms of the TSI that address practicing secondary science teachers would be useful for future research into inquiry efficacy.

Both the TSI and the qualitative portion of this study rely heavily on self-reported data from the participants. In doing so, two related concerns must be prudently addressed: social desirability bias and halo error. In regards to assessing teachers' beliefs, in this case about scientific inquiry and inquiry as an instructional tool, it can be argued that outside sources are incapable of knowing what a person believes better than the actual person (Gonyea, 2005; Pace, Barahona, & Kaplan, 1985). However, what a person believes and what he/she conveys to the researcher may be altered by the respondent's desire to portray a positive image (Beretvas, Meyers, & Leite, 2002; Gonyea, 2005; Nancarrow & Brace, 2000). This may also be evident in their reported actions. It is important that research that employs self-reporting use methods of triangulation to verify participant responses. The halo error is of particular concern with regard to the administration of the TSI. Explained by Thorndike in 1920, the halo error is the tendency of a participant to give consistent responses across a set of items based on their general perception of the survey. Although tested for validity and reliability by both the designer of the instrument and the researcher, halo error must be taken into consideration due to the length of the survey and the complexity of the construct on inquiry.

### *Summary*

This chapter details the research questions and methodological framework that guided this research. Within the mixed method structure, each approach is discussed. Descriptions are provided about the Rivers to Reefs/Coastlines program and the teachers participating in the extended portion of the research. Detail is given regarding each of the methods used to address the research questions. Conclusion of this chapter highlights the limitations of the study. In the chapters to follow, I submit the cases for Gina, Sally, Jeff, Rosie, Rachel, and Carolyn respectively.

# CHAPTER FOUR

## Findings: Inquiry Efficacy

### *Quantitative Results of the TSI*

Analysis of the TSI data was conducted using the SAS (1999) program. Participants were assigned a number to indicate their identity and identifiers of years experience, gender, grade and subject taught were included. Scores on the pre-test, post-test and delayed post-test were entered as 1 through 5 to indicate their response for each item. Although the program had an N(32), several participants failed to complete all 69 questions on each of the surveys. Missing data in research can reduce sample size, decrease statistical power and bias estimates (Roth, 1994). Missing data can be especially problematic in any repeated measures design, whereas a missing measurement of items at one data collection could result in a loss of all of the subject's data (Laird, 1988, Roth, 1994). Considering approximately one-third of the sample population failed to answer some portion of the survey items, it was important to address the issue of missing data.

There were twelve participants who had missing data. Careful analysis of the unanswered items revealed that six of the participants skipped entire pages of the survey or had no data at all for one or more of the survey administrations. Participant 27 declined to complete the pretest, answering only five questions. Comments written in the margins of the TSI indicated her desire not to participate further in the surveys. Participant 13 completed the pretest as well as the delayed post, but no data were given for the post-test. This was also the case for participant 25 and 30. Participants 19 and 23 completed the pretest and post-test but were unable to be located by the researcher to complete the delayed post-test. Participant 9 failed to answer 18 questions on the post-test. Participants 10, 14, 20 and 32 each left only one item blank. In each of these cases the items left blank appear to be unrelated, indicating that the item may have been overlooked or misunderstood or challenging only to the individual participant. Table 4.1 outlines the surveyed items that were not answered.

Table 4.1

*Missing Survey Items*

| Participant | Pre-test | Post-test | Delayed Post-test |
|---|---|---|---|
| 9 | - | 32-34, 36, 37, 40, 42, 46,49,52,53, 55, 59, 60, 62, 65, 67, 68 | - |
| 13 | 64-69 | 1-69 | - |
| 14 | 1-57 | - | - |
| 17 | - | - | 4, 24 |
| 19 | - | - | 1-69 |
| 20 | - | 50 | - |
| 23 | - | - | 1-69 |
| 25 | - | 1-69 | - |
| 27 | 4, 7-69 | 1-69 | 1-69 |
| 29 | 46 | - | - |
| 30 | 47, 49 | 1-69 | - |
| 32 | - | 8 | - |

The missing data were addressed individually using the methods outlined by Roth (1994). In the cases of participants 13, 14, 19, 25, 27 and 30, greater than 25% of the data was missing.

At this level, implementing missing data techniques could result in dramatically different results (Stumpf, 1978). It was decided that despite sacrificing large amounts of data, this data would be of limited use and should be removed entirely from the analysis (Malhorta, 1987). The remaining participants in question with the exception of participant 9 were missing less than 3% of the data. In addition, the items left blank were missing completely at random. Roth (1994) asserts that any missing data technique would be appropriate for analysis of participants with 5% or less of missing data. Additional literature states that the there is little difference in the results when using various missing data techniques (MDT) if the number of missing data is small and in random patterns (Frane, 1976; Gilley & Leone, 1991; Kaufman, 1988; Raymond & Roberts, 1987).

This research was based on a repeated measures design and therefore allows the researcher to have data points on the same measurement given at different times. Additionally, the TSI is designed such that questions are categorized according to the five essential features of inquiry as outlined by the NSES. These items are typically highly correlated and can be used to interpolate the missing data value from the nearest points of the same variable. Statistical tests performed by the creator of the TSI as well as the researched verify the correlation of survey items. A detailed report of these values may be found in Appendix E. Therefore, this approach was used to estimate a value for the missing data for participants 10, 14, 20 and 32. For each of the participants, the missing datum was identified by its subcategory. The mean for the participant for that category excluding the missing item was calculated and the resulting value inserted. The calculated mean was determined using only the values for the subcategory for the particular survey administration where items were missing. Missing data for post-test items were interpolated using the subcategory means for that participant's post-test scores. Participant 9 had eighteen missing items from the post-test survey. Although this borders the 25% limited outlined by Roth (1994), as a case study subject, it was deemed important to attempt to keep her data. Furthermore, in identifying the items omitted, it was revealed that they were evenly distributed in the subcategories of the TSI. Thus, values could be determined using the means of the other subcategory items that were answered. Given that more insight could be gleaned from the qualitative portion of this study, the decision to interpolate the missing item values was made using the same previously mentioned approach.

### *Pretest Baseline Data*

Individual items means on the pretest ranged from a low of 3.033 (1.217) for item 54, to a high score on item 8 of 4.533 (.6288). This illustrates that on a whole, the participants were already operating on an efficacy level at or above the median level. Due to the nature of recruitment of participants for the R2R program, all of the participants have completed, or are in the process of completing advanced degrees. These findings parallel the research that suggests that self-efficacy is positively correlated with the level of education (Bandura, 1977; Riggs & Enoch, 1990).

### *Post Workshop Results*

To determine if the R2R program resulted in any measurable difference in inquiry efficacy of participants, two-tailed, dependent t-tests were run using SAS. For the purposes of this study, standard deviation values will be presented in parentheses following any measure of means or difference in means within the text.

Analysis was conducted comparing the means of scores on the composite of all sixty nine questions on the pre-test and post-test (n=27). Results indicate that there was a statistically significant difference in pre-test and post-test TSI scores with an increase of a mean of 20.659

points (34.606), p = 0.0046. Further analysis included t-tests of the difference of means of questions broken down into Personal Self Efficacy and Outcome Expectancy subcategories. Again, statistically significant increases were found and at nearly equal values: 10.963 (19.056) and 9.462 (15.849) points respectively. Increases were also significant in pre-test and post-test scores of each of the Essential Features as well as each of the Variations with the exception of Variation D, with a p value of 0.513. The largest increase in item means were found in Essential Feature 2: Learner gives priority to evidence in responding to questions and in Variation A and B, demonstrating a gain in efficacy on the student -directed side of the inquiry continuum. Table 4.2 outlines the difference in means between each administration of the TSI. Complete analysis of the TSI subcomponents are provided in Appendix F. Although further research would be merited to confidently eliminate possible confounding factors, these results provide a foundation that tentatively suggests that participants were positively impacted by participation in the authentic scientific inquiry provided by the R2R program.

Table 4.2
*Difference in Means*

| Label | n | Difference in Means | Standard Deviation | t value | p value | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| Posttest – Pretest | 27 | 20.659 | 34.606 | 3.10 | .0046 | -16 | 133 |
| Delayed Posttest – Pretest | 26 | -6.169 | 43.753 | -0.72 | .4789 | -160 | 51 |
| Delayed Posttest-Pretest w/o outlier 28 | 25 | -0.015 | 31.124 | -0.00 | .9981 | -74 | 51 |

In reviewing the change in individual survey item means from pretest to post-test, only one item showed a loss in mean value: item 47. The measured loss is slight, with a difference in means of -.019 points (0.904) and is not statistically significant (p = 0.9). Items 38 and 62 reveal no change in means from participation in the R2R program. These items are detailed in Table 4.3. Complete item analysis may be found in Appendix G. In items 38 and 62, the participant mean on the pretest was already scoring above a four, indicating an above median efficacy for their ability to conduct these tasks with their students. The lack in significant change in item 47 was puzzling whereas this item is subcategorized in Essential Feature 2, which showed the greatest increases overall.

Table 4.3

*No Gain Items Post-test - Pretest*

| Item | Label | Mean Pretest | Mean Post-test | Difference in Means |
|---|---|---|---|---|
| 38 | I will be able to provide demonstrations through which students can focus their queries into manageable questions for investigation. | 4.200 (0.846) | 4.25 (0.752) | 0 (1.074) |
| 47 | My students will analyze data that has been supplied, while following teacher instruction. | 3.850 (1.108) | 3.875 (1.068) | -0.019 (0.904) |
| 62 | I will be able to model for my students the guidelines to be followed when sharing and critiquing explanations. | 4.194 (0.703) | 4.286 (0.763) | 0 (0.769) |

* Different n occur for the calculation of pretest, post-test and difference in means values, therefore, values in this table represent the SAS output

Studies indicate that the impact on efficacy from professional development is greatest on those who begin with the lowest efficacy beliefs (Riggs, 1995; Roberts, Henson, Tharp, & Moreno, 2001). This is consistent with the results found in this study. The three lowest pretest scores also showed the highest gains in the post-test measure. Participant 4 scored 171 out of a possible 345 on the pretest, increasing 62 points on the post-test. Participant 17 scored 178, gaining 133 points and participant 21 gained 97 points increasing from 215 on the pretest to 312 on the post-test survey. It is interesting to note that all of these three participants are first and second grade teachers. Conversely, the top two highest scores: participants 7 (318) and 20 (337), actually measured losses in inquiry efficacy on the post-test. In fact, with reductions of 14 and 16 points respectively, they showed the largest deficit on the post-test survey.

### Stability of Changes in Efficacy

To determine if these gains in measured inquiry efficacy were stable, a delayed post-test was administered during the second semester following participation in the R2R program. A comparison of means revealed that increases gained following participation in the program were consistent over time. Results show a loss of six points overall but this was determined not to be a significant difference in means ($p = 0.479$). As with the comparisons between the pretest and post-test, analyses were conducted looking at each of the subcategories of the TSI, each showing no significant change in value. Full analyses can be found in Appendix F. In conducting the t-tests of the post-test and the delayed post-test, one participant emerged as an outlier, with a drop of 160 points between the post-test and delayed post-test. The outlier, participant 28 was identified as Sally, one of the case study participants. Investigation into her dramatic drop in perceived inquiry efficacy were addressed during her case study and are addressed at length in the Chapter 8 cross-case analysis. Even though results of the t-test for the delayed post and post-test difference of means were already determined not to be significant with the inclusion of the data from participant 28, an additional t-test was performed (n =25) removing her as an outlier. In removing Sally's data, the difference in means of the overall composite score changed from a drop of 6.169 points (43.753) to a drop of 0.015 (31.124), again attesting to the stability of the efficacy gains. Item analysis of the delayed post and post-test surveys yields that only item 64 dropped a statistically significant amount. The post-test mean for this item was calculated as 4.107 (0.875) and a delayed post-test value of 3.552 (0.985) with a reduction in means of .500 (1.105), p = 0.029. Delayed post means ranged from a low of 3.103 (1.291) to a high of 4.586 (0.907).

Individual stability of efficacy varied, with some participants increasing over time while others measured loss. Table 4.4 highlights each participant's difference in means on the pretest and post-test measurement as well as the post and delayed post-test survey. Eleven participants showed increases in efficacy over the course of the months following the R2R program while fourteen measured decreases. No clear pattern could be established between the participants who increased in efficacy over time in comparison to those who showed loss. Comparisons of difference of means with variables such as years of experience, level of instruction and degree held yielded no discernable pattern or parallels.

Table 4.4

*Individual Difference in Means*

| Participant | Pretest/Post-test | Post-test/Delayed Post-test | Years Experience | Level of Instruction | Degree |
|---|---|---|---|---|---|
| 1 | 1 | 14 | 1 | H | MEd* |
| 2 | 28 | -25 | 16 | H | PhD* |
| 3 | 12 | 39 | 3 | N/A | PhD* |
| 4 | 62 | 0 | 5 | E | MEd* |
| 5 | 35 | -12 | 2 | H | MEd* |
| 6 | 5 | 4 | 0 | M | MEd* |
| 7 | -14 | 13 | 4 | N/A | MEd* |
| 8 | -6 | -15 | 0 | M | MEd* |
| 9 | -4 | 13 | 17 | H | MEd |
| 10 | 8 | -8 | 12 | M | PhD* |
| 11 | -14 | 43 | 0 | H | MEd* |
| 12 | 26 | -21 | 3 | M | MEd |
| 13 | - | - | 1 | H | MEd* |
| 14 | - | -17 | 8 | N/A | PhD* |
| 15 | 18 | -15 | 1 | H | MEd* |
| 16 | 48 | -60 | 0 | H | MEd* |
| 17 | 133 | -32 | 4 | E | MEd* |
| 18 | 10 | -9 | 5 | M | MEd* |
| 19 | 44 | - | 1 | NA | MEd* |
| 20 | -16 | -10 | 12 | NA | PhD* |
| 21 | 97 | -74 | 2 | E | MEd* |
| 22 | -4 | 51 | 1 | NA | MEd* |
| 23 | 39 | - | 9 | E | EdS* |
| 24 | -4 | 33 | 13 | M | MEd |
| 25 | - | - | 3 | H | MEd |
| 26 | -36 | 39 | 30 | H | MEd |
| 27 | - | - | 12 | M | MEd |
| 28 | 3 | -160 | 1 | H | MEd* |
| 29 | -3 | 13 | 27 | M | MEd |
| 30 | - | - | 10 | NA | MEd* |
| 31 | -5 | 40 | 10 | H | PhD* |
| 32 | 23 | -4 | 5 | NA | PhD* |

*Participants whose data was removed from analysis due to incompletion are represented by a dash (-). Level of instruction is listed H for high school, M for middle and E for elementary. NA applies to those not teaching. An asterisk is shown for degrees in progress at time of survey.

## *Summary*

Quantitative analysis of the TSI results of participants indicates that statistically significant gains in inquiry efficacy are achieved overall following participation in the R2R program. Furthermore, these gains can be considered stable over the course of a school year following the program. The following chapters will take a closer look at the individual efficacy changes of six participants. The in-depth study of these cases will serve to illustrate how these measured changes in inquiry efficacy are translated into classroom practice. They will also identify perceived conditions that either hinder or aid in implementing inquiry activities in their classroom.

# CHAPTER 5

## Introduction to the Case Studies

### *Participant Case Vignettes*

### *Case Studies*

The case study approach is one way to address "how" and "why" questions in research (Yin, 1994). The use of the TSI measured a significant change in the beliefs of teachers in their ability to use inquiry as a teaching and learning strategy following participation in the R2R program. This study, however, also addresses how this translates to classroom instruction. One method to approach this could have simply involved a tabulation of the newly generated or modified inquiry lessons used by the participants. However, the researcher recognizes that inquiry exists on a continuum. Data collection that was limited to mere numbers would not provide a depth of understanding of where on this continuum these teachers feel they are able to operate in the traditional classroom. Furthermore, this study identifies the impediments that these participants feel may limit their use of inquiry or the conditions that support its use. It was felt that quantitative analysis alone, was insufficient to adequately address the research questions.

According to Yin (1994, p. 134-135), multiple case reports can be addressed using various formats. Cases can be presented as multiple narratives, with each case receiving its own chapter or section followed by a separate cross-case analysis. Other reports may be structured to follow a framework of questions and answers. This research study will employ yet another alternative in which the bulk of the findings are presented as the cross-cases analysis. During the coding process, several themes emerged repeatedly. To avoid redundancy of addressing these themes separately in each of the cases, the use of the cross case analysis as the medium for presenting the findings of the research questions seemed most concise.

Most of the participants in the R2R program either had recently completed a higher degree or were currently working on one. The concept of inquiry is one that is commonly addressed in the science education graduate classes of these teachers. In consideration of the social bias factor, it is important to address the issue of whether or not these participants would feel comfortable speaking honestly regarding their practices and use of inquiry. They were aware of the focus of this research and might therefore have anticipated a value placed on the use of inquiry as seen by the researcher. To develop trustworthiness in this research, it was important to establish an emic relationship with the participants. If viewed as a peer, rather than a researcher, it was felt that they would feel more at ease expressing any perceived shortcomings in their use of inquiry and the obstacles hindering its further use in their classrooms. With this in mind, I spent the whole of the R2R program working alongside and affiliating with the participants. I discussed with them casually, my own experiences as a practicing teacher. In this regard, my research bordered on participant observation. Schensul, Schensul and LeCompte (1999) describe participant observation as "the process of learning through exposure to or involvement in the day-to-day or routine activities of participants in the research setting" (p.91). Although my observations of the enactment of lessons were limited, as a practicing teacher in the same county as many of the participants, I could certainly relate to the format and structure of their schools and school policies. Our shared stories and experiences served to form an environment of casualness, and it is hoped an atmosphere where participants felt comfortable sharing their perceptions and classroom practices.

In addition, trustworthiness was established using member checking (Erlandson et. al., 1993; Guba & Lincoln, 1989). Participant characterizations as well as results from the cross-case analysis were sent to each case member for their review to check for description authenticity and accuracy.

To create a foundational understanding of the participants, each is portrayed in an abbreviated characterization. Descriptions of their school environment, classroom structure and the courses taught are provided within the vignettes. Although this study did not seek to identify the conceptions of inquiry held by each participant, it was felt that providing a brief explanation and example of their understanding of inquiry may serve to create a richer contextual description from which to analyze the findings.

## *Participant Characterizations*

### *Jeff*

#### *Classroom context and instructional atmosphere.*

Jeff is an Advanced Placement Physics teacher in a suburban high school. The school is located in an upper middle class suburb of a major southern city. The school has recently been expanded and Jeff's room is housed in a newer portion of the building. Serving approximately 2000 students, 24% receive free or reduced lunch and 5% are of limited English proficiency. Jeff has taught at his current high school for 6 years. Classes consist of no more than 21 students and follow the traditional 50 minute period. Jeff teaches 3 AP Physics B and 2 AP Physics C courses.

To create a realistic understanding of Jeff for the context of this research, it may be best to begin with an anecdote from the R2R program. All participants were required to generate or modify a lesson that incorporated inquiry and infused some aspect of the content presented at or inspired by the program. Jeff's lesson, which will be addressed in further detail later in this case study, was presented in a Powerpoint slide show. With energy and vigor, Jeff explained how he would challenge his students to address the physics behind the oceanic tides. This quaint introduction to his topic was quickly followed by several slides containing mathematical equations of a complexity unknown and overwhelming to the majority of the now slack-jawed, participant audience. With a grin as wide as one of his equations, Jeff began to simplify the tasks and provide us with a clear vision of the goals of his lesson, if not the actual content. It was clear that Jeff was no ordinary physic teacher and his was no ordinary physics class.

An observation of Jeff's classroom also lends itself to understanding Jeff's philosophy of teaching and teaching style. Upon entering a spacious science room, rimmed with lab counters and cabinets, one immediately notices the movie posters that cover nearly every inch of available real estate on the walls. The majority are science fiction movies, such as the X-Files and Star Wars. The limited sizes of Jeff's classes allows for a more intimate and collegiate atmosphere. Lab tables are arranged in a U shape with a large couch positioned in the bottom of the U. At the time of my visit, a small class of eleven was pecking away feverishly on lap tops. Two students were sitting on the couch, two were perched on lab tables and Jeff monitored their activity from his desk. Even the arrangement of his desk suggests a more involved position with the students. Many science labs are equipped with a tall demonstration table with the teacher's desk abutted so the teacher has the position of power behind the segregating structure. Jeff's desk was situated in front of the demonstration table, making him more accessible to his students. On the corner of his desk sits a two foot tall trebuchet. Excitement and curiosity elicited in seeing this is quickly compounded when the five foot trebuchet in the corner comes in to view. Jeff's entire room is littered with a sundry of physics equipment:  refractive mirrors, student constructed wind mills and generators, and a bowling ball attached to a string.  Every corner invites investigation.

Perhaps most telling is a poster quoting Einstein: “Imagination is more important than knowledge”.  In talking with Jeff, it is clear that he places a tremendous amount of value in creativity and independent thinking.  This desire to foster imagination within the realm of science was also observed through Jeff’s frequent use of the introduction of new technology.  At the time of my visit, Jeff used the last five minutes of his class to show a CNN streaming video clip regarding a new non-lethal weapon that uses a laser pulse to generate a burst of plasma, stimulating nerve cells and causing temporary but excruciating pain.  Whether these topics directly relate to current class content or happen to be recently in the news, Jeff is able to demonstrate to his students how science is continually being applied in the world around them to create exciting and imaginative technology.  The response of the class indicated that his intention had clearly hit its mark in generating interest about science and igniting imaginations.

Jeff’s classes are unique in that he deals entirely with seniors.  In two of his classes, the students are taking their second year of physics.  Having students that are working on this level has afforded Jeff opportunities in his classroom that perhaps few other teachers can claim.  In addition, as an AP course, he can have maximum of only twenty one students.  Jeff admits that the limited class size, maturity and ability level of his students allow him a greater range of assignment possibilities than he may have teaching the college prep level.

> *I do get the chance to do more stuff like this with the second year students (inquiry lessons) because there is so much more time. I can be much more of a 'okay guys, do this. I'll be over here if you have any questions.' And wander around and keep an eye on them…. I try not to get in their way. The stuff that I can get away with in my ...both the*

> *first and second year classes because I have students that want to be here. They want to learn. They are not questioning the value of being here. They understand that this is going to make a huge difference, at least in their choices.*

*Conception of inquiry.*

Jeff defines inquiry as “anything where I am going out and investigating on my own and I don’t need somebody’s instruction”. This idea of inquiry as a freedom to pursue answers on one’s own is illustrated in one of Jeff’s assignments where his students are asked to create a generator.

> *… I tell students…I give them a four word project and then I give them no other guidelines at all. It’s ‘Build an electric generator.’. You have two weeks. It just freaks them out until they realize how incredibly simple it is. So that kind of inquiry, where they are cut loose and on their own.*

Jeff’s undergraduate degree was received in Physics as opposed to science education. This background in science and experience with scientific research has lent itself to his view of how questions should be addressed and answered in a science class. He expresses a frustration with the way scientific inquiry is typically portrayed in the classroom.

> *My pet peeve right now is that we are still teaching the scientific method, and there is no such thing. But it is part of the curriculum, it is part of the standards and that’s one of the things I like about my AP classes. I can walk in there, and the first week and tell the kids remember that scientific method thing? It’s a lie! Scientist do not use that. You march me a scientist in here and let me show this list to them and say ‘Do you really do this?’, I guarantee they will say ‘well, no. No I don’t.’ You know, obviously I run*

> *experiments, but it's not…. It's inquiry is what it is. They do not make that distinction like they should. They need to drop the whole scientific methods thing.*

The conception of inquiry for Jeff also includes an element of discovery. In reflection of his experiences on this coast, he illustrates several examples in which he felt he was participating in this type of inquiry. In one case, Jeff recalls one of the program's excursions to Osabaw Island. Participants of the program were given a guided tour by a local naturalist and encouraged to ask questions about their observations. Jeff states:

> *In doing that and just wandering around and being told that the shoreline used to be here. And being able to look for it yourself and see that, yeah, the dunes have built up from a little bit of grass and then it built this whole shoreline and it marched it's way toward the sea….And really guided discovery because I would have never noticed that some of the whelks were clockwise and some were counter clockwise if somebody hadn't pointed it out to me. Oh look! All of these wonderful shells, did you notice? No! I hadn't!*

Jeff's construct of inquiry seems to exist on a continuum, allowing for situations where the investigations are very unstructured, as with the generator project, to learning opportunities that are guided or directed by the instructor.

### *Gina*

#### *Classroom context and instructional atmosphere.*

Gina is a veteran teacher of 32 years. The last 21 have been spent at her current school, a public high school located in a growing suburban city in the southeast. With a population of approximately 1000 students, 40% are Hispanic, with 17% of limited English proficiency. Over one-half of the student body are eligible for free and reduced lunch. Gina teaches four classes of

English as a Second Language (ESOL) science, three of which are Ecology courses and one Biology course, each on block schedule.

There are two dominant characteristics that emerge in observing Gina's class: the limited English of her students and her frequent use of the outdoors as a foundation for lessons. Gina's classes have various levels of language learners. Not only is she dealing with ranges in student ability, but also great diversity in the primary language of each student as well as their level of English proficiency. Gina seems to have an insuppressible positive attitude and gives no indication that she feels her teaching could be hindered or limited by these challenges.

Gina's room is bright and sunny, with environmental posters and student work peppering much of the walls. With an affinity for frogs, their presence is noted in vibrant posters, various desk ornaments and the occasional beanie baby. Desks are arranged facing the front of the classroom and teacher demonstration table. Situated on one side of the classroom is a large table surrounded by chairs.

In talking with Gina, her love for the outdoors permeates into her classroom instruction. She typically takes her students outside for observations or activities about once a week, with the block schedule allowing for greater time for outdoor excursions. The campus is situated on a small parcel of wooded land with a stream cutting through the edge of the property. Upon one of my visits, the students were lead outside to an amphitheater embedded in the wooded area. They were playing the role of a naturalist and after spending the better part of an hour investigating and identifying several items, they were asked to sit quietly and sketch the amphitheater. This activity was designed to hone their observational skills and students were instructed to leave out no detail. While outside, the students were eager to mill about and ask Gina what they had discovered. Rocks were overturned and leaves torn from limbs for closer inspection. Their enthusiasm for the opportunity to be outside and investigate nature was surpassed only by Gina's.

One of the mainstays of Gina's science classes is the use of science journals. Students record their lab activities in the journals as well as field sketches from their trips to the outdoor classroom. During her experience in the R2R program, Gina noted the abundance of journals in the microbiology lab.

> *When we went over to the microlab that's there across the compound, what do they have? Every single one had those darn composition books and this was this month and this was this month…. I keep saying (this is) real science. I keep emphasizing real science and they want us to emphasize real science. Well, here it was staring me in the face. I thought, oh! I'm going to take this back to my kids too.*

Gina emphasizes several science skills in the journals that do not necessarily depend heavily on a strong grasp of English. As aforementioned, observation skills are frequently used, calling on students to count organisms in a particular area or to draw what it is they are seeing. Using the journals, Gina is able to employ what she feels is authentic science in a method that is accessible to her students.

*Conception of inquiry.*

Gina's construct of inquiry appears to center around questioning. She defines inquiry as "Questioning as to why something is, happens or is seen". To elaborate, she provides an example of a current topic her students are working on.

> *For a lot of the kids I pose the question, you know. Today the question was biomes, but we had already talked about it before you came. Because we had been doing biomes this week. I said, well what biome are we in? Well, we are in temperate deciduous forest.*

> *How do you know? Because you told us. Well maybe we need to go out and look at it and find out if it matches our description.*

Each of the many examples provided by Gina depicts inquiry in the context of a teacher-guided lab or activity. These activities each include a heavy emphasis on questioning. Students are given prompts to help direct their discovery of the intended concept and challenge misconceptions.

> *I mean it was like. No big deal. I know how to create labs that work with simple ideas and get the kids thinking. So eventually we will have to go out at least one more time to see the stream and get more of that detail…. Then when we discuss it we will discuss more about: How do you know this really is a temperate deciduous forest that we live in? Of course I know I'm going to hear, 'well duh, there were no leaves on the trees.' You know, and I know I'm going to get that as an answer real quick because of my emphasis. But then we will talk about what makes it. Why isn't it a coniferous forest? We've got pines. What's the difference? So you can just take those ideas with the kids and especially with the ESOL kids who don't have a lot of English.*

In addition to questioning, Gina explains how the labs and activities use inquiry. She states that, "Data collection of anything is always inquiry based because you don't know what you will find." Other examples of labs conducted in the outdoor classroom illustrate her use of data collection. Students were asked to capture and count crayfish in the stream. Gina recalls the excitement of her students as they waded knee deep into the stream.

> *In forty minutes they had to gather as many crayfish and salamanders as they could find. And if they could gather any of the water striders, you know, they had to gather anything that they saw moving in the stream or on the stream. They went crazy. They loved*

> *it….Gonzalo who speaks no English was the best crayfish seer, because they were only about this big and they were almost transparent….And they just, you know, it was like 'Miras! Miras! Look at this! Look at this!' So in forty minutes they were all over that stream and they were* ***in*** *it.*

Gina's classes are scaffolded to meet the language needs of her students. However, within her framework of guidance and directed questioning, the focus is on student discovery and construction of understanding. The excitement of what Gina describes as "digging in the dirt" is tangible and engages students that may otherwise withdraw from participation due to the struggle with the immense vocabulary associated with learning biological science.

### *Sally*

#### *Classroom context and instructional atmosphere.*

Sally is one of only two science teachers at a small, private parochial school located outside of a large, southeastern city. As such, she is charged with teaching five different science preps: Physical Science, Biology, honors Biology, AP Biology and Anatomy and Physiology. The school is exceedingly small in population in comparison to surrounding public schools. With a student body of approximately one hundred, her class sizes range from only four students in AP Biology to seventeen in Physical Science. Each class is sixty minutes long. Although students are enrolled in seven classes a semester, they are on a rotating schedule where they attend only six classes a day. Sally explains that this schedule actually allows for increased class time per week while providing the students with a break from the heavy course load of seven classes a day.

Her class is arranged in four rows of student desks facing the board and demonstration table. The perimeter of the room is lined with lab counters. Each counter is littered with activities from her various classes:  plants from a biology experiment on one side, while the back counter, splattered with a salt crust from a previously kept fish tank, holds boxes of equipment for future labs.  The right side of the room is fitted with a large window and a door leading to the back field where her classes keep a garden and several bluebird houses. Sally's desk is tucked into a nook in the front corner of her room, her chair framed by the corner walls and the desk, creating a sort of refuge from the rest of the classroom.  The school was established in 2003, and the contents of Sally's room reflect the recent construction, with new desks, quality counters, ample storage stocked with equipment and a squeaky clean brightness that seems absent in older schools.

Sally's background in zoology is evident in her copious use of nature as a source for labs and activities.  The simple act of constructing bluebird houses supplies her biology classes a multitude of observational and data collecting opportunities throughout the year.  And it is not uncommon for the students to step outside the door and gather any creeping or slithering organisms from the bushes for investigation.

*Conception of inquiry.*

Inquiry, as described by Sally, involves a construction of knowledge through problem solving.  Students are commonly engaged in problem-based activities in collaborative groups of two to six.  One example provided by Sally includes a thermal dynamics project in which students attempt to discover the best way to heat a house based on its location in the United States.  They are required to research and consider heating, insulation, efficiency and green power.  As a culmination of this work, they construct a model of their house.  Like many of the activities shared by Sally, the thermal dynamics house project places an emphasis on "doing" science.  She expresses value in providing opportunities for student enjoyment while learning.

> *It is a problem-based learning activity and it's really popular. And they like it so much. And they are learning, and they are doing, and they're making, and they are having so much fun problem solving.*

In addition to generating interest, Sally feels that problem-based lessons are an example of inquiry. She explains:

> *Well, they've got to figure it out. They are inquiring. They are making those connections. They are making that discovery and they are putting their own meaning behind it; their own understanding. And they're making their own connections. I can't force feed connections to somebody. They have to go "Oh! Well this, that and the other thing fit together". So problem based learning to me is inquiry. They are given some basic feeder steps; 'you need to do this, this and this. Here's the situation.' They'll have it and see what they can come up with.*

Descriptions of inquiry in Sally's classroom also include an acknowledgement of a spectrum of inquiry in instruction. In discussing typical activities, Sally provides descriptions using terms like "full inquiry" and "guided inquiry".

> *Well, for me, for an inquiry activity is varying degrees of the student actually doing some exploring on their own and making those connections on their own…. I think inquiry is always a work in progress. It's sort of, um, something that's dynamic. It's always changing and going on depending on the students and depending on the size of class, depending on the level of your class. I mean, to the point where you can present the students with a problem. Here's a problem. Here's a box that's got salt and sugar or salt and … iron filings and poppy seeds in it and sand. Separate it using physical*

> *properties and they can do that. And they did do that…. But, freshman would be like 'what do I do?' So, you would have to hold their hand a little bit.*

### *Rosie*

#### *Classroom context and instructional atmosphere.*

Rosie has twelve years of teaching experience with the last three spent teaching eighth grade Earth Science at a suburban middle school in the Southeast. In a school of approximately 2100 students, 46% are White, 22% Asian, 20% Black and 10% Hispanic. In comparison to the county in which this school is located, there are much fewer students that are eligible for free and reduced lunch (23% compared to 50%) and only 9% of the students are of limited English proficiency. County values are at 14%.

Rosie's classes contain an average of twenty six students each. Students sit at science tables that are arranged in a square in the center of the room. Tables branch into the square, facing the white board. This arrangement is designed to encourage the collaborative work of student pairs. She teaches four classes a day, each fifty minutes long in a small, interior room of the school. The room, only marginally designed for a science class, houses one wall of counter space with two sinks. The walls are draped in earth science posters and exhibits of student work.

With a Masters degree in Microbiology, Rosie has graduate level experience conducting scientific research. This experience may have contributed to Rosie's conception of science as a process. Science, as viewed by Rosie, is not always a step-wise procedure that always results in complete and expected results.

She states:

> *I find that I do have a different view when it comes to the scientific method and things like that, because I know that sometimes it was almost like, you know, after the fact you*

> *know…like it was more an ongoing thing. It wasn't step by step by step, but you managed to get through a lot of those steps, but not exactly in order….*

Rosie also conveys this view of science as a journey of discovery to her students by emphasizing that a correct hypothesis is not the main objective of scientific research, rather one must follow where the evidence takes them. Rosie explains how this is a challenge for some of her better students who strive to always produce the correct answer.

> *Basically I tell them…because they always want it to be perfect. Like they state a hypothesis…. They want it to be perfect and so when they get to their conclusion if they have not found any evidence that supports their hypothesis, they kind of what to go back and change their hypothesis.*

Rosie counteracts this by reminding students that authentic scientific research commonly produces results contrary to the original hypothesis.

> *I'm saying, guys, most of the time the conclusion doesn't support it. It's a big deal when it does, but we are just learning how science is done and that is something that you have to learn. Most of the time that it is not going to support it.*

She directs students to accept the results even if they vary from their hypothesis, but then to go further and begin questioning why the results might have been different than anticipated. A recent pH lab yielded some unexpected results while testing ammonia. The litmus paper provided a reading of seven, but in the discussion, the error was addressed.

> *And whatever happened, our ammonia was reading at seven… and I saw them erasing it and just trying to change it into a base. I said, you know what, I know that these are the weirdest results but we are going to have to keep it the way it is, and we have to think about why. What are some things that may have caused us to get a seven, which we all*

> *recognized as not being the best. Of course we were just using pH paper. So we talked about the variations with that, and maybe if we had better measurements… I talked to them a little bit about ethics in science and imagine somebody doing researching in cancer and they make that one change, something that they know it is supposed to be. We can't do that. It's okay, I'm not going to count off for that. Record your observations the way they were and let's see if we can come up with an explanation for why we got those results. I was walking around the room and I saw people who wanted to change theirs. No, we all know that ammonia should be a base, but let's look at why these results may be wrong.*

Rosie differentiates between the concept of labs and activities in her instruction. Labs, according to Rosie, are a simulation of what scientists might be conducting in the field. Variables are manipulated and data is collected for analysis. In classes such as Earth Science, conducting such lessons may prove challenging. Activities, in contrast, allow the teacher to provide a hands-on experience that "brings the book or notes to life". Although not following the steps of a scientific method, Rosie feels that activities can also incorporate discovery learning and inquiry.

*Conception of inquiry.*

Rosie's conception of inquiry stems from her experiences as a researcher. In describing her understanding, she addresses inquiry as she uses it in both labs and activities. In terms of labs, she states:

> *I guess I see Inquiry as giving students an opportunity to "be scientists". This would entail formulating a reasonable hypothesis, testing it to some*

> *degree, analyzing the data and then drawing reasonable conclusions even if they are not textbookish.*

She elaborates her definition to include more than the methods of scientific research. Problem solving and higher order thinking are also incorporated into her interpretation of inquiry as it may be used in more activity based lessons or even in handouts.

> *But I also include some critical thinking activities as inquiry because to some extent scientists spend considerable time just reasoning out possible outcomes and reasonable explanations. Literally inquiring into an event, observation etc. To some degree thinking logically about a science concept and extrapolating on possibilities is science inquiry to me.*

Although Rosie's experiences as a scientist involved full inquiry, she feels that in the middle school structure, students need more support to conduct investigations or formulate understandings from content.

> *In Middle School I think if any of us do inquiry it is probably guided inquiry where we try to give them more opportunities to find their own way, but yet at the same time we give them some kind of format or something to guide them.*

An example she provides as guided inquiry illustrates how she incorporates discovery and construction of knowledge through hands-on experiences while providing the guiding framework. A three day lab was conducted to investigate the properties of water. Ultimately, the lesson also tied it into connecting an understanding of the properties of water to human impacts on water quality. Only after finishing the exercises did the class move into notes. What follows is the portion of the lesson where students used discovery activities to develop an understanding of the differences between salt, fresh and brackish water.

> *I even introduced terms like brackish, so in the little lab I told them that they had three different colors of water and different colors mostly so they can't see the salt. You know. So they would get water that was red, blue and green. I told them… now one of these are going to represent fresh water. What do you get in fresh water? ... Then one represents salt water, what would be an example of where salt water comes from?... Then one represents brackish water. You may not be familiar with that term brackish water. We've got fresh water, we've got salt water. Does anyone want to take a guess what brackish water is? Then they did the lab with the egg to see if it would float. They already knew about density, and when they kind of realized which one had to be salt water and then they saw the slight difference between the fresh and… and the other one. They began to kind of see the connection of what brackish water was. It was kind of done like that, it was definitely guided….What they ended up having to tell me was…what are these three types of water? What are some characteristics that they all have in common? Because I want them to think about the fact… the pH should always be pretty close to seven. I mean there could be some variation, but close to seven. I wanted them to think about…that salt water is more dense, or has more dissolved stuff, that kind of thing. Differences… obviously salt water has more salt, brackish is kind of in the middle, fresh is not pure, but closer….*

Earth Science offers many opportunities for activities, and Rosie utilizes them frequently to keep her students engaged. Furthermore, she structures these activities to allow students to discover their own answer, while following up with further guidance for those students who need more prompting. By conducting the activities prior to notes, and by allowing students to first build an understanding through hands-on activities and labs, Rosie is implementing her conception of inquiry.

### *Rachel*

#### *Classroom context and instructional atmosphere.*

Rachel is one of the many suburban teachers now giving instruction in a trailer due to the rapid population growth at her school. The population of 2400 for grades six through eight is comparable in size to many of the county's high schools. Her student population is very diverse with 40% African American, 27% White, 22% Hispanic and 6% Asian. On par with the county's average, there are 12% of students with limited English proficiency but the number of students eligible for free and reduced lunch exceeds the system's average by 24% (37% and 61% respectively). Rachel's trailer is located off to the side of the school next to over a dozen such trailers. They are connected by a maze of wooden boardwalks with steps leading up to the front and rear of each trailer. Trailers are typically not designed to accommodate science classrooms, and this trailer is no exception. There are no sinks or rows of counter space or storage. Natural light enters only through the small windows at each door. However, Rachel has the student tables arranged such that flow through the room is not limited and students are able to work collaboratively using their tables as lab stations. In hearing Rachel describe the activities in her classroom, its size is never once regarded.

Even in a workspace perceived by the researcher to be limiting, Rachel spends a great deal of her class time utilizing activities. She considers herself to be a very "hands-on" teacher. In explaining her value of providing experiences for her students, she states: "They can make sense of it in their own language. I just can't imagine constantly giving them…content over and over again and having them memorizing it." One activity Rachel provides to illustrate her use of activities to deepen understanding is a commonly used modeling lesson on the phases of the moon. Before any notes are given regarding phases of the moon, her students are given a Styrofoam ball perched on a stick and a light bulb and asked to simulate the revolution of the moon around the earth. In doing so, the students sketch what they see at several stop points. Once they have completed the modeling activity, the students then work with Rachel in addressing the names of the phases that they identified through their sketching activity. The modeling, she states, "makes it make sense to them so they are not just learning vocabulary."

This emphasis on creating experiences where the students are making meaning of the content can also be seen in Rachel's use of writing in the content area. Cross-curricular lessons are highly encouraged at the middle school level and eighth grade students are also required to pass a county-wide writing exam. However, beyond the value of improving scores on the writing exam, Rachel finds that students benefit from the process of reflecting on the activities that take place in class through the process of writing. She states: "I just think it helps them think about their learning process more."

Furthermore, Rachel feels it is important to provide tangible links to the content for the students. She frequently provides anecdotes or pictures to further illustrate or explain content to connect it to students' everyday lives. However, she finds more value in drawing on those of her students.

> *You know, if I have a student from New Orleans, which I obviously do, when I talk about flooding, I'm primarily going to use their experiences and not mine….I try to use their experiences more so than my experiences.*

*Conception of inquiry.*

Rachel describes inquiry as:

> *I think it is…the teacher allowing the students to learn what they are suppose to learn about the activity that they are doing with perhaps some guidance from the teacher. For me it would just be like giving them an experience and allowing them to learn from the experience, rather than from what I know about the experience.*

Rachel explains further that her understanding of inquiry relies heavily on allowing the material to be personalized by the student. This is done by providing students opportunities to choose areas of interest to further investigate or by allowing students to generate questions to be answered through class that may otherwise have gone uncovered because they are not listed on the county objectives. These tangents may be limited by time and resources, but it is clear that Rachel takes great measures to allow students to pursue their personal interests in relation to the content they are covering in class. Her dedication to supporting this is evidence further by the fact that her students are given a cell phone number in which they can reach Rachel after school hours to discuss a topic of interest or gets clarification on content the student is struggling with. In Rachel's classroom, the types of questions that are asked are typically ones that can be answered through internet searches rather than through experimentation.

### *Carolyn*

#### *Classroom context and instructional atmosphere.*

The first thing one might notice when walking in to Carolyn's classroom is the large assortment of science related *things*. No one category could encapsulate the variety of items she has on display for her students. On the top of her cabinets you'll find an homage to taxidermy. On one side, a small fox is flanked by skulls of various animals. An enormous beehive, corals, and the vetebrae of something clearly large balance the opposite side. Only once you've taken all this in, do you notice the adjoining wall filled almost entirely with fish tanks and a sizable terrarium. From the ceiling dangle cell organelles from a student reenactment of the roles of cell structures. There is hardly a bare space to be found in the classroom. Even Carolyn's computer screen displays a scrolling photo gallery of her students involved in an inexhaustible array of activities.

Ordinarily the board is a prominent structure at the forefront of a classroom. Proportionally with the modestly sized room, the whiteboard in Carolyn's room is remarkably small. This, however, is an appropriate parallel to the emphasis she places on labs and activities as opposed to lecture. Carolyn typically conducts labs two to three times a week, sometimes doing a partial period activity and then regrouping to reflect on the content. These labs are commonly given prior to any discussion or notes about the content. She confesses to giving notes occasionally stating:

> *I usually still do give notes and talk about things maybe one to two days out of a particular topic. But I try not to do it more than that because I don't think…it's boring. Even at its most exciting, which sometimes it is exciting, but even that, you know they go to one class after the other and science should be a class where they are doing science.*

The school at which Carolyn teaches is a magnet school for the fine arts for grades 6-12. The student population of approximately 700 is almost equally White (47%) and African American (41%) with only a small portion of Hispanic and Asian. Whereas the surrounding county has 71% of its students eligible for free and reduced lunch, this school has only 21%. Although a public school, admission into Carolyn's school is selective, based on grades and ability in the fine arts such as dance, music and art. Carolyn teaches five classes: one AP Biology and four honors Biology. Each class contains twenty three to twenty four students.

Carolyn refers to herself as a lifelong Biologist. It is this background, perhaps, that lends itself to her belief that students should be heavily engaged in "doing science". She states: " I know a lot of Biology. I want to share that. And I like for the students to do lots and lots of hands on labs. We do many, many labs." As a self proclaimed "classical traditionalist" in terms of instruction, Carolyn also requires her students to sometime prepare formal lab reports, following the format used in authentic scientific research. However, with each activity or lab, her emphasis is on student synthesis of their knowledge and applying it to higher order questions. She creates a scaffold of questioning with the first questions drawing on rote memory and each successive group of questions becoming more and more challenging.

Carolyn also stresses the importance of the analysis of evidence in this synthesis process, perhaps even more than the actual content of the conclusion they derive. She states:

> *I think students can learn a lot from a cookbook type lab if we can broaden them, deepen them so that the lab actually comes to the thing we are trying to get the students to at least think about. They don't all have to come up with my conclusion, but they have to come up with their conclusion... their idea of what it means. That's what I'm looking for. I'm looking for some kind of thinking that they've thought about this and if it's not exactly lining up…that's ok too as long as it's legitimate and they can defend if…if their evidence leads them to say this.*

Creating opportunities for students to experience authentic science in this way is important to Carolyn. She laments:

> *I think we have a nation of people who don't know what science is. And I think that we may not cause children all to be scientists, obviously, but we can teach people what*

> *science really is and that science does not prove things. People think that science proves things, which is completely untrue. Science only gives evidence.*

*Conception of inquiry.*

Carolyn's perception of inquiry is closely tied to her background as a biologist. Her view of science as a hands-on discipline is frequently reiterated. In fact, in describing inquiry, she states, "Inquiry **is** doing science." She further explains:

> *It is the student pursuing their own ideas and investigating scientifically. They should be thinking scientifically and designing scientifically and they need to verify it, of course with their instructor and then hopefully carrying this out.*

In the classes' many labs, Carolyn describes the activities as "exercises" in which she already knows the answer, and guides her students with prescribed methods. However, she feels that in "true" inquiry "not only should the student not know what the answer will be, but frequently the instructor doesn't know how it is going to come out either". An example of this can be seen in a bacteria lab she will be conducting with her students.

> *You use spices and pepper to see which types of bacteria will be inhibited by these spices. Or maybe enhanced by the spice, I really don't. But it comes with about six different auger with spices and you test these specific bacteria with it…and that would be a kind of inquiry lab that the students can decide how they want to do it and they can choose which things they would want to test and then they could sort of set up their own…*

Carolyn feels that inquiry, by definition, is always student directed. And although she acknowledges a range of inquiry levels she places the most value on guided inquiry for the traditional classroom structure. Guided inquiry is defined by Carolyn as "activities in which the teachers gives some sort of framework and the student groups are able to design as much of the experiment or the activity as possible."

## *In Context of the TSI*

To provide a foundation of understanding of the case participants in connection with the concept of inquiry efficacy, it is important to note their results from the TSI data. Table 5.1 highlights the difference in means for each of the case participants. For participants showed gains following the R2R program, with each showing loses in the delayed posttest similar to the value of the posttest gains. Only two participants showed a negative difference in means in the posttest assessment (Gina and Carolyn) Both of these participants measured positive gains over the course of the year following the program through the delayed assessment. Insight into factors that may have contributed to the decrease in efficacy for Jeff, Sally, Rosie and Rachel as well as the factors that influenced increases in efficacy measured for Gina are outlined in the cross case analysis in Chapter 6. In contrast to the reports given by Carolyn, her actions and her professed beliefs at the time of the research do not align with her results of the TSI.

Table 5.1

*Difference in Means of Case Participants*

| Participant | Posttest – Pretest | Delayed Posttest - Posttest |
|---|---|---|
| Jeff | 28 | -25 |
| Carolyn | -4 | 13 |
| Rosie | 8 | -8 |
| Rachel | 26 | -21 |
| Gina | -36 | 39 |
| Sally | 3 | 160 |

### *Summary*

This chapter has introduced each of the case study participants and provided a snapshot of their classroom context. Participant conceptions of inquiry were described to offer an additional foundation for interpretation of the cases. In the following chapter, the effects of R2R on teachers' use of inquiry in the classroom will be presented as cross-case analyses. The research questions of this study will be used as the bases for the analyses.

# CHAPTER 6

## Findings: The Cross-Case Analysis

In the previous chapter, results from the TSI indicated that after participation in the R2R program, teachers measured a significant increase in their inquiry efficacy beliefs. Two research questions remain, each addressing the transfer of these beliefs to classroom practice. Employing the case study method, six cases of R2R participants that were currently teaching at the secondary level were constructed. Three main sources of data were used for analysis: a) self-reported accounting of the number of modified or created inquiry lessons, b) participant submitted lessons, and c) reflection of typical classroom instruction using the STIR instrument. In multiple meetings with each participant, teachers were asked to describe any lessons they had either created or modified that they felt implemented some form of inquiry. Lessons were submitted to the researcher in cases where they were available (i.e. some lessons did not have a formal write up). In the final meeting, the STIR instrument was used as a reflection tool. Teachers were asked to place their typical teaching style on the continuum. In doing so, they provided multiple examples of lessons that they use as well as revealed factors that they felt facilitated or limited their use of varying degrees of inquiry.

Once all of the interviews had been conducted and transcribed, data were coded using open coding methods (Strauss and Corbin, 1990). Phrases or words that addressed either of the research questions were highlighted within the text and a one word code was written into the margin. Coded data were then sorted into cross case themes. For the readability of the analyses, quotes selected for inclusion were determined by the researcher as the most representative of the participants' as a whole.  Where participants' perceptions varied, a discussion of their unique context is reported.

The benefits of R2R were repeatedly and enthusiastically described by the participants. However, the scope of this study focused only on its influence on any increases in generated or modified inquiry lessons.  This chapter presents the resulting themes gleaned from the teacher cases to formally address the research questions:

1. What changes in inquiry-based science teaching practice are reported by participants following participation in the R2R program?
2. What factors, as perceived by the participating teachers, facilitated or restricted their use of inquiry-based instructional practices in their classrooms?

Extensive interview quotations are included to provide rich illustration and support of the identified themes.

## *Changes in Practice*

As a capstone project for the conclusion of the R2R workshop, teachers were required to generate a lesson that they could use in their own classrooms.  They were encouraged to build on any of the content focused on during the program, tying it directly to the specific school objectives.  Teachers were also encouraged to incorporate aspects of inquiry as they had experienced it on the coast.  Each teacher presented their designed lesson to the R2R class and a compact disc was given to all participants with a collection of the lessons.  During the subsequent year, participants were asked by the researcher to provide a list, artifact or descriptions of any lessons they had generated or modified to utilize inquiry following their experience in R2R.  Each participant cited the lesson that they had created at the program and in all but one case, this was the only reported addition.

With the exception of Gina, each of the participants reported that the lesson they generated on the coast was the only one they felt comfortable saying was a new or modified inquiry lesson. In professing their perceived lack of new inquiry lessons, these teachers seemed almost apologetic and regretful. In our following discussions, each participant provided a vast assortment of labs that they had already been employing. Some of their lessons were inquiry oriented while some were simply for content verification. It was clear from these descriptions that their classes were not in want of some variation of lab experiences however. Regardless of class taught or years of experience, all of the participants relied heavily on activities or labs, reporting a range of lab time per week from 50% to 75%.

Although Sally did implement her R2R lesson, complications and frustrations with executing it have caused her to decide to abandon it for next year. Designed as a very learner-centered lab, students manipulated weights creating ballasts and controlling the buoyancy of their film canister submarines to investigate concepts of density in saltwater and freshwater.

> *I've decided that I'm going to chuck it. It just doesn't work. It's just really a pain in the butt. It was so difficult to pin down the weight, to pin down the ballasts. It was frustrating and the salt tanks were filthy and messy and they were getting water all over the floor and it was becoming a hazard. It takes forever. So it didn't work. It's not working. They get frustrated and I get frustrated.*

Sally did provide other examples of new activities, one of which included the construction of bluebird houses. Although she did not consider it to be a formal lesson, Sally cited the houses as an opportunity for her students to make observations and collect data just as scientists would.

Rebekah's use of her R2R generated lesson suffered a related fate. Rather than utilizing it as a learner centered activity as originally designed, she shortened it for use as a demonstration. Although not completely abandoned, like Sally's lesson, it was diminished to a point that excludes it from being included as an inquiry lesson.

Gina's case was perhaps the most unique in terms of her ability and willingness to add or modify numerous lessons. Although she clearly has many years of experience to have generated a foundation of activities to draw from, she states that she is continually tweaking old lessons to provide her ESOL students with opportunities to explore and investigate to build their knowledge. As the study progressed, keeping an accurate account of the exact number of new or modified inquiry lessons became a challenge. With each subsequent interview she described numerous investigations her students had conducted. Due to the time span between interviews and the fluid nature of some of the lessons, allowing students to take meaningful tangents and diversions when a "teachable moment" arose, pinning down a numerical value became more of an approximation. Gina provided lesson plans for several activities she defined as being inquiry related. Each investigative lesson began with a simple question such as "What lives along and in our stream?" The formats were simplistic and reflected her focus on the scientific skills of observation and data collection. By her own reports, Gina feels that following the R2R workshop, her use of inquiry activities had increased from 40% prior, to approximately 95% currently. These percentages reflect her classification of her labs and investigations as inquiry.

Although the participants vary in their years of teaching experience, discussions of their classroom practice showed that each relies heavily on activities and laboratory experiences. Each reported that approximately half of their weekly class time is spent on some hands-on activity or application of the content. However, this is reported to have been their teaching style before participation in R2R. Although inquiry may not necessarily be the main focus of these activities, each places value on providing experiences for their students to *do* science.

The emphasis on hands-on experiences in each of these classes may stem from the participants' prior experiences in authentic scientific research. Rosie, Carolyn, Sally and Jeff each have their educational backgrounds in sciences. Although Gina and Rachel have received their respective degrees in education, both reported participating in multiple professional development courses that engaged them in research practices. Furthermore, all of the participants are currently enrolled in, or have in the past taken graduate level courses in science education. If their courses focused on constructivist pedagogy, this may have also influenced the participants' decisions to employ activities that are learner focused.

The six teachers selected for the case studies are not purported to be representative of teacher populations as a whole. Although selected to get a sampling from high school and middle school levels, the nature of the R2R workshop influenced the participant selection pool. Each of these teachers has completed a minimum of a master's degree, and two of the participants are currently working on doctorate degrees in science education. Table 5.1 shows the educational background of the teachers.

Table 5.1

*Participant Educational Background*

| Participant | Bachelors | Masters | Doctorate |
|---|---|---|---|
| Sally | B.S. Zoology | M.Ed. Science Education | |
| Gina | B.S. Science Education | M.Ed. Science Education | |
| Jeff | B.S. Physics | M.Ed. Science Education | Ph.D. Science Education* |
| Carolyn | B.S. Biology | M.Ed. Science Education | Ph.D. Zoology |
| Rachel | B.S. Middle School Education | M.Ed. Science Education | |
| Rosie | B.S. Biology | M.S. Biology | Ph.D. Science Education * |

* Degree in progress

## *Influences on Inquiry Use*

The participants eagerly shared many aspects of the program they were able to bring back to their classroom practice. Sally, Gina and Rachel commented on their use of journaling and reflection. Carolyn was especially eager to share the specimens she was able to bring back and Rosie's classroom walls were covered in posters from the coast. All of the participants remarked on how the program reconnected them with their enthusiasm for science and reenergized them for the coming school year. However, despite all the benefits that were taken away from the program, their transfer of this experience to the development of new or modified inquiry lessons was limited. Analysis of the cases revealed several repeating themes amongst the participants. These limiting factors are presented in order of the frequency in which they emerged from the data.

### *Time Limitation*

The perception of a limitation of time was reported most often as a restrictive factor in teachers' use of inquiry. Obligations to local standards and preparation for high stakes testing influenced the type as well as the number of inquiry labs and activities participants were able or willing to implement, regardless of the purported importance they placed on using inquiry-based lessons to enhance learning. Jeff explained how the confines of the classroom context impact his ideal for science instruction as:

> *The way a science class should operate is you have lots and lots of equipment and you tell the students…there is the equipment, you go figure it out. We don't have time for that. And I don't think there will ever be time created in the curriculum for that kind of inquiry….It is so difficult, having to crack a whip and get them hurdled through a ton of*

> *material and at the same time, giving them enough free reign to do their own investigations.*

This perceived constraint on time affects the type of labs Jeff has implemented. Jeff comments, “Because of the time, I do cookbook labs”. These labs are structured to guide the students through predetermined steps to reach a conclusion that supports or verifies a topic they are covering. Rosie also voiced perceived limitations on the time available for inquiry. She remarked:

> *They definitely take a lot longer. So where you could have done one kind of demonstration lab in one period, a guided inquiry lab might take a couple of days or three days…so we don’t’ always have that extra time.*

Time constraints were addressed in the context of the school year as well as in reference to a single class period. Sally expressed her feelings that a lab that utilizes inquiry cannot be conducted in the fifty-minute class period, stating that the hope of doing so is “ridiculous”.

Generating inquiry labs was also reported to be a time consuming task that limited participants’ creation of new activities. Rosie stated that “the time involved in coming up with it and putting together materials...” was certainly a factor in her decisions not to implement inquiry activities for some lessons.

The limiting factor of time can be broken down into two main subcomponents: preparation for standardized testing and teacher adherence to mandated science objectives. These perceived restrictions were discussed with frequency by all of the participants. The frustrations with the increase in high stakes testing as a result of No Child Left Behind elicited strong emotions from the participants and commanded the largest amount of data regarding perceived limitations on inquiry use. Carolyn and Jeff became especially heated when discussing their aggravation in accommodating testing schedules.

*Testing.*

In discussing the use of inquiry in their classrooms, each of the participants had a tremendous amount to say about the influence of testing on their ability to control the content and direction of their classroom instruction.

Jeff states:

> *Well, I'll be so bold as to blame the whole standards issue, from what (my) county has gone to, to the No Child Left Untested Act (sic), and the fact that now if it is not going to show up as an item on the standardized test, there are too many in the administration that feel that you are not focusing well enough. And they are worried about their school not making AYP (annual yearly progress), and everybody having to get fired.*

He continued on about AYP stating:

> *It has become throughout my career more and more restrictive. They say they want inquiry but then they want to turn around and have high standardized test scores. When they figure out how to make a test that tests inquiry in a standardized test environment, ok, fine, but until then, you are wanting to teach one thing and test another and it's not going to happen. The teachers will teach to the test because they are looked badly upon if their students are not doing well.*

Rosie also alluded to the concern of poor testing reflecting on her ability as a teacher. She affirmed:

> *We've got to show improvement. If your kids know a lot about this set of AKS, but not for these two over here…so your kids do poorly on the post test and overall because of those tow areas. Then that will reflect badly on you.*

In discussing the demands of test preparation and test administration, Carolyn became very agitated. She asserted:

> *Right now, education is really terribly into only testing. And we say that we want a lot of critical thinking, but most of our testing is just volumes of this material that we have to cover. We are losing a lot of the depth of our education system because we are unable to take time to let students look at the natural world…to let them go outside with a journal and think about it…. I am always rushed and pushed because there are so many other things, and the testing calendar is so horrible that the children are pulled out form learning over and over and over. Our county has a practice test, has a mock test for the practice test. They have to practice for the practice before they can take the practice test of the real test, and they have to take them all(for each subject)….For four days they had to do the practice test and then another four days they had to take the test. So that is three or four weeks of instruction that they didn't actually get to even learn in the eighth grade. They didn't even get to learn some of the material that is very important science that they even needed to lean because they were being…because we had so much time that they were being pulled out for practice testing. So it is really very, very sad. So that takes away from the creative and really cool teaching strategies that teachers can be allowed to do.*

In viewing inquiry in the context of the Essential Features outlined by the NSES (NRC, 1996), tasks such as data analysis, evaluation of alternative explanations, and proposing hypotheses are provided as indicators of inquiry. Jeff, Rosie, Rachel, Sally and Carolyn all remarked on the limitations of time on their use of learner-centered aspects of these tasks. Reflection of their typical lessons using the STIR revealed that they often feel they have to sacrifice the opportunities to empower their students with more ownership of their learning in an effort to adequately prepare them for test content.

Rosie lamented that she does not have the option of spending any quality time addressing alternative explanations of scientific understandings. She stated:

> *I want them to think about alternative explanations, but I don't want..if it is something that may or may not be a prevailing idea or theory, I don't want them to spend too much energy when I know that what is going to be on the CRCT (standardized test) is going to be such and such and so I definitely end up with explicitly saying 'here's the main idea and here are some other explanations' and you try to generate it from them. What are some things you have heard? What do you think could be..? But I always come back to what could be the prevailing theory or idea because that's what you've gotta know.*

Jeff explicitly commented on the weight of the Advanced Placement (AP) exam on the determination of what skills he has time to incorporate. He felt that although his classes deal with calculating and verifying concepts using data, he does not give time for evaluating data.

> *I don't have time. The time it takes them to evaluate…and that's something they're not going to be asked to do on the AP exam. And really, that is one of the most definitive scales I use for determining whether or not something stays in what I teach. If it is going to show up on the AP exam, then it's going to be in the class. If not, then it's gone, regardless of how important I think it is, because there is no time. Not in the first year*

> *classes. Second year classes we can do all sorts of stuff, but I still try to keep them focused on the exam and getting prepped for it so they have a good chance of passing it.*

Sally, who's private school does not have to meet requirements of the No Child Left Behind legislation still feels the pressures of test preparation and student achievement on national exams. She stated:

> *We do a lot of standardized testing in this school. We do a lot of ACT prep and SAT prep. And so we're like brainwashed. This is where your students are. They are not meeting or they are meeting or they are exceeding the benchmarks of the ACT or plan of the Explorer. This is the rubric, see if you are doing these things. What can you do to improve on their college readiness?*

*Mandated Curriculum.*

In 1996, the National Research Council published the *National Science Education Standards*. These Standards serve as a guideline for the content and skills students should obtain during each grade level of science education. Within states and counties, local objectives have been devised building on those of the NSES. Sally is the only participant that does not teach in a school with predetermined science objectives. However, she pointed out that she uses the state's standards to guide her teaching. The participants noted that the objectives they are expected, rather, required to cover limit not only the content they can cover, but also the methods they feel they have time to utilize. Carolyn stated that "we are hemmed in more and more by what we have to cover". In addition to the lists of required objectives, the participants teaching in the public school systems are also typically obligated to follow a strict curriculum calendar. Each of the teachers, including Sally, remarked how they felt pressure to curtail activities to "keep up".

Jeff's situation is someone unique in that in teaching at the AP level, there are no state or local objectives that he is required to follow. However, the College Board does provide guidelines (College Board, 2007). Jeff stated:

> *So I've got to follow the AP guidelines and in the first year it is extremely restrictive because of the amount of material that we have to cover…. I seem to be doing fairly well so far, getting the kids prepared for the test, but there is no time to stop and look at application.*

Although the College Board also provides guidelines for Physics C, or second year class, the amount of content is much less. Jeff continued, "The second year class I've effectively got twice as much time to cover the materials, so we've got a lot of time to go in and do different things."

Rosie expressed a frustration with her efforts to implement inquiry. She explained that she make attempts to use lessons that are more student-centered but ultimately had to regress to a more teacher-centered approach to ensure that the students are receiving the material they are required to know. She stated, "I'm always going to come back to this just because I want to make sure they got out of it what I think they are supposed to get out of it." Illustrating her attempts to employ inquiry she stated:

> *I'll give them a little bit more time and then I'll realize that they're not going to get anything done unless I…I then go to basically leading them and telling them kind of what you need to be thinking about and how are you going to have to analyze this…And again, I always come back to this because it's like they've got to get out of it what they have to get out of it. And this is AKS (objectives) and verification.*

Rachel articulated a curbed ability to stray from the outlined curriculum. She provides many opportunities for her students to ask questions of personal interest related to the current topic. However, she feels tangents are inhibited oftentimes by the need to cover all of the necessary content. She explained, “I would love perhaps to elaborate more than just a homeroom discussion about it. But that’s what I am not free to do because I have very specific guidelines that I am supposed to teach.”

Gina expressed a contrasting view of the required objectives. As an ESOL (English as a Second Language) instructor of environmental science classes, she is restricted by two sets of standards. She is required to follow the state GPS (Georgia Performance Standards) and the language WIDA standards (World Class Instructional Design and Assessment Language Objectives). Despite the additional requirements, Gina did not convey any perceived limitations by the structure of the established standards for her classes. She stated that the WIDA standards actually give her “sheltered classes validity for academic content while students continue to learn English language and its structures.” She also stated that she felt the GPS, which have recently replaced the state’s previous standards, the Quality Core Curriculum Standards (QCCs) were less strict and allowed for more teacher freedom in instructional choices. In reflection of her use of the QCCs, she quipped, “If you look, oh my gosh, there’s like 35 of them. Now if there are really only 18 weeks in the semester, how can you cover them? I don’t know how people in regular environmental science can do it.” Gina’s support of the current GPS may stem from her involvement in helping to create the guiding frameworks for the Biology content. These frameworks provide teachers with a list of the content standards along with supplementary resources such as vocabulary, lists of common student misconceptions, and possible guiding essential questions.

*Miscellaneous Time Factors.*

Time constraints external to the school environment were also identified as a limiting factor. Three of the participants were currently enrolled in graduate classes: Jeff, Rosie and Sally. Each had various numbers of courses they took in the evenings. In addition to the workload they may have had in these courses, both Jeff and Rosie commuted approximately an hour to attend these classes. Jeff noted:

> *Just the idea that I'm home working on my PhD program, my classes are going to suffer. I can't do as much with them and really making them better. I'm always working on trying to make next year's class better by fixing stuff this year and I haven't really had the opportunity to do that this year because there is no extra time.*

Sally, in particular seemed the most affected by responsibilities outside of school. She made numerous references to the demands on her time. Her role as a student, a parent, and a wife left her little time outside of school to dedicate to her role within the classroom. These demands are compounded by the pressures she experience within the school setting balancing her many science preps. She stated:

> *I go to school and I'm a mommy. So my time is just…I don't have a lot of time.*
>
> *The number of science disciplines was also a concern. Sally was really the only one who had a significant number of different preps….It is a real pain in the butt. I feel like I can't develop my classes right now. I always devote all this energy to these new classes, like the AP and the Anatomy and Physiology. I haven't taken Anatomy and Physiology since I was 21. And AP? All I do is read for those two classes. Thank god the other ones I've had for a while, but I haven't been able to put any time in to them. I want to develop a real unit…but I don't have time to develop it.*

*Student Limitations*

Although the participants ranged in the grades they taught from eighth to twelfth, there was a recurrent theme regarding the limitations of inquiry use based on the population of students they taught. This theme was comprised of two subcomponents: ability and behavior. The ability of students acting a limiting factor was discussed by each of the participants. They recognized that within their different science preps, and for some, within each class period, the range of student ability and behavior affected the types of lessons and instructional methods the participants employed. The concepts of ability and behavior were somewhat varied amongst the participants, however.

*Student ability.*

In Gina's case, any reference of ability was only in regards of language. Her students were coming to her class with very diverse English language fluency and educational history:

> *They don't have the background. They might have if they were a regular kid, but quite often, it depends on what their science schooling was in Mexico, Honduras, or El Salvador. Because they end up with a broken education. Some of them don't have as much background and so quite often, I am doing (more guided activities)…. The first couple of weeks, you could just see the eyes were like 'oh, my god. What am I doing in this place? I cannot speak the language.' And now you just see their brains going. And so, we've just started out one day..we did observational labs. We learned to do field sketching. We are keeping our journal field books.*

As a result, she modified her lessons to begin with science skills that did not necessarily depend heavily on language skills, such as observation, sketching and data collection. As the year progressed and students had more developed language skills, she could incorporate more of the tasks that involved a communication of application and synthesis of content.

Carolyn, Jeff, Sally and Rosie made distinctions of their ability to use inquiry lessons based on the grade level of students as well as the tracking level. There seemed to be a consensus that students in the advanced classes were more capable of engaging in learner-centered activities. These students were perceived to be more mature, motivated and have the necessary content foundation to spend more time on application and synthesis of knowledge. Carolyn compared her AP classes and her ninth graders stating:

> *In AP, I have less number of labs, but they are longer. Their lab experiences allow that and they have information, knowledge type information and they have thinking abilities that they can truly synthesize the ideas together. In my younger students, not all of them are focused and interested in science.*

The delineation between the advanced students and "regular" is also noted by Sally. She stated:

> *We do spend more time on the content knowledge in the regular than we would in the honors classes….When you get in those high level classes, with the much smarter children, you are going to have those kids that are able to make those connections and do it and just go figure this out. Plus, they are motivated to do it, whereas a student that is on-level isn't going to be as motivated to do that. And they require a little more guidance even if they are in a senior class.*

Jeff, who teaches only Advanced Placement physics classes differentiated between his first year Physics B class and the second year Physics C class. This differentiation is based not on student ability, but rather on the varying curriculum demands of the two courses. However, Jeff recognized that the students in both of his classes offer him opportunities to employ labs and investigations that he would be unable to conduct in lower level classes. He stated:

> *The stuff that I can get away with, with both the first and second year classes is because I have students that want to be here. They want to learn. They are not questioning the value of being here. They understand that this is going to make a huge difference, at least in their choices.*

Both Sally and Rosie specifically addressed their perception that their students were not "ready" to engage in inquiry activities. Citing students' lack of prior experience in such activities, they stated that their students were resistant to participating in inquiry labs in ways in which were conducive to knowledge construction. Sally described this as a need to "train" students to think and work in a more inquiry based way. She elaborated:

> *As we progress toward the year, I try to get more and more learning centered. They are coming from a middle school which is very teacher centered. They don't do anything but sit and take guided notes, so you have to build them into this. You can't throw them in because they don't tend to swim….In the 9th grade class where they've never been given free range to go, think, and do something, they are not used to that. So you kind of have to work them in to that.*

Rosie noted similar experiences with her students. When she attempts to utilize an inquiry activity, she interprets an unease with her students in the liberal structuring of the activity or requirements. This is especially so with her higher achieving students. Unlike the benefits of having the advanced students mentioned by Carolyn, Sally and Jeff, Rosie's best students are uncomfortable in making their own investigational decisions. Rosie illustrates her reluctant and defeatist transition from learner-centered to teacher-centered instruction:

> *I will begin by thinking I can do this and the first class, I realize that 'oh my god' and I'll even try to give it some time because that class is ok to experiment with. I'll get looks of consternation and by the time they come back from lunch, I will have some type of guideline that I'm now putting on the transparency and saying 'ok, here is your information, how do we want to organize this?' and it's a step by step process. By the later classes, I'm not even giving them the option of coming back over here. I just assume that no one is going to be able to do it. So from that point on it is sort of step by step with the layout.*

Rosie elaborates about the frustrations of having to challenge the students to move out of their comfort zones.

> *After they have been so used to doing these types of labs where you kind of know where you are supposed to end. The idea of being some open base out there and 'oh gosh, how do I know if I am doing it right?' Especially for those kids who are used to making A's on everything. They want to know exactly 'what is it going to end up? What is going to be the correct answer?'*

*Behavior.*

Behavioral concerns were one of the first limitations mentioned by Rosie. She was quick to elaborate that the issue of behavior with her students regarded their "energy level" and ability to stay on task when opportunities for more independent work was provided. Rosie stated:

> *It's not that there are intellectual limitations or anything. It's just about behavioral development. I feel like I've moved a little less away from student centered things I've done in the past because of the management part of it. I hate that that's the case, but I feel like theirs' has to be a little more structured.*

Rosie commented that the behavioral component varied year per year and that the students she had this year were just especially “energetic” limiting her ability to conduct hands-on activities more so than in the past.

Sally chose to abandon her lesson that was generated at the R2R program after struggling with balancing the value of the gained knowledge with the hassle of conducting the lab. She recalls that her “rambunctious ninth graders”, although enjoying themselves, were failing to conduct the necessary forethought and analysis before plunging into the investigation. As a result, she felt the students were simply “playing” and “guessing”. The preparation and subsequent clean up of the submersible lab was viewed simply as not worth the effort.

### *Accommodating Disciplines*

The participants that have taught different science disciplines during their career shared their experiences implementing inquiry in the different courses. Sally, Rachel, Gina and Carolyn each expressed their belief that certain classes were more conducive to conducting inquiry. There was a consensus amongst Sally, Rachel and Carolyn that physical science was the easiest to implement opportunities for students to engage in learner focused activities. They felt that the content lent itself to learning experiences where students frequently had to problem solve through hands-on investigation. In contrast, chemistry was perceived to be the least accommodating due to safety concerns.

Carolyn stated:

> *A lot in the physical science, not chemistry, because with chemistry, you can’t let them see what happens and mix all of these things. You can let them confront six powders in a row that you kind of know what they are, but you can’t let them just mix anything they want to. But in physical science in the physics part they really can do that. They can*

> *design their thing and make… they can carry out more of an open ended inquiry type labs.*

Sally reaffirmed saying, "I think for safety reasons, the chemistry is a little dangerous. I think physics and I think the physics part of physical science offers the most. To me it offers the most opportunities. "

In Rachel's opinion, physical science offered more opportunities for students to engage in the type of investigation and research similar to what scientists practice. She stated that Earth Science was limiting in this regard, noting that it would be difficult to simulate conditions to investigate the more comprehensive earth science concepts. She expanded on this stating that similar limitations existed on their opportunities for data collection. She felt that the Earth Science class afforded opportunities to work with data that was provided from sources such as NASA, but that the students did not have many occasions for activities where they collected the data to support a concept. She explained, "As far as hardcore data that we would be dealing with in Earth Science, it often tends to be data from NASA. Obviously, they collect observations, but numerical data not significantly in Earth Science."

Sally and Gina feel that Biology content is especially difficult to adapt for inquiry lessons. Sally voiced, "I think inquiry … for biology is probably one of the hardest things to come up with." Gina's opinion paralleled Sally's in this regard. Although she feels that in her Environmental Education class, inquiry "is a given", she finds it much more difficult to develop her Biology lessons to include it, relying instead of what she terms "cookbook labs".

### *Pedagogical Content Knowledge*

A dearth of pedagogical content knowledge appeared to affect the creation, modification and implementation of inquiry activities of those participants teaching multiple disciplines or those teaching out of their field of specialty. For middle school teacher certification there is not the same level of in-depth science content knowledge required as for high school science instruction. Although Rosie had a significant science background, receiving a M.Ed. in Microbiology, she was teaching Earth Science. Her knowledge of the particulars of Earth Science content and student learning limited her comfort level with creating inquiry activities. Rachel also expressed that she was able to create more inquiry labs in the content that she was more comfortable with.

This limitation is especially unambiguous in the case of Sally. With five different science preps, Sally expressed her exasperation with the many challenges in creating inquiry lessons for all of her classes. She stated, "I'm sure there's probably a lot in chemistry but I'm just not that chem. savvy. It's been a long time. I have a lot of chemistry under my belt, but it's been a million years…so I don't feel comfortable enough to be doing real inquiry with chemistry."

### *Class Context*

Remaining factors listed by the participants could be grouped into the category of class context including equipment, class size, room size and the setting of a traditional classroom.

Jeff's school has just completed a sizable five story addition to the school. As a result, he has been assigned a new room in the new building. The room is quite large with plenty of storage. However, the transition has resulted in misplaced equipment.

> *Things have been a little hectic this year with the move, getting my lab equipment to be available. So I haven't been able to do as many labs as I want to and some of the labs that I have been able to do, I've had to cut back because equipment is missing right now.*

Carolyn and Sally commented that they might be more apt to use inquiry in classes that were smaller. Sally admitted using much more learner-centered methods with her class of four, but in addition to being a smaller class, this is also her advanced class. Carolyn's perception of a suitable class size for inquiry use also included the context of the room size. She remarked that her classroom did not provide adequate space for higher quality and in-depth investigation with her larger classes.

### *Summary*

This chapter outlined the comparative themes from the cases of Sally, Jeff, Rachel, Rosie, Carolyn and Gina. Each touted the perceived benefits they derived from their experiences in the R2R program. Although they felt the professional development experience was worthwhile, through the course of the year following the program, its influence had not resulted in marked changes in inquiry use with the exception of Gina. Reasons provided for the dearth of new or modified inquiry lessons were found to include limitations on time, pedagogical content knowledge and student ability. The following chapter discusses these findings in light of existing research literature and presents implications for science teacher education and directions for future research.

# CHAPTER SEVEN

## Discussion and Conclusion

### *Review of the Study*

The purpose of this study was to identify the effects of the coastal marine workshop, Rivers to Reefs, on teacher participants in terms of inquiry efficacy and practice. These questions are: Following participation in the Rivers to Reefs/Coastlines program,

1. What changes in inquiry efficacy can be measured?
2. What changes in inquiry-based science teaching practice are reported by participants?
3. What factors, as perceived by the participating teachers, facilitated or restricted their use of inquiry-based instructional practices in their classrooms?

To address the first question, participants in two consecutive summer workshops were administered the TSI survey as a pretest prior to the workshop and again as a post-test at the conclusion of the two week program. Using SAS, dependent, one-tailed t-tests were run to identify any significant changes in inquiry efficacy. In addition, a delayed post-test was mailed to participants a year following their involvement in R2R. Additional t-tests were used to compare any difference of means from the post-test and delayed post-test to measure stability of any changes.

Case studies of six participants were used to address the final two research questions. Multiple interviews and artifact collection were conducted to ascertain the effects of the program on teachers' use of inquiry in their classrooms. In addition, any conditions perceived by the participant that either hindered or assisted in their use of inquiry were identified and discussed.

Results from the TSI indicate that the R2R program may have a significant, positive effect on teachers' beliefs regarding their ability to use inquiry as a teaching and learning tool. Furthermore, these increases in efficacy are consistent over time. However, as revealed by the cases, these gains are not typically being translated into any remarkable change in classroom practice.

## *Discussion*

### *Obstacles to Inquiry Implementation*

A summary of findings in the cross-case analysis was provided in Chapter Six. Without exception, each teacher expressed feeling limited in their ability to generate or modify lessons to include inquiry following the River to Reefs program. This section focuses on this aspect of the findings and relates it to the existing literature. The literature base concerning perceived obstacles to the use of inquiry in instruction was outlined in Chapter Two. One source in particular serves to organize the findings of this study into three concise categories. These categories have been identified by Anderson (1996) as the technical dimension, the political dimension and the cultural dimension.

The technical dimension refers to teachers' beliefs of their efficacy regarding constructive teaching methods as well as their concern with other teaching responsibilities and the constraints of their classroom context. Teachers may also feel challenged by engaging students in a new, active learning role (Barrow, 2006). The political dimension refers to the general support of inquiry teaching by the school and parents. Conflict over teaching strategies may exist within the school and teachers may be limited financially in terms of available resources and equipment. The cultural issue, which Anderson claims to be the most important, deals with teachers' beliefs of the value of inquiry in a school culture that may focus on content coverage in an effort to prepare students for testing and the next level of schooling.

The limitations perceived by the participants on their creation and implementation of inquiry activities parallel the categories outlined by Anderson (1996). The dominant theme that emerged could be described as the cultural dimension, whereas each of the teachers felt that their school environment placed a tremendous emphasis on student performance on standardized tests. To adequately prepare for these exams, participants felt compelled to closely follow state or local science standards. These goals were perceived by the participants to place severe time constraints on their instructional choices and thus limit their ability to incorporate more inquiry oriented lessons.

The remaining limitations that were identified through the case analysis can be categorized as Anderson's technical dimension. Each theme is related to the participants' beliefs about their abilities to implement inquiry or their students' ability to learn successfully through this method of instruction.

One factor that emerged from the cases included the teachers' perception of their students' abilities to engage in learner-centered instruction where they were expected to exercise more control over the direction of the investigations. Several of the teachers (Sally, Carolyn, and Jeff) expressed their beliefs that advanced students were more capable of engaging in and learning from inquiry oriented instruction. These students were perceived to possess the maturity, the desire to learn and the necessary knowledge base to participate effectively in activities where they are asked to make more decisions and form conclusions more independently. Conversely, in classes of "regular" students, inquiry was more difficult to employ. Rosie in particular commented on her frustrations in having to revert to more didactic instruction when her students failed to make the intended connections during an inquiry lesson. Teachers (Rosie and Sally) also commented on their concern with their students' ability to remain focused and direct their energy and efforts in to solving the problem at hand. Inquiry activities were viewed by these participants as active, hands-on lessons and as such, could result in student behavioral issues.

Another factor addressed by participants (Rachel, Sally, Gina and Carolyn) involved their perception that certain science disciplines were more conducive to implementing inquiry oriented lessons. Chemistry was viewed as the least favorable in light of safety concerns with the use of chemicals, fire and glassware. Physical Science was reported to be the easiest discipline to incorporate inquiry. They felt that the nature of the content almost required the use of hands-on activities to discover the central concepts. Materials used to explore these topics were viewed as "safe". Gina added that inquiry was also easily executed in Environmental Science. She noted that school surroundings offered an easily accessed and appropriate setting for creating opportunities for students to investigate their surroundings using authentic scientific research methods.

The pedagogical content knowledge of participants for each discipline they taught was revealed to influence their use of inquiry. The participants were forthcoming in their unease in creating inquiry lessons for subjects out of their area of specialty or background (Rosie, Sally, Rachel). Studies by Magnusson and Palincsar (1995) and Flick (1995) emphasize the importance of strong content and pedagogical content knowledge in developing inquiry teaching. This factor was especially evident in Sally's case, teaching five different preps, of which, three were not her educational background. Conversely, with thirty two years of experience, Gina had a rich teaching history to draw upon. Teaching the majority of her classes in an area she felt both experienced and interested in was evidenced in the ease in which she altered her lessons to employ inquiry.

The final factor revealed included contexts of the classroom. Carolyn and Sally cited the size of their classes as a limiting factor; Carolyn suggesting that groups as small as five being ideal for authentic inquiry. Current construction at Jeff's school was reported to have interfered with his ability to locate the necessary equipment to implement additional labs, and even limited his ability to execute some of his established activities.

The political dimension outlined by Anderson (1996), was on touched on peripherally and in the context of the accountability component of the No Child Left Behind legislation. Participants cited their concern over AYP requirements and the pressures for high student achievement on standardized testing. Jeff and Carolyn were particularly vocal about their disdain for the emphasis on testing in their schools.

Several other studies conducted prior to the publication of the 1996 NSES cite similar obstacles hindering the use of inquiry in classrooms (Costenson & Lawson, 1986; Welch et al., 1981; Eltinge & Roberts, 1993; Blanchard 2006). The significance of these studies, beyond providing a corroborating list of impediments to inquiry reform efforts, is that it shows that these roadblocks existed prior to the national reemphasis of inquiry through the Standards. Despite efforts of policy makers and teacher educators, the very same impediments continue to undermine reform.

### *Fostering Inquiry Instruction*

In determining the factors that facilitate or impede inquiry use, experiences with participants tended to solely lean towards expression of the hindrances. Gina was the only participant who began and ended her discussions with illustrations of the values of inquiry and how she made use of it at every opportunity. Therefore, factors that aided in inquiry implementation had to be inferred somewhat circuitously.

Each of the participants' relayed their appreciation for having been required to generate an inquiry lesson during the R2R program. Rhonda expressly stated that due to the demands of her schedule she would not have likely generated even one inquiry lesson had it not been a requirement. These sentiments were not volunteered, but rather solicited during the interviews. When asked how important it was that the program required the construction of a lesson, each participant replied, "Very." In creating a structured environment for teachers to generate and share inquiry oriented lessons, R2R was able to encourage implementation of at least one additional inquiry lesson in participants' classrooms; a promising but modest starting point.

Sally, Carolyn, Rosie, Gina and Rachel conveyed their beliefs that certain science disciplines were more conducive to using inquiry activities. All but Gina stated that physical science offered the most opportunities for students to engage in hands-on investigations. They viewed the content as supportive of student-centered exploration and the materials used in such lessons as "safe". Unfortunately, only Sally was currently even teaching a physical science course. Gina, in contrast, felt that Environmental Science offered the most opportunity for inquiry. She held a strong conviction that students needed to be outside "getting their hands dirty" and the lessons she utilized in class were designed as investigations that integrated content with the students' surroundings. Four of Gina's five classes were Environmental Science. This may have allowed her to dedicate a good deal of her planning and preparation on this course, making modification and generation of activities easier than those participants' whose attention was divided among several preps.

In addition to finding the nature of Environmental Science to be supportive of inquiry, the structure of Gina's ESOL courses allowed for more freedom of content. Currently, her students are not required to take an End of Course Test (EOCT). Although her classes were still mandated to follow the state GPS standards, there was no standardized test that would be given to measure her students' mastery of these objectives. Considering the perceived pressure of testing voiced by the other participants, it may be that in not having a high stakes exam offers teachers the comfort to employ different teaching strategies.

### *Discrepant Beliefs and Practice*

A vast literature base supports the understanding that teachers' beliefs, knowledge and goals are important determinants of teacher practice (Clark & Peterson, 1986; Calderhead, 1996). Schoenfeld (1998) describes how within teachers "at any given moment, there is a constellation of highly activated beliefs, goals, and knowledge." (p. 15). In an ideal situation, these three components work synchronously to direct class instruction. However, the classroom context is complex and oftentimes, these three components may not align and conflict is created. When the components that underlie teacher practice are in conflict, the current context may determine which component is granted priority. Kegan and Lahey (2001) refer to this as "competing commitments".

In this study, it seems that for all of the participants, save Gina, the goals of high test scores and covering all of the intended curriculum outweighed their professed belief in their ability to use inquiry in their class as effective instruction. The literature notes similar discrepancies between teacher beliefs and their practice (Brickhouse & Bodner, 1992; Bryan, 2003; Luft, 2001; Haney & McArthur, 2002). A study by Moore (2003), of preservice teachers' translation of constructivist learning theory to field practice yielded that without exception, procedural concerns of time management, lesson planning and classroom management were perceived as more important than the theory presented in their college classes. Although the teachers involved in the R2R study are not novice teachers, similar beliefs were revealed, conflicting with their reported value of inquiry.

### *Classroom Context*

The findings from this study add to the literature base identifying the chasm between what is emphasized in teacher education and what is practiced in classrooms. Although continued exposure to theory may impact beliefs, there is still much to consider in bridging the gap between beliefs and practices. The contexts of the classroom and school environment are vital considerations. If teachers feel that limitations of a traditional classroom inhibit them from implementing theory, great care needs to be taken by instructors to provide opportunities for the teachers to confront these beliefs and have experiences in which they can directly see the benefit of using inquiry. According to the situated learning approach (Lave & Wenger, 1991), knowledge and skills should be presented in an authentic context that represents the settings and applications in which a teacher would normally use that newly constructed knowledge. Osborne (1998), states that there is a marked contextual difference between the classroom and the environments in which teachers are being taught. Teachers are creating knowledge under very different circumstances than they will be expected to use that knowledge. Research shows that there is a strong link between classroom practice and whether or not teachers were given an opportunity to reflect on their learning in the context of their class (Brouwer, 1989; Freudenthal, 1991).

The R2R program required participants to construct a lesson rooted in some aspect of their experiences on the coast. The intent was to provide an opportunity for teachers to relate the experiences in the program to the context of their classrooms as well as allow the participants to share their ideas with the other participants. In some regard, this was an effective approach to encourage the teachers to use inquiry in their classrooms. Each of the teachers reported using the lesson that they had designed during the program in some capacity. However, this was not necessarily a lasting impact. Sally implemented her R2R lesson, but afterwards felt that her students were not able to effectively operate on the level of thinking required to complete the tasks. In addition, she did not feel that the time needed to conduct the lesson was the most effective or efficient method to convey the needed content. Other case study participants confess that although they use the lesson they created, this has not translated to modification or generation of other new inquiry lessons (Rosie, Rachel, Carolyn and Jeff). These results seem to suggest that connections to classroom instruction perhaps need to be more explicit and more frequent to result in prolonged and significant change from professional development experiences.

### *Alignment of Administrative and Educator Goals*

Bybee (1993) and Duschl (1990) state that in order for reform to take root, teachers must act as the “change agent”. Efforts for reform should focus on affecting the beliefs and thereby the practices of the teachers. However, the cross-case analysis revealed that each of the teachers felt some measure of constraint on their time by mandated curriculum or administration of high stakes tests. Both of these factors are external to the teacher.

In Georgia, many counties have developed their own list of content standards. Although inquiry and its related skills are strongly emphasized in the National Science Education Standards, a quick review of county-wide objectives where half of the participants teach give inquiry only modest attention, referring to the term only once in the whole of the each of the science disciplines, and at no point is the term defined or discussed further. As an example, this county utilizes a NSES derivative referred to as Acquired Knowledge and Skills Objectives (AKS). For the sciences, these AKS are broken down into Characteristics of Science and Academic Knowledge. Displayed on the website to appear equally emphasized, navigation through the links reveals that the objectives bare far more content than skill related goals. Within the Skills objectives, several Indicators of Achievement, the subcomponents of each objective, may be interpreted to support the use of inquiry. Students are expected to design and conduct scientific investigations, for example. However, these listed goals do not align with the methods in which student achievement is measured. For example, each student in the state of Georgia is required to pass the Georgia High School Graduation Test (GHSGT), as the name implies, before matriculation. A reported 30-32% of the science portion of the test questions is related to process or research skills. Description of this portion states:

> *For assessment purposes, students will be expected to recognize, interpret, and use the terminology of the scientific method, evaluate designs and data, and decide how best to present results of an experiment or investigation. Students will be expected to recognize basic terminology (e.g. hypothesis, control, experimental variable) various types of graphs and other data display techniques, and sources of invalidity in experiments.*

The science portion of the exam is entirely in multiple choice format. Using this structure may prove challenging if attempting to measure a students ability to plan and conduct scientific investigations. Although measuring this is not an impossibility, per se, the sample questions provided reveal that student knowledge of science skills focus strongly on recognition of terms and steps, not on their ability to perform or engage in such skills. Furthermore, the scientific method is presented in the GHSGT as a consistent and unvarying step-wise process. A sample question provided asks:

*For any laboratory experiment, what should be the first step?*

*A) form a hypothesis*

*B) State the problem*

*C) Perform an experiment*

*D) Write a conclusion*

(Georgia Department of Education, 2007)

Again, it appears that in contrast to the teaching and learning goals of national standards, measures of achievement focus more on student memorization of content. Even the most conservative views of inquiry would likely not include the task of recognizing terms as an exercise in or measure of scientific inquiry.

An introduction to the GHSGT sample questions states:

*Many of the item types may be unfamiliar to students who have not had much experience with questions that require them to apply what they have learned to new situations or to solve complex problems with simple concepts.* (Georgia Department of Education, 2007)

This admission to the discrepancy between what learning will be measured and what learning the administrative structures believe is occurring in classes is troubling. Equally troubling is the absence of measures of inquiry related knowledge or skills on high stakes tests in which teachers are held accountably by current legislation.

Despite their measured beliefs regarding the value of the use of inquiry as an instructional and learning tool, any change in action of the case study participants was mitigated by their perception of what was expected of them by the school. The accountability now placed on teachers with the NCLB legislation clearly weighs heavily on what teachers feel they are allowed to do in their classroom and how their time is best spent preparing their students for these measures of progress. A 2003 study conducted by Ingersol, found that 46% of science teachers who leave the profession cite a lack of administrative support. Disparity between how a teacher believes is the appropriate way to instruct and the methods supported by the administration may not only negatively affect efforts to include inquiry in science instruction, but may also be contributing to teacher attrition.

Ultimately, the teachers decide what takes place in their classrooms, and therefore they should continue to be a focus of reform. However, I would propose that efforts should not only work from the "bottom up" but also from "top down". If teachers feel that administration and curriculum does not support the changes that research indicates needed for effective instruction or if the actions counter or impede the use of such strategies, then it would seem unlikely that teachers would change their practices, regardless of their beliefs.

### *Ceiling Effect*

Roberts et al. (2001), suggests that measures of self efficacy may experience a ceiling effect when respondents score relatively high initially on surveys. Data collected from the case participants indicate that all were operating above the median value of the instrument. The concept of the ceiling effect, however, is of more interest in terms of the amount of activities they already use in their classes. Each of the participants reported dedicating substantial amounts of class time to hands-on activities and investigations. Admittedly, not all of these were considered by the participants to be inquiry oriented. None-the-less, if teachers' perceive they are already implementing reform based efforts by employing constructivist strategies, there may not be a strong motivation to make further changes.

### *Highly Qualified Teachers*

In the school accountability component of the NCLB act, schools were to be required to have “high qualified teachers” in every classroom by the 2005-2006 school year. As defined by the United States Department of Education (2007), “highly qualified” is meant to imply that teachers hold a bachelor’s degree in the subject area they teach and have demonstrated a high level of competency through rigorous state subject tests. In addition, teachers should have obtained full state certification and passed the state licensing exams to be considered “highly qualified”. However, shortages in the availability of science teachers have caused the Department of Education to modify the NCLB legislation. In light of the fact that many science teachers are required to teach more than one science discipline, NCLB has indefinitely altered the requirements, stating that teachers may be certified as “broad field”. Although this flexibility may aid in filling science teacher positions, one can’t help but be concerned with the possible compromise of required depth of content knowledge. Magnusson & Palincsar (1995) argue that inquiry teaching requires adequate content knowledge. If science teachers are required to teach multiple disciplines, it would not be surprising that their knowledge of any one area may be limited by efforts to attend to the others. A jack of all trades is a master of none.

In addition to content knowledge, use of inquiry is dependent on a teacher’s pedagogical content knowledge. ( Flick,1995). PCK involves an understanding of the instructional methods that are pertinent to specific content. Borko & Putnam (1996) stress the importance of opportunities for teachers to deepen and expand their content knowledge. With out a foundation of subject matter knowledge, it is challenging for teachers to develop an understanding of the subject in the context of the learner. In science, this knowledge should include an understanding of the processes of inquiry (Eick, 2000; Lederman, 1992; Lowery, 2002). In the case of Sally in particular, her educational background in science and her initially high measures of inquiry efficacy were not enough to overcome the demands of teaching five different science preps. She lacked the needed content knowledge for all of those subjects to adequately develop PCK to the point of supporting change. This is a complex issue that must address issues such as teacher retention and recruitment, thereby reducing the need for any one science teacher to shoulder the instruction of multiple disciplines.

### *Experience in the Sciences*

Participants who described their conception of inquiry in terms of being highly student centered were those who either had educational backgrounds in the sciences as opposed to education, or had several professional development experiences that engaged them in authentic scientific research. These were also the participants who were noted to use labs and activities frequently in their classroom instruction, regardless as to the level of inquiry (Jeff, Rosie, Carolyn and Gina). These findings parallel similar results reported by Windschitl (2001) in which preservice teachers who had significant undergraduate or professional experiences with scientific research were more likely to use guided and open inquiry in their classrooms. As aforementioned, teachers typically teach in the way that they were taught. This has tremendous implications on the structure of professional development and preservice teacher education. If the National Science Education Standards call for teachers to employ inquiry as a fundamental component of instruction, then teacher preparation and inservice should be designed in such as way as to engage teachers in authentic research.

## *Conclusion*

### *Directions for Future Research*

As with many research studies, the process of finding answers also generated many questions. Identification of the subcomponent of inquiry efficacy within the concept of teacher beliefs is relatively novel. Even more recent is the development of instruments in which to measure this construct. The avenues in which this area can be developed are vast and increasingly important as science education reform continues to place a heavy emphasis on the use of inquiry.

### *Influencing Inquiry Efficacy and Use.*

This research study sampled participants from two of the R2R workshops. Results of the TSI might yield further insight into inquiry efficacy beliefs of different subgroups of teachers if larger samples sizes were available. Is inquiry efficacy influenced by years of experience? What measurable differences in efficacy can be found between groups that have or have not had extensive scientific research backgrounds? Do particular science disciplines lend themselves to more positive inquiry efficacy beliefs?

The nature of this study also limited the duration of investigation to the course of one year following the program. Future research may also want to take a more longitudinal look at the effects of Rivers to Reefs or similar programs on teachers' inquiry efficacy. In addition, over time, the R2R program may have long term effects on the use of inquiry as teachers continue to develop PCK.

### *Professed Beliefs.*

Shoenfeld (1998) establishes a clear distinction between professed beliefs and attributed beliefs. The interviews and TSI survey conducted in this study can only claim to have captured participants' professed beliefs. Attributed beliefs may be assigned when observing behaviors, but are still at best filtered through the lens of the researcher. This study was not designed to determine the attributed beliefs about participants' conceptions of inquiry. Rather, it measured professed beliefs of inquiry efficacy through the TSI as well as professed beliefs or perceptions of factors that affected the generation of inquiry activities following participation in R2R. The term perception is used here interchangeably with professed beliefs with the qualification that both reflect the participants' communicated understanding of their truths rather than the deeply held and stable attributed beliefs that underlie action. Future research may dedicate more attention to establishing a more thorough understanding of teachers' attributed beliefs regarding inquiry as a teaching and learning tool. Preliminary reflection on the transcripts revealed that a consensus could not be found amongst the participants in defining the characteristics of inquiry. Furthermore, research may seek to identify how closely teachers' professed beliefs of inquiry align with the class instruction they consider to be reflective of inquiry practice.

### *Contextual Constraints.*

Another perspective that may be used as a lens for investigation of the translation of beliefs to practice is Fords (1992), personal agency beliefs component of the Motivational Systems Theory. According to Ford, personal agency beliefs include a capability belief and a context belief. The capability beliefs include an individual's perception of their ability to function effectively. The contextual component includes perceptions about the support and responsiveness of the environment. Although the capability belief component is closely related to Bandura's Personal Self-efficacy construct, Ford argues that his context component is more encompassing than the Science Teacher Outcome Expectancy (STOE) outlined by Bandura. Whereas Bandura's STOE is a measure of teacher's belief that their teaching will result in student learning, Ford's context belief takes in to consideration the entire context of the teacher and learner, including administration, parents, other teachers and the physical environment (Haney & Lumpe, 1998).

Interviews with the participants revealed that they perceive the traditional classroom context and the atmosphere of the school to be unsupportive of their conceptions of inquiry instruction. Further research investigating the contextual beliefs of teachers using instruments such as the Contexts Beliefs About Teaching Science Instrument (CBATS) could serve to further identify external impediments to implementing reform efforts such as inquiry.

*Teacher Retention Rates.*

Hill & Barth (2004) note that teachers are commonly frustrated with high stakes testing, citing that in preparation of the exams, much of the pleasure and creativity of teaching is lost. They also express concerns that in test focused instruction, true learning may not be taking place. Dissatisfaction with their ability to influence school policy and feelings of ineffectiveness can contribute to teacher attrition (Buckley et al, 2005; Certo & Fox, 2002; Ingersoll, 2003; Norton, 1999). With teacher retention rates an increased area of concern, especially in critical areas like science (Billingsley, 1993; Darling-Hammond, 2006; Ingersol, 2003), it might be prudent to understand if programs similar to R2R have any impact on keeping teachers in the classroom.

At length during the research study, participants talked about the many perceived values of the program. These included descriptions of the many posters and resources they were given, the networks of collaborative teachers formed, and the opportunity to be in the position of a student again. However, the most often cited benefit was described as a “recharging” or “renewing” experience.

> *Well, that is something very important…getting me excited about science again. That was a big thing because I came back really pumped, really energized and that is a huge*

> *thing for teachers….That it is really important teachers get recharged like that, and get excited again about what they teach and various ways of teaching it. - Rosie*

> *…It was just reconnecting with science research. Actually doing all that stuff and finding out and exploring. It kind of rejuvenates you in a way. Because you're sitting in here doing this stuff teaching and you forget what it's all about. You are thinking in terms of chapters and numbers and homework…You forget the real meaning of science and what real scientists are doing out there. You could think about it, like if you…being a religious school, we have retreats and reconnect your soul and God. You can reconnect with science in something like that and it is so important. - Sally*

Most of the case study participants shared a sense of being reenergized as a result of involvement in the R2R program. If these purported feelings of renewed vigor to teach science equate to increased teacher retention, then the quality of science instruction can be increased by providing programs similar to R2R. Experienced teachers typically have higher levels of PCK than novice teachers (Clermont, Borko, & Krajcik, 1994; Tippins, Kagan, & Jackson, 1993). Retaining veteran teachers could thereby improve the quality of instruction occurring in science classrooms.

#### *Inquiry PCK.*

If content knowledge and pedagogical content knowledge are of utmost importance in determining teacher's use of inquiry, future research may investigate measures of teacher's inquiry PCK. Such an initiative is already in the beginning phases at West Michigan University (2007). The Pedagogy of Science Inquiry Teaching test (POSIT) is currently under development and could serve as a model for additional measures or as an instrument for related research. The test will be comprised of classroom teaching vignettes that pose a pedagogical problem. Questions require higher order thinking skills as well as address the Inquiry-Item-Criteria. Results of such measures can be used for summative evaluation of teacher preparation and profession inservice programs.

### *Concluding Summary*

This study has shown that providing practicing teachers with opportunities to experience authentic scientific research can significantly increase teachers' inquiry efficacy. These increases, although seemingly stable, do not, however, result in marked changes in instructional practices. These results contribute to the developing literature base regarding the challenges in enacting educational reform and the divide that sometimes exists between beliefs and practice. Previous studies show that professional development for teachers may do well to model the techniques they wish teachers to use. Professional learning should also involve prolonged engagement (Gess-Newsome, et al., 2003; Keys & Bryan, 2001) in authentic scientific research and a collaborative support structure to assist in translation of methods to classroom practice. Efforts should also be made to ensure that current reform is supported and promoted by the administrative structures that work closely with and influence teachers' choices in instructional strategies. While research should continue to identify perceived obstacles to implementing reform, teacher education programs and professional learning experiences need to offer teachers an opportunity to confront their beliefs about reform and how it may fit in the context of their teaching. If teachers have the education, support, resources and opportunities to utilize inquiry in their classes, their students will benefit from the many cited advantages of inquiry use, not the least of which includes improved science learning.

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# APPENDICES

# APPENDIX A

## Rivers to Reefs Syllabus and Schedule

### *Course Syllabus*

Course objectives:

1. Improve the content knowledge of in-service teachers in mathematics and the biological and chemical sciences, using Georgia's estuaries and offshore marine environment as a case study.
2. Introduce teachers to, and involve them with, ongoing research on Georgia's coast.
3. Introduce teachers to a variety of water quality issues – show how water quality impacts fisheries and examine how watersheds, tides and estuaries relate to water quality.
4. Familiarize teachers with water quality issues associated with accelerated human development along Georgia's coast.
5. Utilize on-line resources such as GALILEO and GIL to access and review current research.
6. Familiarize teachers with analytical and sampling tools used in estuarine research.
7. To introduce the usefulness of advanced teaching tools including distance learning (using the Georgia Statewide Academic and Medical System, i.e., GSAMS), the Internet, analytical and computer presentation software, and digital graphics technology.
8. Use "hands on" learning to improve teaching skills in laboratory activities, field studies, and computer media presentations.
9. Provide an opportunity for teachers to collaborate on data collection, analysis, and presentation of research findings.
10. Provide an opportunity for in-service teachers to obtain either graduate credit or Staff Development Unit (SDU) credit focused on teaching coastal ecology water quality assessment.

Pre-workshop assignment:

- Read Chapter 2 from the *Adopt-A-Stream Biological and Chemical Stream Monitoring* manual
- Write a 1-2 page synopsis of the assigned chapters
- Develop 2-5 questions you'd like to find the answers to during the workshop
  - *These documents may be neatly handwritten or typed, and will serve as springboards for our initial discussions of water quality issues.*

Pre and post test:

- You are required to complete a brief multiple choice test designed to measure prior knowledge against the knowledge acquired as a result of the course.

Portfolio development:

- See the attached page on Portfolio Assessment. Your portfolio will minimally include the following components:
  - Field Notebook - must contain class and laboratory notes (these will be reviewed)
  - Curriculum Project – identify an activity to integrate with your curriculum
  - Presentation on a selected water quality topic to develop for student audience
  - Journal article submission – draft document intended to be submitted to a professional journal

Resources:

- SkIO / UGA Marine Sciences library
- MECA computer lab - internet access, GALILEO, MS Word, ExCel, PowerPoint, etc.
- Reference texts, lab manuals, and handouts

*Tentative Schedule*

Rivers to Reefs 2006
JULY 5-18, 2006

| DATE / TIME | ACTIVITY | STAFF |
|---|---|---|
| WED. JULY 5 | | |
| 1:00 PM | On-site check in, room assignments | Williams, Goldberg |
| 1:30 PM | Orientation & Expectations, then facilities tour | Williams |
| 3:00 PM | Aquarium tour | Finkle, Lingebach |
| 4:00 PM | Journaling | Lapolla, Butler |

| | | | |
|---|---|---|---|
| | 5:30 PM | dinner | |
| | 6:30 PM | Pre-test (in cafeteria) | Butler |
| | 7:00 PM | Introduction to Georgia's Coastal Ecosystems | Williams |
| THRS. JULY 6 | | | |
| | 7:30 AM | Breakfast (low tide @ 7:22 AM) | |
| | 8:30 AM | Plankton lab | Crawfish |
| | 10:00 AM | Macro- invertebrate Lab | Crawfish |
| | 11:30 AM | Overview of charts, GPS, GIS | Williams, Goldberg |
| | 12:30 PM | Lunch | |
| | 1:30 PM | Group A: GPS, chart & map orientation | Williams, Lapolla |
| | | Group B: GIS Activity | Goldberg |
| | 3:00 PM | A & B switch activities | |
| | 5:30 PM | Dinner | |
| | 6:30 PM | Library & On-Line resources (GIL, Galileo) | Goldberg |
| | 7:30 PM | Movie: Water, A Precious Resource (Nat Geo) | Goldberg |
| FRI. JULY 7 | | | |
| | 7:30 AM | Breakfast | |
| | 8:15 AM | Introduction to the salt marsh | Sanders |
| | 9:15 AM | Salt marsh transect (low tide at 11:40 AM) | Sanders, Crawfish |
| | 12:00 PM | Lunch | |
| | 1:00 PM | Adopt-A-Stream certification class | Sweeney-Reeves |
| | 3:30 PM | Shannon-Weiner Index simulation " | |
| | 5:30 PM | dinner | |
| | 6:30 PM | Computer simulation (The Bay) - cafeteria | Goldberg |
| SAT. JULY 8 | | | |
| | 7:30 AM | Continental breakfast | |
| | 8:30 AM | Intro to Studies at Sea | Williams, Lapolla, Goldberg |
| | 9:30 AM | Board R/V Sea Dawg for "Studies at Sea" | |
| | 12:30 PM | Boxed lunch onboard Sea Dawg | Williams, Lapolla, Goldberg |
| | 2:00 PM | Return to dock, clean up | |
| | 3:00 PM | Project & journal time | Butler |
| | 5:30 PM | Dinner (cook out) | Goldberg |
| | 7:00 PM | "COASTAL IMAGES" (music & photography) | Bob & Judy Williams |
| SUN. JULY 9 | | | |
| | 8:00 AM | Continental breakfast & prep lunch | |
| | 9:00 AM | Small boats to Wassaw Island NWR | Crawford, Frick |
| | 12:00 PM | Boxed lunch on the beach | |
| | 2:00 PM | Depart Wassaw | |
| | 3:00 PM | Project & journal time | |
| | 6:00 PM | Pizza or dinner on own in Savannah | Goldberg |
| | 8:00 PM | Optional movie | |
| MON. JULY 10 | | | |
| | 7:30 AM | Continental breakfast | |

| | | |
|---|---|---|
| 8:30 AM | Marine Microbiology | Dr. Frischer |
| 9:30 AM | Microbiology lab | Frischer lab |
| 12:30 PM | Lunch | |
| 1:30 PM | G.E.O.R.G.I.A. Project & water quality | Sanders |
| 3:00 PM | Portfolio development & library research | Butler, Goldberg |
| 5:30 PM | Dinner | |
| 7:00 PM | Movie: Sapelo | |

TUES. JULY 11

| | | |
|---|---|---|
| 7:30 AM | breakfast | |
| 9:00 AM | MATS, Tilapia, BERM projects and tour | Dick Lee |
| 12:30 PM | Lunch | |
| 1:00 PM | Micrbiology lab follow up | Frischer |
| 2:00 PM | Dr. Jim Nelson - TBA | |
| 4:00 PM | TBA | |
| 5:30 PM | dinner | |
| 7:30 PM | Movie: Rivers to Reefs (NOAA) | Goldberg |

WED. JULY 12 R/V Savannah

| | | |
|---|---|---|
| 7:30 AM | board the R/V Savannah - breakfast onboard | Williams, Butler |
| 8:30 AM | begin station sampling | Williams, Goldberg |
| 11:00 AM | GRNMS orientation | Sakas |
| 1:00 PM | lunch | |
| 2:00 PM | continue station sampling | Williams, Goldberg |
| 3:00 PM | NOAA divers and ROV operations | Sakas, McFall |
| 4:30 PM | GIS data prep & entry entry | Goldberg |
| 6:00 PM | dinner | |
| 7:00 PM | Journal entries | |
| 9:00 PM | return to dock | |

THRS. JULY 13

| | | |
|---|---|---|
| 7:30 AM | Continental breakfast | |
| 8:30 AM | Final preparations for project, presenatation, and journal | |
| 12:30 PM | Lunch | |
| 2:30 PM | Gyotaku | Schmidt |
| 5:30 PM | Dinner | |
| 8:00 PM | Begin packing for Sapelo | |
| 12:00 PM | Lunch on the river bank | |
| 4:30 PM | Take out and clean up | |
| 5:30 PM | Dinner at Love's Catfish House | |

SAT. JULY 15 Sapelo Island

| | | |
|---|---|---|
| 7:30 AM | Breakfast | |
| 8:30 AM | Begin presentations | Butler, Williams |
| 11:30 AM | Pack vehicles for Sapelo | |
| 12:00 PM | Lunch | |
| 1:00 PM | Depart for Meridian | |
| 2:30 PM | Arrive at Meridian & Sapelo Island Visitor's Ctr. | |
| 3:30 PM | Ferry departs Meridian for Sapelo Island | |
| 4:30 PM | Settle in | |

| | | |
|---|---|---|
| 5:30 PM | Dinner, then distribute evaluations | |
| 8:00 PM | Sea Island Basketry | Yvonne Grovner |

SUN. JULY 16 Sapelo Island

| | | |
|---|---|---|
| 7:30 AM | breakfast | |
| 8:30 AM | TBA | |
| 12:30 PM | Lunch at the Big House | |
| 1:30 PM | North end island tour | Fran Stewart,<br>Crawfish, Maunde |
| 5:30 PM | Dinner | |
| 7:00 PM | workshop reflections (SIMH) | Butler |
| 10:00 PM | Turtle walk | Crawford |

MON. JULY 17 Sapelo Island

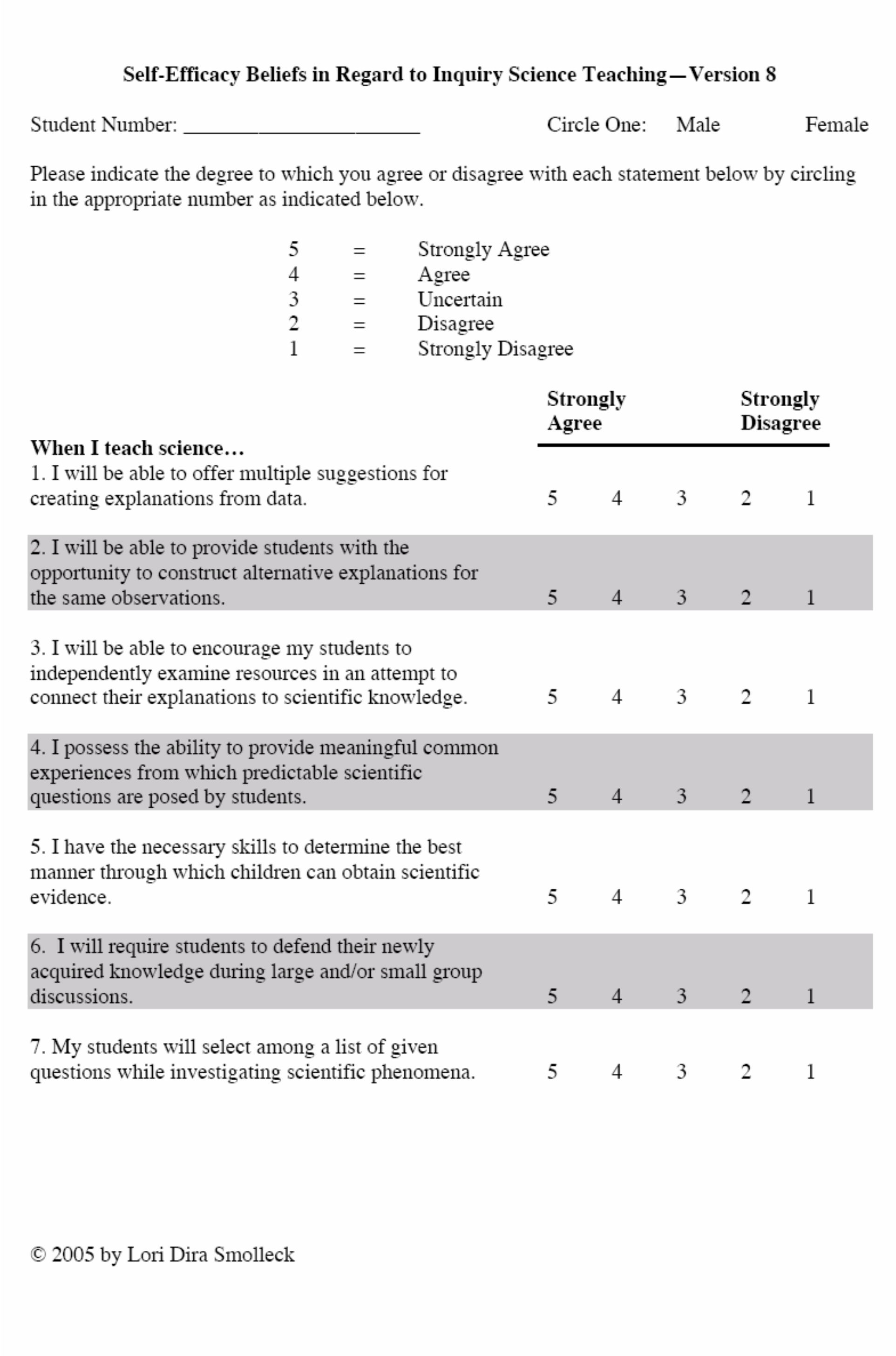
| | | |
|---|---|---|
| 6:00 AM | Continental breakfast | |
| 7:00 AM | Meet at Big Hole for seining | Williams, Crawford |
| 8:05 AM | Low Tide (neap) | |
| 10:30 AM | Fish cleaning @ Cap'n Tracy's | |
| 12:30 PM | Lunch at the Big House / turn in evaluations | |
| 2:00 PM | Basket making - economic applications of barrier island ecology | Yvonne Grovner |
| 6:30 PM | Low Country Boil & Fish Fry in Hog Hammock | |

TUES. JULY 18

| | | |
|---|---|---|
| 7:30 AM | "Big House" breakfast | |

# APPENDIX B

## The Teaching Science as Inquiry Instrument



### Self-Efficacy Beliefs in Regard to Inquiry Science Teaching—Version 8

Student Number: ______________________ Circle One: Male Female

Please indicate the degree to which you agree or disagree with each statement below by circling in the appropriate number as indicated below.

5 = Strongly Agree
4 = Agree
3 = Uncertain
2 = Disagree
1 = Strongly Disagree

| **When I teach science…** | **Strongly Agree** | | | | **Strongly Disagree** |
|---|---|---|---|---|---|
| 1. I will be able to offer multiple suggestions for creating explanations from data. | 5 | 4 | 3 | 2 | 1 |
| 2. I will be able to provide students with the opportunity to construct alternative explanations for the same observations. | 5 | 4 | 3 | 2 | 1 |
| 3. I will be able to encourage my students to independently examine resources in an attempt to connect their explanations to scientific knowledge. | 5 | 4 | 3 | 2 | 1 |
| 4. I possess the ability to provide meaningful common experiences from which predictable scientific questions are posed by students. | 5 | 4 | 3 | 2 | 1 |
| 5. I have the necessary skills to determine the best manner through which children can obtain scientific evidence. | 5 | 4 | 3 | 2 | 1 |
| 6. I will require students to defend their newly acquired knowledge during large and/or small group discussions. | 5 | 4 | 3 | 2 | 1 |
| 7. My students will select among a list of given questions while investigating scientific phenomena. | 5 | 4 | 3 | 2 | 1 |

| **When I teach science…** | **Strongly Agree** | | | | **Strongly Disagree** |
|---|---|---|---|---|---|
| 8. I will provide opportunities through which children will obtain evidence from observations and measurements. | 5 | 4 | 3 | 2 | 1 |
| 9. I will expect my students to make the results of their investigations public. | 5 | 4 | 3 | 2 | 1 |
| 10. I will be able to provide opportunities for students to become the critical decision makers when evaluating the validity of scientific explanations. | 5 | 4 | 3 | 2 | 1 |
| 11. I will be able to guide students in asking scientific questions that are meaningful. | 5 | 4 | 3 | 2 | 1 |
| 12. I will be able to provide opportunities for my students to describe their investigations and findings to others using their evidence to justify explanations and how data was collected. | 5 | 4 | 3 | 2 | 1 |
| 13. I will create (plan) investigations through which students will be expected to gather particular evidence. | 5 | 4 | 3 | 2 | 1 |
| 14. I will be able to negotiate with students possible connections between/among explanations. | 5 | 4 | 3 | 2 | 1 |
| 15. I will expect students to independently develop explanations using what they already know about scientifically accepted ideas. | 5 | 4 | 3 | 2 | 1 |
| 16. I encompass the ability to encourage students to review and ask questions about the results of other students' work. | 5 | 4 | 3 | 2 | 1 |
| 17. I will be able to guide students toward appropriate investigations depending on the questions they are attempting to answer. | 5 | 4 | 3 | 2 | 1 |
| 18. I will be able to create the majority of the scientific questions needed for students to investigate. | 5 | 4 | 3 | 2 | 1 |
| 19. I possess the ability to allow students to devise their own problems to investigate. | 5 | 4 | 3 | 2 | 1 |

| When I teach science… | Strongly Agree |  |  | Strongly Disagree |  |
|---|---|---|---|---|---|
| 20. My students will make use of data in order to develop explanations as a result of teacher guidance. | 5 | 4 | 3 | 2 | 1 |
| 21. I will be able to play the primary role in guiding the identification of scientific questions. | 5 | 4 | 3 | 2 | 1 |
| 22. I will be able to guide students toward scientifically accepted ideas upon which they can develop more meaningful understandings of science. | 5 | 4 | 3 | 2 | 1 |
| 23. I possess the abilities necessary to provide students with the possible connections between scientific knowledge and their explanations. | 5 | 4 | 3 | 2 | 1 |
| 24. I will expect students to recognize the connections existing between proposed explanations and scientific knowledge. | 5 | 4 | 3 | 2 | 1 |
| 25. I will expect students to ask scientific questions. | 5 | 4 | 3 | 2 | 1 |
| 26. I possess the skills necessary for guiding my students toward explanations that are consistent with experimental and observational evidence. | 5 | 4 | 3 | 2 | 1 |
| 27. My students will investigate questions I have developed. | 5 | 4 | 3 | 2 | 1 |
| 28. My students will create scientific explanations based on evidence, as a result of teacher assistance. | 5 | 4 | 3 | 2 | 1 |
| 29. My students will derive scientific evidence from instructional materials such as a textbook. | 5 | 4 | 3 | 2 | 1 |
| 30. I will be able to encourage students to gather the appropriate data necessary for answering their questions. | 5 | 4 | 3 | 2 | 1 |
| 31. I will be able to offer/model approaches for generating explanations from evidence. | 5 | 4 | 3 | 2 | 1 |
| 32. I will be able to coach students in the clear articulation of explanations. | 5 | 4 | 3 | 2 | 1 |

| **When I teach science…** | **Strongly Agree** | | | | **Strongly Disagree** |
|---|---|---|---|---|---|
| 33. Through the process of sharing explanations, I will be able to provide students with the opportunity to critique explanations and investigation methods. | 5 | 4 | 3 | 2 | 1 |
| 34. I will require students to create scientific claims based on observational evidence. | 5 | 4 | 3 | 2 | 1 |
| 35. I will expect my students to think about other reasonable explanations that can be derived from the evidence presented. | 5 | 4 | 3 | 2 | 1 |
| 36. I will be able to facilitate open-ended, long-term student investigations in an attempt to provide opportunities for students to gather evidence. | 5 | 4 | 3 | 2 | 1 |
| 37. I will be able to help students refine questions posed by the teacher or instructional materials, so they can experience both interesting and productive investigations. | 5 | 4 | 3 | 2 | 1 |
| 38. I will be able to provide demonstrations through which students can focus their queries into manageable questions for investigation. | 5 | 4 | 3 | 2 | 1 |
| 39. I will require students to develop explanations using evidence. | 5 | 4 | 3 | 2 | 1 |
| 40. I will be able to utilize worksheets as an instructional tool for providing a data set and walking students through the analysis process. | 5 | 4 | 3 | 2 | 1 |
| 41. My students will refine their explanations using possible connections to scientific knowledge that have been provided. | 5 | 4 | 3 | 2 | 1 |
| 42. I will be able to model for my students prescribed steps or procedures for communicating scientific results to the class. | 5 | 4 | 3 | 2 | 1 |
| 43. I will be able to provide my students with possible connections to scientific knowledge through which they can relate their explanations. | 5 | 4 | 3 | 2 | 1 |

| **When I teach science…** | **Strongly Agree** | | | **Strongly Disagree** | |
|---|---|---|---|---|---|
| 44. I will be able to provide my students with evidence to be analyzed. | 5 | 4 | 3 | 2 | 1 |
| 45. My students will engage in questions I have provided them. | 5 | 4 | 3 | 2 | 1 |
| 46. My students will engage in questions that are provided by a variety of sources such as the textbook. | 5 | 4 | 3 | 2 | 1 |
| 47. My students will analyze data that has been supplied, while following teacher instruction. | 5 | 4 | 3 | 2 | 1 |
| 48. I will expect my students to clarify the questions provided in an attempt to enhance science learning. | 5 | 4 | 3 | 2 | 1 |
| 49. I will be able to provide my students with the data needed to support an investigation. | 5 | 4 | 3 | 2 | 1 |
| 50. My students will communicate and justify their explanations to the class using broad guidelines that have been provided. | 5 | 4 | 3 | 2 | 1 |
| 51. My students will choose the questions they would like to investigate from a list provided. | 5 | 4 | 3 | 2 | 1 |
| 52. My students will analyze teacher provided data in a particular manner. | 5 | 4 | 3 | 2 | 1 |
| 53. My students will form their explanations using evidence that has been provided. | 5 | 4 | 3 | 2 | 1 |
| 54. I will be able to provide my students with all evidence required to form explanations through the use of lecture and textbook readings. | 5 | 4 | 3 | 2 | 1 |
| 55. My students will construct explanations from evidence using a framework I have provided. | 5 | 4 | 3 | 2 | 1 |
| 56. I will expect my students to follow predetermined procedures when justifying their explanations. | 5 | 4 | 3 | 2 | 1 |
| 57. My students will determine what evidence will be most useful for answering their scientific question(s). | 5 | 4 | 3 | 2 | 1 |

| **When I teach science…** | **Strongly Agree** | | | | **Strongly Disagree** |
|---|---|---|---|---|---|
| 58. My students will design their own investigations and gather the evidence necessary to answer a particular question. | 5 | 4 | 3 | 2 | 1 |
| 59. I will expect my students to collaborate with me in an attempt to construct criteria for sharing and critiquing explanations. | 5 | 4 | 3 | 2 | 1 |
| 60. My students will share and critique explanations while utilizing broad guidelines that have been provided. | 5 | 4 | 3 | 2 | 1 |
| 61. I will expect students to use internet based resources or other materials to further develop their investigations. | 5 | 4 | 3 | 2 | 1 |
| 62. I will be able to model for my students the guidelines to be followed when sharing and critiquing explanations. | 5 | 4 | 3 | 2 | 1 |
| 63. I will be able to instruct students to independently evaluate the consistency between their own explanations and scientifically accepted ideas. | 5 | 4 | 3 | 2 | 1 |
| 64. I will expect my students to negotiate with me the criteria for sharing and critiquing explanations. | 5 | 4 | 3 | 2 | 1 |
| 65. I will be able construct with students the guidelines for communicating results and explanations. | 5 | 4 | 3 | 2 | 1 |
| 66. I will expect my students to refine questions that have been provided. | 5 | 4 | 3 | 2 | 1 |
| 67. I will be able to provide my students with explanations. | 5 | 4 | 3 | 2 | 1 |
| 68. I will expect my students to justify explanations using given steps and procedures. | 5 | 4 | 3 | 2 | 1 |
| 69. My students will comprehend teacher presented explanations. | 5 | 4 | 3 | 2 | 1 |

Table 1
*Distribution of Items*

| | A | B | C | D |
|---|---|---|---|---|
| Learner engages in scientifically oriented questions | 4, 19, 25 | 7, 11, 51 | 37, 38, 48, 66 | 18, 21, 27, 45, 46 |
| Learner gives priority to evidence in responding to questions | 36, 57, 58 | 5, 13, 17, 30 | 8, 44, 49, 53 | 29, 40, 47, 52, 54 |
| Learner formulates explanations from evidence | 2, 10, 34, 35, 39 | 20, 26, 28 | 1, 31, 55 | 67, 69 |
| Learner connects explanations to scientific knowledge | 3, 15, 61, 63 | 14, 22, 24 | 23, 41, 43 | XXXXXXXX |
| | A | B | C | D |
| Learner communicates and justifies explanations | 6, 12, 33 | 9, 16, 32, 59, 64, 65 | 50, 60, 62 | 42, 56, 68 |

Green = Personal Self-Efficacy
Personal Self-Efficacy Total = 34

Orange = Outcome Expectancy
Outcome Expectancy Total =35

# APPENDIX C

## Internal Consistency of the TSI

### *Statistics Reported by Dira-Smolleck*

*Self Efficacy*

| Essential Feature | N | Items | α | Item Mean | Item Variance |
|---|---|---|---|---|---|
| 1 | 184 | 7 | .6579 | 3.95 | .07 |
| 2 | 181 | 8 | .6583 | 3.79 | .28 |
| 3 | 183 | 6 | .6749 | 4.05 | .03 |
| 4 | 183 | 6 | .7582 | 4.07 | .004 |
| 5 | 183 | 6 | .7566 | 4.16 | .01 |

*Outcome Expectancy*

| Essential Feature | N | Items | α | Item Mean | Item Variance |
|---|---|---|---|---|---|
| 1 | 182 | 8 | .7833 | 3.75 | .15 |
| 2 | 181 | 8 | .7026 | 3.73 | .29 |
| 3 | 179 | 7 | .6701 | 3.97 | .14 |
| 4 | 183 | 4 | .6034 | 4.07 | .04 |
| 5 | 181 | 8 | .6801 | 3.81 | .19 |

## APPENDIX D

## Internal Consistency of the TSI

### *Statistical Analysis of the Researcher*

| | |
|---|---|
| **69 Variables:** | pr1 pr2 pr3 pr4 pr5 pr6 pr7 pr8 pr9 pr10 pr11 pr12 pr13 pr14 pr15 pr16 pr17 pr18 pr19 pr20 pr21 pr22 pr23 pr24 pr25 pr26 pr27 pr28 pr29 pr30 pr31 pr32 pr33 pr34 pr35 pr36 pr37 pr38 pr39 pr40 pr41 pr42 pr43 pr44 pr45 pr46 pr47 pr48 pr49 pr50 pr51 pr52 pr53 pr54 pr55 pr56 pr57 pr58 pr59 pr60 pr61 pr62 pr63 pr64 pr65 pr66 pr67 pr68 pr69 |

**Cronbach Coefficient Alpha**

| Variables | Alpha |
|---|---|
| Raw | 0.976099 |
| Standardized | 0.977063 |

**Cronbach Coefficient Alpha with Deleted Variable**

| | Raw Variables | | Standardized Variables | | |
|---|---|---|---|---|---|
| Deleted Variable | Correlation with Total | Alpha | Correlation with Total | Alpha | Label |
| **pr1** | 0.4257 | 0.9760 | 0.438690 | 0.9770 | Multiple suggestions for creating explanations from data |
| **pr2** | 0.5322 | 0.9758 | 0.554563 | 0.9768 | Opportunity to construct alternative explanations |
| **pr3** | 0.7159 | 0.9755 | 0.732424 | 0.9765 | Independently examine resources to connect explanations to scientific knowledge |
| **pr4** | 0.5977 | 0.9757 | 0.608976 | 0.9767 | Common experiences from which predictable scientific questions are posed |
| **pr5** | 0.7118 | 0.9756 | 0.708332 | 0.9765 | Determine best manner by which children can obtain scientific evidence |
| **pr6** | 0.5066 | 0.9759 | 0.510991 | 0.9769 | Defend their newly acquired knowledge during group discussions |
| **pr7** | 0.5321 | 0.9758 | 0.538033 | 0.9768 | Select among list of given questions while investigating scientific phenomena |
| **pr8** | 0.4764 | 0.9759 | 0.496078 | 0.9769 | Obtain evidence from observations & measurements |

| Cronbach Coefficient Alpha with Deleted Variable | | | | | |
|---|---|---|---|---|---|
| | Raw Variables | | Standardized Variables | | |
| Deleted Variable | Correlation with Total | Alpha | Correlation with Total | Alpha | Label |
| **pr9** | 0.2763 | 0.9764 | 0.277662 | 0.9773 | Make the results of their investigations public |
| **pr10** | 0.4356 | 0.9760 | 0.450603 | 0.9770 | Become critical decision makers when evaluating validity of scientific explanations |
| **pr11** | 0.7792 | 0.9754 | 0.792579 | 0.9764 | Guide students in asking meaningful scientific questions |
| **pr12** | 0.6796 | 0.9756 | 0.689620 | 0.9765 | Describe their investigations & findings using evidence for justification |
| **pr13** | 0.4938 | 0.9759 | 0.488330 | 0.9769 | Create (plan) investigations through which students gather particular evidence |
| **pr14** | 0.6112 | 0.9757 | 0.609692 | 0.9767 | Negotiate with students possible connections between/among explanations |
| **pr15** | 0.6366 | 0.9756 | 0.651291 | 0.9766 | Independently develop explanations using known scientifically accepted ideas |
| **pr16** | 0.5494 | 0.9758 | 0.561597 | 0.9768 | Review & ask questions about the results of other students' work |
| **pr17** | 0.6110 | 0.9757 | 0.631571 | 0.9766 | Appropriate investigations for the questions they are attempting to answer |
| **pr18** | 0.5725 | 0.9758 | 0.566282 | 0.9768 | Create majority of scientific questions needed for students to investigate |
| **pr19** | 0.6142 | 0.9757 | 0.629370 | 0.9767 | Allow students to devise their own problems to investigate |
| **pr20** | 0.5310 | 0.9758 | 0.527711 | 0.9768 | Make use of data to develop explanations as a result of teacher guidance |
| **pr21** | 0.3658 | 0.9762 | 0.352116 | 0.9771 | Play the primary role in guiding the identification of scientific questions |
| **pr22** | 0.6376 | 0.9757 | 0.652938 | 0.9766 | Scientifically accepted ideas to develop meaningful understandings of science |
| **pr23** | 0.7325 | 0.9755 | 0.749842 | 0.9764 | Possible connections between scientific knowledge & explanations |
| **pr24** | 0.4829 | 0.9759 | 0.466361 | 0.9769 | Recognize connections between proposed explanations & scientific knowledge |
| **pr25** | 0.5254 | 0.9758 | 0.511941 | 0.9769 | Expect students to ask scientific questions |
| **pr26** | 0.7199 | 0.9755 | 0.718741 | 0.9765 | Explanations consistent with experimental & observational evidence |
| **pr27** | 0.3740 | 0.9762 | 0.367109 | 0.9771 | Students will investigate questions I have developed |

**Cronbach Coefficient Alpha with Deleted Variable**

| Deleted Variable | Raw Variables | | Standardized Variables | | Label |
|---|---|---|---|---|---|
| | Correlation with Total | Alpha | Correlation with Total | Alpha | |
| **pr28** | 0.4770 | 0.9759 | 0.467141 | 0.9769 | Create scientific explanations based on evidence |
| **pr29** | 0.6747 | 0.9756 | 0.656327 | 0.9766 | Derive scientific evidence from instructional materials such as a textbook |
| **pr30** | 0.6914 | 0.9756 | 0.707032 | 0.9765 | Gather the appropriate data necessary for answering their questions |
| **pr31** | 0.7535 | 0.9756 | 0.756049 | 0.9764 | Offer/model approaches for generating explanations from evidence |
| **pr32** | 0.7449 | 0.9754 | 0.742735 | 0.9764 | Coach students in the clear articulation of explanations |
| **pr33** | 0.7908 | 0.9754 | 0.803707 | 0.9763 | Critique explanations & investigation methods |
| **pr34** | 0.6554 | 0.9756 | 0.639006 | 0.9766 | Require students to create scientific claims based on observational evidence |
| **pr35** | 0.6099 | 0.9757 | 0.620581 | 0.9767 | Expect students to think about other reasonable explanations from evidence |
| **pr36** | 0.5738 | 0.9758 | 0.583250 | 0.9767 | Facilitate open-ended, long-term student investigations for gathering evidence |
| **pr37** | 0.6683 | 0.9756 | 0.677742 | 0.9766 | Refine questions so they can experience interesting & productive investigations |
| **pr38** | 0.7486 | 0.9755 | 0.754474 | 0.9764 | Focus their queries into manageable questions |
| **pr39** | 0.6845 | 0.9756 | 0.691059 | 0.9765 | Require students to develop explanations using evidence |
| **pr40** | 0.7431 | 0.9754 | 0.740988 | 0.9765 | Use data worksheets as an instructional tool for the analysis process |
| **pr41** | 0.7663 | 0.9754 | 0.761639 | 0.9764 | Refine explanations using possible connections to scientific knowledge |
| **pr42** | 0.6962 | 0.9755 | 0.700284 | 0.9765 | Model for prescribed steps or procedures for communicating scientific results |
| **pr43** | 0.7022 | 0.9756 | 0.707414 | 0.9765 | Connections to scientific knowledge for relating their explanations |
| **pr44** | 0.7680 | 0.9754 | 0.772398 | 0.9764 | Provide students with evidence to be analyzed |
| **pr45** | 0.5517 | 0.9758 | 0.531341 | 0.9768 | Engage in questions I have provided them |
| **pr46** | 0.6945 | 0.9755 | 0.684479 | 0.9766 | Engage in questions from a variety of sources such as textbooks |
| **pr47** | 0.5952 | 0.9758 | 0.566753 | 0.9768 | Analyze data that has been supplied |

| Cronbach Coefficient Alpha with Deleted Variable | | | | | |
|---|---|---|---|---|---|
| | Raw Variables | | Standardized Variables | | |
| Deleted Variable | Correlation with Total | Alpha | Correlation with Total | Alpha | Label |
| **pr48** | 0.7366 | 0.9755 | 0.732810 | 0.9765 | Clarify the questions provided to enhance science learning |
| **pr49** | 0.6724 | 0.9756 | 0.656258 | 0.9766 | Provide the data needed to support an investigation |
| **pr50** | 0.6268 | 0.9757 | 0.633714 | 0.9766 | Communicate & justify their explanations using broad guidelines |
| **pr51** | 0.5329 | 0.9759 | 0.520098 | 0.9768 | Choose questions they would like to investigate from a list |
| **pr52** | 0.5339 | 0.9758 | 0.511054 | 0.9769 | Analyze teacher provided data in a particular manner |
| **pr53** | 0.5923 | 0.9757 | 0.566820 | 0.9768 | Form their explanations using evidence |
| **pr54** | 0.6172 | 0.9757 | 0.598720 | 0.9767 | Provide evidence required to form explanations through lectures & textbooks |
| **pr55** | 0.5877 | 0.9758 | 0.569153 | 0.9768 | Construct explanations from evidence using a provided framework |
| **pr56** | 0.6787 | 0.9756 | 0.665916 | 0.9766 | Follow predetermined procedures when justifying their explanations |
| **pr57** | 0.5797 | 0.9758 | 0.576338 | 0.9767 | Determine what evidence most useful for answering scientific question(s) |
| **pr58** | 0.5813 | 0.9758 | 0.599333 | 0.9767 | Design their own investigations & gather the evidence necessary |
| **pr59** | 0.4863 | 0.9759 | 0.511289 | 0.9769 | Collaborate with me to construct criteria for critiquing explanations |
| **pr60** | 0.7142 | 0.9755 | 0.737626 | 0.9765 | Share & critique explanations while utilizing broad guidelines |
| **pr61** | 0.3139 | 0.9762 | 0.322899 | 0.9772 | Use internet based resources etc. to further develop investigations |
| **pr62** | 0.5125 | 0.9759 | 0.531588 | 0.9768 | Model the guidelines for sharing & critiquing explanations |
| **pr63** | 0.7760 | 0.9754 | 0.792422 | 0.9764 | Evaluate consistency between explanations & accepted ideas |
| **pr64** | 0.6757 | 0.9756 | 0.678564 | 0.9766 | Negotiate criteria for sharing & critiquing explanations |
| **pr65** | 0.6661 | 0.9756 | 0.684765 | 0.9766 | Construct guidelines for communicating results & explanations |
| **pr66** | 0.6621 | 0.9756 | 0.674804 | 0.9766 | Refine questions that have been provided |
| **pr67** | 0.6004 | 0.9757 | 0.571379 | 0.9768 | Provide my students with explanations |

| Cronbach Coefficient Alpha with Deleted Variable | | | | | |
|---|---|---|---|---|---|
| | Raw Variables | | Standardized Variables | | |
| **Deleted Variable** | **Correlation with Total** | **Alpha** | **Correlation with Total** | **Alpha** | **Label** |
| **pr68** | 0.7436 | 0.9754 | 0.720068 | 0.9765 | Justify explanations using given steps & procedures |
| **pr69** | 0.4380 | 0.9760 | 0.450319 | 0.9770 | Comprehend teacher presented explanations |

# APPENDIX E

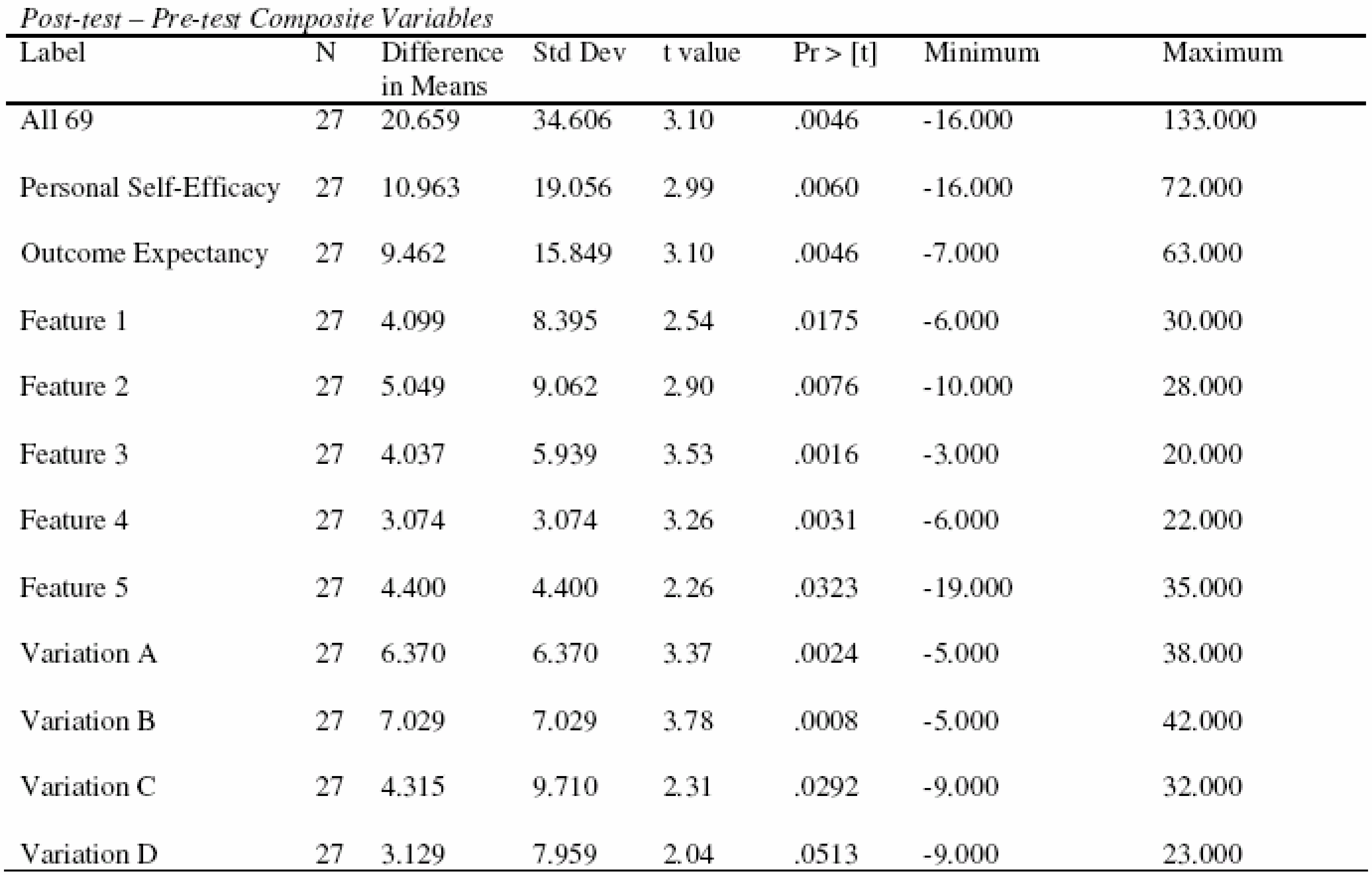
## TSI Subcategory Correlation

*Standardized Cronbach Coefficient Alpha Values*

| Essential Feature | A | B | C | D |
|---|---|---|---|---|
| 1 | .6117 | .5644 | .8390 | .7927 |
| 2 | .7446 | .7821 | .7376 | .8681 |
| 3 | .7526 | .6983 | .5579 | .6788 |
| 4 | .7460 | .5052 | .7734 | |
| 5 | .8265 | .7779 | .7996 | .8046 |

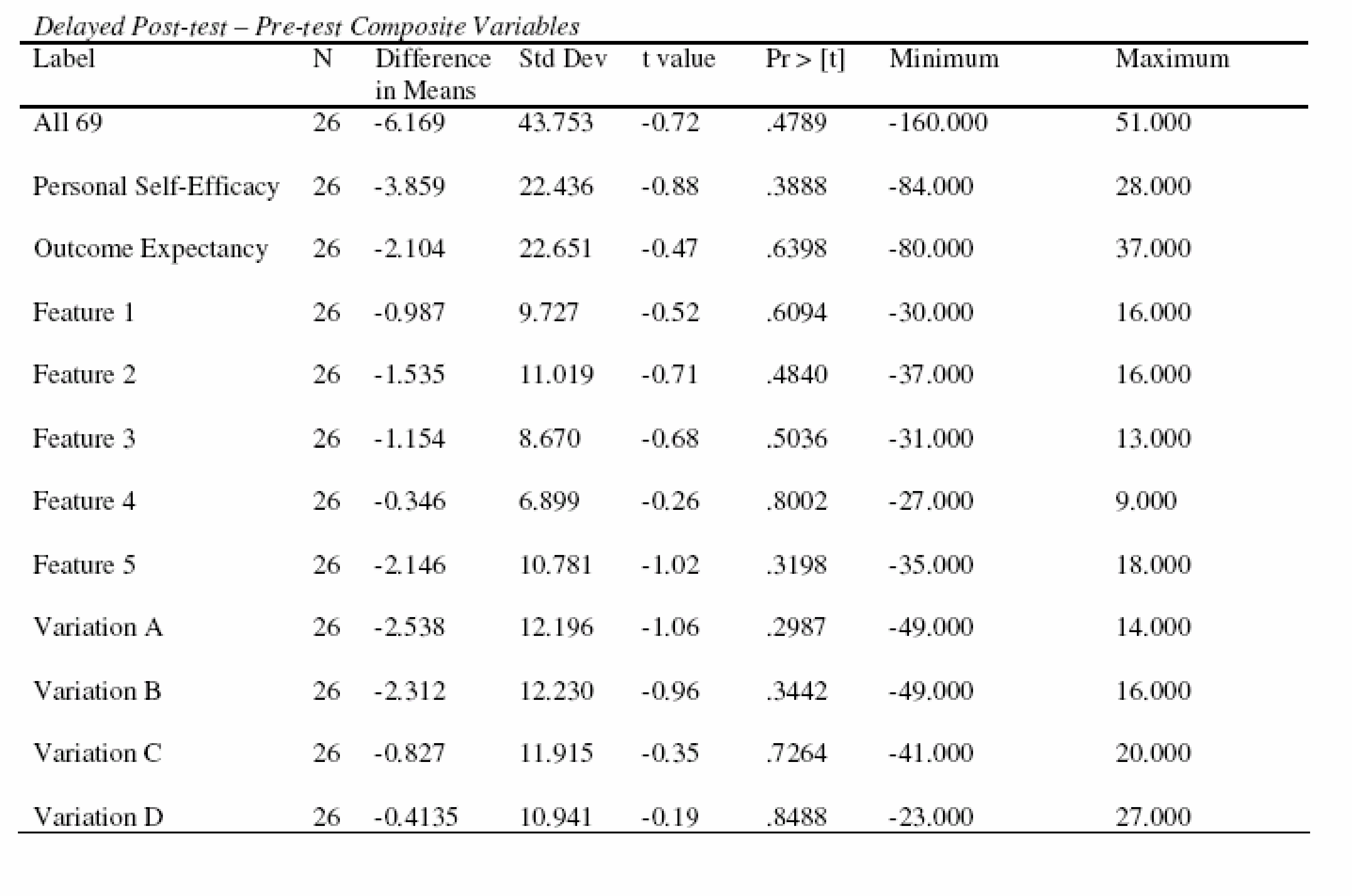
# APPENDIX F

## Complete TSI Administration Analyses



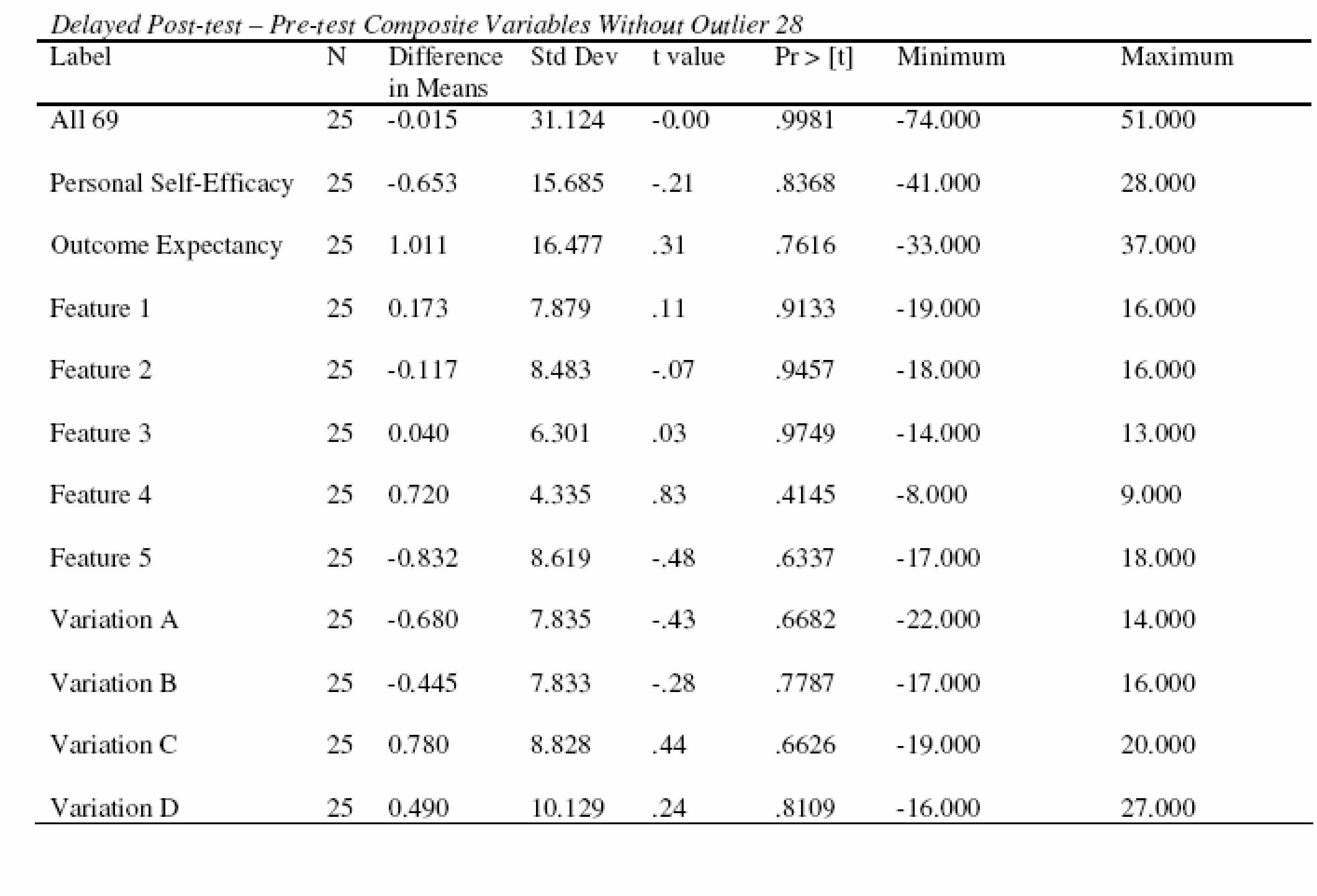
*Post-test – Pre-test Composite Variables*

| Label | N | Difference in Means | Std Dev | t value | Pr > [t] | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| All 69 | 27 | 20.659 | 34.606 | 3.10 | .0046 | -16.000 | 133.000 |
| Personal Self-Efficacy | 27 | 10.963 | 19.056 | 2.99 | .0060 | -16.000 | 72.000 |
| Outcome Expectancy | 27 | 9.462 | 15.849 | 3.10 | .0046 | -7.000 | 63.000 |
| Feature 1 | 27 | 4.099 | 8.395 | 2.54 | .0175 | -6.000 | 30.000 |
| Feature 2 | 27 | 5.049 | 9.062 | 2.90 | .0076 | -10.000 | 28.000 |
| Feature 3 | 27 | 4.037 | 5.939 | 3.53 | .0016 | -3.000 | 20.000 |
| Feature 4 | 27 | 3.074 | 3.074 | 3.26 | .0031 | -6.000 | 22.000 |
| Feature 5 | 27 | 4.400 | 4.400 | 2.26 | .0323 | -19.000 | 35.000 |
| Variation A | 27 | 6.370 | 6.370 | 3.37 | .0024 | -5.000 | 38.000 |
| Variation B | 27 | 7.029 | 7.029 | 3.78 | .0008 | -5.000 | 42.000 |
| Variation C | 27 | 4.315 | 9.710 | 2.31 | .0292 | -9.000 | 32.000 |
| Variation D | 27 | 3.129 | 7.959 | 2.04 | .0513 | -9.000 | 23.000 |



*Delayed Post-test – Pre-test Composite Variables*

| Label | N | Difference in Means | Std Dev | t value | Pr > [t] | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| All 69 | 26 | -6.169 | 43.753 | -0.72 | .4789 | -160.000 | 51.000 |
| Personal Self-Efficacy | 26 | -3.859 | 22.436 | -0.88 | .3888 | -84.000 | 28.000 |
| Outcome Expectancy | 26 | -2.104 | 22.651 | -0.47 | .6398 | -80.000 | 37.000 |
| Feature 1 | 26 | -0.987 | 9.727 | -0.52 | .6094 | -30.000 | 16.000 |
| Feature 2 | 26 | -1.535 | 11.019 | -0.71 | .4840 | -37.000 | 16.000 |
| Feature 3 | 26 | -1.154 | 8.670 | -0.68 | .5036 | -31.000 | 13.000 |
| Feature 4 | 26 | -0.346 | 6.899 | -0.26 | .8002 | -27.000 | 9.000 |
| Feature 5 | 26 | -2.146 | 10.781 | -1.02 | .3198 | -35.000 | 18.000 |
| Variation A | 26 | -2.538 | 12.196 | -1.06 | .2987 | -49.000 | 14.000 |
| Variation B | 26 | -2.312 | 12.230 | -0.96 | .3442 | -49.000 | 16.000 |
| Variation C | 26 | -0.827 | 11.915 | -0.35 | .7264 | -41.000 | 20.000 |
| Variation D | 26 | -0.4135 | 10.941 | -0.19 | .8488 | -23.000 | 27.000 |



*Delayed Post-test – Pre-test Composite Variables Without Outlier 28*

| Label | N | Difference in Means | Std Dev | t value | Pr > [t] | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| All 69 | 25 | -0.015 | 31.124 | -0.00 | .9981 | -74.000 | 51.000 |
| Personal Self-Efficacy | 25 | -0.653 | 15.685 | -.21 | .8368 | -41.000 | 28.000 |
| Outcome Expectancy | 25 | 1.011 | 16.477 | .31 | .7616 | -33.000 | 37.000 |
| Feature 1 | 25 | 0.173 | 7.879 | .11 | .9133 | -19.000 | 16.000 |
| Feature 2 | 25 | -0.117 | 8.483 | -.07 | .9457 | -18.000 | 16.000 |
| Feature 3 | 25 | 0.040 | 6.301 | .03 | .9749 | -14.000 | 13.000 |
| Feature 4 | 25 | 0.720 | 4.335 | .83 | .4145 | -8.000 | 9.000 |
| Feature 5 | 25 | -0.832 | 8.619 | -.48 | .6337 | -17.000 | 18.000 |
| Variation A | 25 | -0.680 | 7.835 | -.43 | .6682 | -22.000 | 14.000 |
| Variation B | 25 | -0.445 | 7.833 | -.28 | .7787 | -17.000 | 16.000 |
| Variation C | 25 | 0.780 | 8.828 | .44 | .6626 | -19.000 | 20.000 |
| Variation D | 25 | 0.490 | 10.129 | .24 | .8109 | -16.000 | 27.000 |

# APPENDIX G

## Complete TSI Item Analysis

Pretest: Personal Self-Efficacy
Feature 1: Learner Engages in Questions

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr4 | Common experiences from which predictable scientific questions are posed | 30 | 4.0666 | 0.9071 | 2 | 5 |
| pr11 | Guide students in asking meaningful scientific questions | 30 | 4.3000 | 0.7497 | 2 | 5 |
| pr18 | Create majority of scientific questions needed for students to investigate | 30 | 3.4333 | 1.1943 | 1 | 5 |
| pr19 | Allow students to devise their own problems to investigate | 30 | 4.1000 | 0.7588 | 2 | 5 |
| pr21 | Play the primary role in guiding the identification of scientific questions | 30 | 0.7588 | 0.9965 | 1 | 5 |
| pr37 | Refine questions so they can experience interesting & productive investigations | 30 | 3.8333 | 0.8742 | 2 | 5 |
| pr38 | Focus their queries into manageable questions | 30 | 4.2000 | 0.8469 | 2 | 5 |

Posttest: Personal Self-Efficacy
Feature 1: Leaner Engages in Questions

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po4 | Common experiences from which predictable scientific questions are posed | 28 | 4.2500 | 0.6454 | 3 | 5 |
| po11 | Guide students in asking meaningful scientific questions | 28 | 4.7142 | 0.4600 | 4 | 5 |
| po18 | Create majority of scientific questions needed for students to investigate | 28 | 3.7500 | 1.1097 | 1 | 5 |
| po19 | Allow students to devise their own problems to investigate | 28 | 4.3928 | 0.6288 | 3 | 5 |
| po21 | Play the primary role in guiding the identification of scientific questions | 28 | 4.1071 | 1.1333 | 1 | 5 |
| po37 | Refine questions so they can experience interesting & productive investigations | 28 | 4.0595 | 0.7859 | 2 | 5 |
| po38 | Focus their queries into manageable questions | 28 | 4.2500 | 0.7515 | 3 | 5 |

Difference: Post-test – Pretest
Feature 1 : Learner Engages in Questions

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff4 | Common experiences from which predictable scientific questions are posed | 27 | 0.1481 | 1.0635 | 0.72 | 0.4756 |
| diff11 | Guide students in asking meaningful scientific questions | 27 | 0.3703 | 0.8388 | 2.29 | 0.0301 |
| diff18 | Create majority of scientific questions needed for students to investigate | 27 | 0.4814 | 1.2517 | 2.00 | 0.0562 |
| diff19 | Allow students to devise their own problems to investigate | 27 | 0.2222 | 0.8006 | 1.44 | 0.1612 |
| diff21 | Play the primary role in guiding the identification of scientific questions | 27 | 0.3703 | 0.9260 | 2.08 | 0.0477 |
| diff37 | Refine questions so they can experience interesting & productive investigations | 27 | 0.2098 | 0.8970 | 1.22 | 0.2350 |
| diff38 | Focus their queries into manageable questions | 27 | 0 | 1.0741 | 0.00 | 1.0000 |

Difference: Delayed Post – Post-test
Feature 1: Learner Engages in Questions

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff2_4 | Common experiences from which predictable scientific questions are posed | 26 | -0.0384 | 1.0384 | -0.19 | 0.8517 |
| diff2_11 | Guide students in asking meaningful scientific questions | 26 | -0.1538 | 0.8338 | -0.94 | 0.3558 |
| diff2_18 | Create majority of scientific questions needed for students to investigate | 26 | -0.0769 | 1.2937 | -0.30 | 0.7643 |
| diff2_19 | Allow students to devise their own problems to investigate | 26 | -0.3076 | 1.0107 | -1.55 | 0.1332 |
| diff2_21 | Play the primary role in guiding the identification of scientific questions | 26 | -0.2692 | 1.3132 | -1.05 | 0.3059 |
| diff2_37 | Refine questions so they can experience interesting & productive investigations | 26 | 0.0512 | 1.1143 | 0.23 | 0.8164 |
| diff2_38 | Focus their queries into manageable questions | 26 | 0 | 1.1661 | 0.00 | 1.0000 |

Pretest: Personal Self-Efficacy
Feature 2: Learner Gives Priority to Evidence

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr5 | Determine best manner by which children can obtain scientific evidence | 31 | 3.5161 | 0.7243 | 2 | 5 |
| pr17 | Appropriate investigations for the questions they are attempting to answer | 30 | 4.1000 | 0.7588 | 2 | 5 |
| pr30 | Gather the appropriate data necessary for answering their questions | 30 | 4.2666 | 0.6914 | 3 | 5 |
| pr36 | Facilitate open-ended, long-term student investigations for gathering evidence | 30 | 3.9000 | 0.9595 | 2 | 5 |
| pr40 | Use data worksheets as an instructional tool for the analysis process | 30 | 3.9666 | 0.9994 | 1 | 5 |
| pr44 | Provide students with evidence to be analyzed | 30 | 3.9333 | 1.0482 | 1 | 5 |
| pr49 | Provide the data needed to support an investigation | 30 | 3.7666 | 1.0400 | 1 | 5 |
| pr54 | Provide evidence required to form explanations through lectures & textbooks | 30 | 3.0333 | 1.2172 | 1 | 5 |

Post-test: Personal Self-Efficacy
Feature 2: Learner Gives Priority to Evidence

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po5 | Determine best manner by which children can obtain scientific evidence | 28 | 4.2500 | 0.5181 | 3.0000 | 5 |
| po17 | Appropriate investigations for the questions they are attempting to answer | 28 | 4.3928 | 0.6288 | 3.0000 | 5 |
| po30 | Gather the appropriate data necessary for answering their questions | 28 | 4.5357 | 0.6372 | 3.0000 | 5 |
| po36 | Facilitate open-ended, long-term student investigations for gathering evidence | 28 | 4.4821 | 0.6307 | 3.0000 | 5 |
| po40 | Use data worksheets as an instructional tool for the analysis process | 28 | 4.3035 | 0.9163 | 2.0000 | 5 |
| po44 | Provide students with evidence to be analyzed | 28 | 4.2857 | 0.7126 | 3.0000 | 5 |
| po49 | Provide the data needed to support an investigation | 28 | 3.8928 | 1.1655 | 1.0000 | 5 |
| po54 | Provide evidence required to form explanations through lectures & textbooks | 28 | 3.3928 | 1.2572 | 1.0000 | 5 |

Difference Post-test – Pretest
Feature 2: Learner Gives Priority to Evidence

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff5 | Determine best manner by which children can obtain scientific evidence | 27 | 0.6666 | 0.9198 | 3.77 | 0.0009 |
| diff17 | Appropriate investigations for the questions they are attempting to answer | 27 | 0.2222 | 0.8473 | 1.36 | 0.1846 |
| diff30 | Gather the appropriate data necessary for answering their questions | 27 | 0.2592 | 0.9842 | 1.37 | 0.1828 |
| diff36 | Facilitate open-ended, long-term student investigations for gathering evidence | 27 | 0.5000 | 1.0469 | 2.48 | 0.0199 |
| diff40 | Use data worksheets as an instructional tool for the analysis process | 27 | 0.3518 | 0.8967 | 2.04 | 0.0518 |
| diff44 | Provide students with evidence to be analyzed | 27 | 0.3703 | 1.1485 | 1.68 | 0.1058 |
| diff49 | Provide the data needed to support an investigation | 27 | 0.2592 | 1.2887 | 1.05 | 0.3055 |
| diff54 | Provide evidence required to form explanations through lectures & textbooks | 27 | 0.2592 | 1.0225 | 1.32 | 0.1992 |

Difference Delayed Post – Post-test
Feature 2: Learner Gives Priority to Evidence

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff2_5 | Determine best manner by which children can obtain scientific evidence | 26 | -0.3589 | 0.8890 | -2.06 | 0.0501 |
| diff2_17 | Appropriate investigations for the questions they are attempting to answer | 26 | -0.0769 | 0.9347 | -0.42 | 0.6784 |
| diff2_30 | Gather the appropriate data necessary for answering their questions | 26 | 0 | 0.9797 | 0.00 | 1.0000 |
| diff2_36 | Facilitate open-ended, long-term student investigations for gathering evidence | 26 | -0.3269 | 0.9689 | -1.72 | 0.0977 |
| diff2_40 | Use data worksheets as an instructional tool for the analysis process | 26 | -0.3653 | 1.2292 | -1.52 | 0.1422 |
| diff2_44 | Provide students with evidence to be analyzed | 26 | 0.1153 | 0.9519 | 0.62 | 0.5421 |
| diff2_49 | Provide the data needed to support an investigation | 26 | 0.1153 | 1.2108 | 0.49 | 0.6313 |
| diff2_54 | Provide evidence required to form explanations through lectures & textbooks | 26 | -0.2307 | 1.2746 | -0.92 | 0.3647 |

Pretest: Personal Self- Efficacy
Feature 3: Learner Formulates Explanations

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr1 | Multiple suggestions for creating explanations from data | 31 | 4.0000 | 0.8944 | 1 | 5 |
| pr2 | Opportunity to construct alternative explanations | 31 | 4.0000 | 0.7745 | 2 | 5 |
| pr10 | Become critical decision makers when evaluating validity of scientific explanations | 30 | 3.9333 | 0.7849 | 2 | 5 |
| pr26 | Explanations consistent with experimental & observational evidence | 30 | 3.8666 | 0.8193 | 2 | 5 |
| pr31 | Offer/model approaches for generating explanations from evidence | 30 | 4.0000 | 0.6432 | 3 | 5 |
| pr67 | Provide my students with explanations | 30 | 4.1666 | 0.8339 | 2 | 5 |

Post-test: Personal Self-Efficacy
Feature 3: Learner Formulates Explanations

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po1 | Multiple suggestions for creating explanations from data | 28 | 4.3571 | 0.6214 | 3 | 5 |
| po2 | Opportunity to construct alternative explanations | 28 | 4.2857 | 0.4600 | 4 | 5 |
| po10 | Become critical decision makers when evaluating validity of scientific explanations | 28 | 4.3214 | 0.7228 | 3 | 5 |
| po26 | Explanations consistent with experimental & observational evidence | 28 | 4.3928 | 0.9164 | 1 | 5 |
| po31 | Offer/model approaches for generating explanations from evidence | 28 | 4.4642 | 0.6372 | 3 | 5 |
| po67 | Provide my students with explanations | 28 | 4.2500 | 0.9279 | 2 | 5 |

Difference : Post-test – Pretest
Feature 3:  Learner Formulates Explanations

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff1 | Multiple suggestions for creating explanations from data | 27 | 0.3703 | 0.9666 | 1.99 | 0.0571 |
| diff2 | Opportunity to construct alternative explanations | 27 | 0.2962 | 0.8234 | 1.87 | 0.0728 |
| diff10 | Become critical decision makers when evaluating validity of scientific explanations | 27 | 0.4074 | 0.8883 | 2.38 | 0.0248 |
| diff26 | Explanations consistent with experimental & observational evidence | 27 | 0.4814 | 0.9352 | 2.68 | 0.0127 |
| diff31 | Offer/model approaches for generating explanations from evidence | 27 | 0.4444 | 0.6979 | 3.31 | 0.0027 |
| diff67 | Provide my students with explanations | 28 | 0.1071 | 0.8751 | 0.65 | 0.5226 |

Difference:  Delayed Post – Post-test
Feature 3:  Learner Formulates Explanations

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff2_1 | Multiple suggestions for creating explanations from data | 26 | -0.1153 | 0.8638 | -0.68 | 0.5021 |
| diff2_2 | Opportunity to construct alternative explanations | 26 | -0.0769 | 0.7442 | -0.53 | 0.6028 |
| diff2_10 | Become critical decision makers when evaluating validity of scientific explanations | 26 | -0.2307 | 0.9922 | -1.19 | 0.2468 |
| diff2_26 | Explanations consistent with experimental & observational evidence | 26 | -0.0384 | 1.1128 | -0.18 | 0.8615 |
| diff2_31 | Offer/model approaches for generating explanations from evidence | 26 | 0.0769 | 0.9347 | 0.42 | 0.6784 |
| diff2_67 | Provide my students with explanations | 26 | -0.0384 | 0.7200 | -0.27 | 0.7876 |

Pretest: Personal Self-Efficacy
Feature 4: Learner Connects Explanations to Knowledge

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr3 | Independently examine resources to connect explanations to scientific knowledge | 31 | 3.8387 | 1.0032 | 1 | 5 |
| pr14 | Negotiate with students possible connections between/among explanations | 30 | 3.8666 | 0.7302 | 2 | 5 |
| pr22 | Scientifically accepted ideas to develop meaningful understandings of science | 30 | 4.0666 | 0.7396 | 2 | 5 |
| pr23 | Possible connections between scientific knowledge & explanations | 30 | 4.1333 | 0.8603 | 2 | 5 |
| pr43 | Connections to scientific knowledge for relating their explanations | 30 | 4.1000 | 0.7588 | 2 | 5 |
| pr63 | Evaluate consistency between explanations & accepted ideas | 31 | 3.7419 | 0.8550 | 1 | 5 |

Post-test: Personal Self-Efficacy
Feature 4: Learner Connects Explanations to Knowledge

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po3 | Independently examine resources to connect explanations to scientific knowledge | 28 | 4.4285 | 0.6341 | 3 | 5 |
| po14 | Negotiate with students possible connections between/among explanations | 28 | 4.2500 | 0.6454 | 3 | 5 |
| po22 | Scientifically accepted ideas to develop meaningful understandings of science | 28 | 4.2142 | 0.8758 | 2 | 5 |
| po23 | Possible connections between scientific knowledge & explanations | 28 | 4.4285 | 0.5039 | 4 | 5 |
| po43 | Connections to scientific knowledge for relating their explanations | 28 | 4.4285 | 0.6900 | 2 | 5 |
| po63 | Evaluate consistency between explanations & accepted ideas | 28 | 4.2142 | 0.6862 | 3 | 5 |

Difference: Post-test – Pretest
Feature 4: Learner Connects Explanations to Knowledge

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff3 | Independently examine resources to connect explanations to scientific knowledge | 27 | 0.5925 | 0.9306 | 3.31 | 0.0027 |
| diff14 | Negotiate with students possible connections between/among explanations | 27 | 0.4074 | 0.8883 | 2.38 | 0.0248 |
| diff22 | Scientifically accepted ideas to develop meaningful understandings of science | 27 | 0.1111 | 0.9740 | 0.59 | 0.5585 |
| diff23 | Possible connections between scientific knowledge & explanations | 27 | 0.2222 | 0.8473 | 1.36 | 0.1846 |
| diff43 | Connections to scientific knowledge for relating their explanations | 27 | 0.2962 | 0.8688 | 1.77 | 0.0881 |
| diff63 | Evaluate consistency between explanations & accepted ideas | 28 | 0.4642 | 0.8380 | 2.93 | 0.0068 |

Difference: Delayed Post – Post-test
Feature 4: Learner Connects Explanations to Knowledge

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff2_3 | Independently examine resources to connect explanations to scientific knowledge | 26 | 0.0384 | 0.9992 | 0.20 | 0.8460 |
| diff2_14 | Negotiate with students possible connections between/among explanations | 26 | -0.1153 | 0.9519 | -0.62 | 0.5421 |
| diff2_22 | Scientifically accepted ideas to develop meaningful understandings of science | 26 | 0.1538 | 1.0466 | 0.75 | 0.4605 |
| diff2_23 | Possible connections between scientific knowledge & explanations | 26 | -0.1153 | 0.9519 | -0.62 | 0.5421 |
| diff2_43 | Connections to scientific knowledge for relating their explanations | 26 | -0.2692 | 0.8744 | -1.57 | 0.1290 |
| diff2_63 | Evaluate consistency between explanations & accepted ideas | 26 | -0.1538 | 0.8805 | -0.89 | 0.3815 |

Pretest: Personal Self-Efficacy
Feature 5: Learner Communicates and Justifies Explanations

| Items | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr12 | Describe their investigations & findings using evidence for justification | 30 | 4.0666 | 0.7849 | 2 | 5 |
| pr16 | Review & ask questions about the results of other students' work | 30 | 3.6666 | 0.9589 | 2 | 5 |
| pr32 | Coach students in the clear articulation of explanations | 30 | 3.7666 | 1.0063 | 2 | 5 |
| pr33 | Critique explanations & investigation methods | 30 | 3.7666 | 0.8976 | 2 | 5 |
| pr42 | Model for prescribed steps or procedures for communicating scientific results | 30 | 4.1000 | 0.8847 | 2 | 5 |
| pr62 | Model the guidelines for sharing & critiquing explanations | 31 | 4.1935 | 0.7032 | 3 | 5 |
| pr65 | Construct guidelines for communicating results & explanations | 31 | 3.8629 | 0.8160 | 2 | 5 |

Post-test: Personal Self-Efficacy
Feature 5: Learner Communicates and Justifies Explanations

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po12 | Describe their investigations & findings using evidence for justification | 28 | 4.5000 | 0.6382 | 3 | 5 |
| po16 | Review & ask questions about the results of other students' work | 28 | 4.3571 | 0.6214 | 3 | 5 |
| po32 | Coach students in the clear articulation of explanations | 28 | 4.3809 | 0.6951 | 3 | 5 |
| po33 | Critique explanations & investigation methods | 28 | 4.1428 | 0.6506 | 3 | 5 |
| po42 | Model for prescribed steps or procedures for communicating scientific results | 28 | 4.2857 | 0.9759 | 1 | 5 |
| po62 | Model the guidelines for sharing & critiquing explanations | 28 | 4.2857 | 0.7628 | 2 | 5 |
| po65 | Construct guidelines for communicating results & explanations | 28 | 4.1309 | 0.6563 | 3 | 5 |

Difference: Post-test – Pretest
Feature 5: Learner Communicates and Justifies Explanations

| **Item** | **Label** | **N** | **Mean** | **Std Dev** | **t Value** | **Pr > \|t\|** |
|---|---|---|---|---|---|---|
| diff12 | Describe their investigations & findings using evidence for justification | 27 | 0.3703 | 0.7916 | 2.43 | 0.0223 |
| diff16 | Review & ask questions about the results of other students' work | 27 | 0.5185 | 0.8931 | 3.02 | 0.0057 |
| diff32 | Coach students in the clear articulation of explanations | 27 | 0.5432 | 0.8430 | 3.35 | 0.0025 |
| diff33 | Critique explanations & investigation methods | 27 | 0.2962 | 0.9928 | 1.55 | 0.1331 |
| diff42 | Model for prescribed steps or procedures for communicating scientific results | 27 | 0.1111 | 1.1875 | 0.49 | 0.6309 |
| diff62 | Model the guidelines for sharing & critiquing explanations | 28 | 0 | 0.7698 | 0.00 | 1.0000 |
| diff65 | Construct guidelines for communicating results & explanations | 28 | 0.2023 | 0.8380 | 1.28 | 0.2122 |

Difference: Delayed Post – Post-test
Feature 5: Learner Communicates and Justifies Explanations

| **Item** | **Label** | **N** | **Mean** | **Std Dev** | **t Value** | **Pr > \|t\|** |
|---|---|---|---|---|---|---|
| diff2_12 | Describe their investigations & findings using evidence for justification | 26 | -0.3461 | 0.9356 | -1.89 | 0.0709 |
| diff2_16 | Review & ask questions about the results of other students' work | 26 | -0.2692 | 1.0791 | -1.27 | 0.2150 |
| diff2_32 | Coach students in the clear articulation of explanations | 26 | -0.1025 | 1.0740 | -0.49 | 0.6305 |
| diff2_33 | Critique explanations & investigation methods | 26 | -0.1538 | 1.0841 | -0.72 | 0.4760 |
| diff2_42 | Model for prescribed steps or procedures for communicating scientific results | 26 | 0.0384 | 1.4277 | 0.14 | 0.8918 |
| diff2_62 | Model the guidelines for sharing & critiquing explanations | 26 | -0.0769 | 1.1974 | -0.33 | 0.7460 |
| diff2_65 | Construct guidelines for communicating results & explanations | 26 | -0.1410 | 0.8389 | -0.86 | 0.3995 |

Pretest: Outcome Expectancy
Feature 1: Learner Engages in Questions

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr7 | Select among list of given questions while investigating scientific phenomena | 30 | 3.3666 | 0.8502 | 2 | 5 |
| pr25 | Expect students to ask scientific questions | 30 | 4.1666 | 0.7914 | 2 | 5 |
| pr27 | Students will investigate questions I have developed | 30 | 3.8333 | 0.9855 | 2 | 5 |
| pr45 | Engage in questions I have provided them | 30 | 4.0333 | 0.9994 | 2 | 5 |
| pr46 | Engage in questions from a variety of sources such as textbooks | 30 | 3.8333 | 1.0854 | 1 | 5 |
| pr48 | Clarify the questions provided to enhance science learning | 30 | 3.8666 | 0.7760 | 2 | 5 |
| pr51 | Choose questions they would like to investigate from a list | 30 | 3.4333 | 1.1351 | 1 | 5 |
| pr66 | Refine questions that have been provided | 31 | 3.5806 | 0.9582 | 2 | 5 |

Post-test: Outcome Expectancy
Feature 1: Learner Engages in Questions

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po7 | Select among list of given questions while investigating scientific phenomena | 28 | 3.5000 | 1.0715 | 1 | 5 |
| po25 | Expect students to ask scientific questions | 28 | 4.5714 | 0.7417 | 2 | 5 |
| po27 | Students will investigate questions I have developed | 28 | 3.7857 | 1.0665 | 1 | 5 |
| po45 | Engage in questions I have provided them | 28 | 4.1785 | 0.8189 | 2 | 5 |
| po46 | Engage in questions from a variety of sources such as textbooks | 28 | 4.1071 | 0.9940 | 2 | 5 |
| po48 | Clarify the questions provided to enhance science learning | 28 | 4.2142 | 0.9172 | 2 | 5 |
| po51 | Choose questions they would like to investigate from a list | 28 | 3.8928 | 0.9940 | 2 | 5 |
| po66 | Refine questions that have been provided | 28 | 3.8928 | 0.8751 | 2 | 5 |

Difference: Post-test – Pretest
Feature 1: Learner Engages in Questions

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff7 | Select among list of given questions while investigating scientific phenomena | 27 | 0.1851 | 1.2414 | 0.78 | 0.4453 |
| diff25 | Expect students to ask scientific questions | 27 | 0.4814 | 1.0513 | 2.38 | 0.0250 |
| diff27 | Students will investigate questions I have developed | 27 | 0.1111 | 0.9336 | 0.62 | 0.5417 |
| diff45 | Engage in questions I have provided them | 27 | 0.1481 | 1.0635 | 0.72 | 0.4756 |
| diff46 | Engage in questions from a variety of sources such as textbooks | 27 | 0.2222 | 0.9740 | 1.19 | 0.2465 |
| diff48 | Clarify the questions provided to enhance science learning | 27 | 0.3333 | 0.8770 | 1.97 | 0.0590 |
| diff51 | Choose questions they would like to investigate from a list | 27 | 0.5185 | 1.0141 | 2.66 | 0.0133 |
| diff66 | Refine questions that have been provided | 28 | 0.2857 | 0.9759 | 1.55 | 0.1330 |

Difference: Delayed Post – Post-test
Feature 1: Learner Engages in Questions

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff2_7 | Select among list of given questions while investigating scientific phenomena | 26 | -0.1923 | 1.0205 | -0.96 | 0.3458 |
| diff2_25 | Expect students to ask scientific questions | 26 | -0.2692 | 1.0023 | -1.37 | 0.1830 |
| diff2_27 | Students will investigate questions I have developed | 26 | 0.1923 | 1.1668 | 0.84 | 0.4087 |
| diff2_45 | Engage in questions I have provided them | 26 | 0.1153 | 1.1428 | 0.51 | 0.6112 |
| diff2_46 | Engage in questions from a variety of sources such as textbooks | 26 | 0.1923 | 0.9805 | 1.00 | 0.3269 |
| diff2_48 | Clarify the questions provided to enhance science learning | 26 | 0.0384 | 1.0763 | 0.18 | 0.8569 |
| diff2_51 | Choose questions they would like to investigate from a list | 26 | -0.1923 | 1.1668 | -0.84 | 0.4087 |
| diff2_66 | Refine questions that have been provided | 26 | -0.0769 | 1.0553 | -0.37 | 0.7133 |

Pretest: Outcome Expectancy
Feature 2: Learner Gives Priority to Evidence

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr8 | Obtain evidence from observations & measurements | 30 | 4.5333 | 0.6288 | 3 | 5 |
| pr13 | Create (plan) investigations through which students gather particular evidence | 30 | 4.1333 | 0.7302 | 3 | 5 |
| pr29 | Derive scientific evidence from instructional materials such as a textbook | 30 | 3.4666 | 1.0742 | 1 | 5 |
| pr47 | Analyze data that has been supplied | 30 | 3.8500 | 1.1075 | 1 | 5 |
| pr52 | Analyze teacher provided data in a particular manner | 30 | 3.4666 | 0.9732 | 1 | 5 |
| pr53 | Form their explanations using evidence | 30 | 3.6333 | 0.8502 | 2 | 5 |
| pr57 | Determine what evidence most useful for answering scientific question(s) | 30 | 3.7666 | 0.7279 | 2 | 5 |
| pr58 | Design their own investigations & gather the evidence necessary | 31 | 3.8387 | 1.0032 | 1 | 5 |

Post-test: Outcome Expectancy
Feature 2: Learner Gives Priority to Evidence

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po8 | Obtain evidence from observations & measurements | 28 | 4.8333 | 0.4303 | 3 | 5 |
| po13 | Create (plan) investigations through which students gather particular evidence | 28 | 4.3214 | 0.7228 | 3 | 5 |
| po29 | Derive scientific evidence from instructional materials such as a textbook | 28 | 3.7857 | 1.0312 | 2 | 5 |
| po47 | Analyze data that has been supplied | 28 | 3.8750 | 1.0682 | 1 | 5 |
| po52 | Analyze teacher provided data in a particular manner | 28 | 3.5625 | 0.9613 | 1 | 5 |
| po53 | Form their explanations using evidence | 28 | 4.0357 | 0.9222 | 2 | 5 |
| po57 | Determine what evidence most useful for answering scientific question(s) | 28 | 4.2857 | 0.7628 | 2 | 5 |
| po58 | Design their own investigations & gather the evidence necessary | 28 | 4.1071 | 0.7859 | 2 | 5 |

Difference: Post-test – Pretest
Feature 2: Learner Gives Priority to Evidence

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff8 | Obtain evidence from observations & measurements | 27 | 0.3456 | 0.7481 | 2.40 | 0.0238 |
| diff13 | Create (plan) investigations through which students gather particular evidence | 27 | 0.1851 | 0.7862 | 1.22 | 0.2320 |
| diff29 | Derive scientific evidence from instructional materials such as a textbook | 27 | 0.3703 | 0.7916 | 2.43 | 0.0223 |
| diff47 | Analyze data that has been supplied | 27 | -0.0185 | 0.9038 | -0.11 | 0.9160 |
| diff52 | Analyze teacher provided data in a particular manner | 27 | 0.1296 | 0.8943 | 0.75 | 0.4581 |
| diff53 | Form their explanations using evidence | 27 | 0.3703 | 1.0794 | 1.78 | 0.0863 |
| diff57 | Determine what evidence most useful for answering scientific question(s) | 27 | 0.4814 | 0.9754 | 2.56 | 0.0164 |
| diff58 | Design their own investigations & gather the evidence necessary | 28 | 0.2857 | 0.9371 | 1.61 | 0.1183 |

Difference: Delayed Post – Post-test
Feature 2: Learner Gives Priority to Evidence

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff2_8 | Obtain evidence from observations & measurements | 26 | -0.2820 | 0.8879 | -1.62 | 0.1178 |
| diff2_13 | Create (plan) investigations through which students gather particular evidence | 26 | 0.1538 | 0.8805 | 0.89 | 0.3815 |
| diff2_29 | Derive scientific evidence from instructional materials such as a textbook | 26 | 0.1538 | 0.9248 | 0.85 | 0.4044 |
| diff2_47 | Analyze data that has been supplied | 26 | 0.0192 | 1.4864 | 0.07 | 0.9479 |
| diff2_52 | Analyze teacher provided data in a particular manner | 26 | -0.0288 | 1.3082 | -0.11 | 0.9114 |
| diff2_53 | Form their explanations using evidence | 26 | -0.1538 | 1.1555 | -0.68 | 0.5035 |
| diff2_57 | Determine what evidence most useful for answering scientific question(s) | 26 | -0.3461 | 1.2310 | -1.43 | 0.1640 |
| diff2_58 | Design their own investigations & gather the evidence necessary | 26 | 0.0769 | 0.9347 | 0.42 | 0.6784 |

Pretest: Outcome Expectancy
Feature 3: Learner Formulates Explanations

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr20 | Make use of data to develop explanations as a result of teacher guidance | 30 | 4.0666 | 0.7396 | 2 | 5 |
| pr28 | Create scientific explanations based on evidence | 30 | 3.7666 | 0.8172 | 2 | 5 |
| pr34 | Require students to create scientific claims based on observational evidence | 30 | 3.8666 | 0.9371 | 1 | 5 |
| pr35 | Expect students to think about other reasonable explanations from evidence | 30 | 4.0666 | 0.6914 | 3 | 5 |
| pr39 | Require students to develop explanations using evidence | 30 | 4.2666 | 0.7849 | 2 | 5 |
| pr55 | Construct explanations from evidence using a provided framework | 30 | 3.6333 | 1.1885 | 1 | 5 |
| pr69 | Comprehend teacher presented explanations | 30 | 3.8333 | 0.7914 | 2 | 5 |

Post-test: Outcome Expectancy
Feature 3: Learner Formulates Explanations

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po20 | Make use of data to develop explanations as a result of teacher guidance | 28 | 4.2857 | 0.6586 | 3 | 5 |
| po28 | Create scientific explanations based on evidence | 28 | 4.2500 | 0.8443 | 2 | 5 |
| po34 | Require students to create scientific claims based on observational evidence | 28 | 4.1250 | 0.7891 | 3 | 5 |
| po35 | Expect students to think about other reasonable explanations from evidence | 28 | 4.5357 | 0.5762 | 3 | 5 |
| po39 | Require students to develop explanations using evidence | 28 | 4.6428 | 0.5587 | 3 | 5 |
| po55 | Construct explanations from evidence using a provided framework | 28 | 3.6964 | 0.9558 | 2 | 5 |
| po69 | Comprehend teacher presented explanations | 28 | 4.0357 | 0.9615 | 1 | 5 |

Difference: Post-test – Pretest
Feature 3: Learner Formulates Explanations

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff20 | Make use of data to develop explanations as a result of teacher guidance | 27 | 0.1851 | 0.9622 | 1.00 | 0.3265 |
| diff28 | Create scientific explanations based on evidence | 27 | 0.4444 | 0.8473 | 2.73 | 0.0113 |
| diff34 | Require students to create scientific claims based on observational evidence | 27 | 0.2777 | 0.8585 | 1.68 | 0.1047 |
| diff35 | Expect students to think about other reasonable explanations from evidence | 27 | 0.4074 | 0.6938 | 3.05 | 0.0052 |
| diff39 | Require students to develop explanations using evidence | 27 | 0.4074 | 0.8883 | 2.38 | 0.0248 |
| diff55 | Construct explanations from evidence using a provided framework | 27 | 0.0185 | 1.1475 | 0.08 | 0.9338 |
| diff69 | Comprehend teacher presented explanations | 28 | 0.2142 | 0.7867 | 1.44 | 0.1610 |

Difference: Delayed Post – Post-test
Feature 3: Learner Formulates Explanations

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff2_20 | Make use of data to develop explanations as a result of teacher guidance | 26 | -0.1153 | 1.1073 | -0.53 | 0.5999 |
| diff2_28 | Create scientific explanations based on evidence | 26 | 0.0384 | 1.2159 | 0.16 | 0.8732 |
| diff2_34 | Require students to create scientific claims based on observational evidence | 26 | -0.0192 | 1.2367 | -0.08 | 0.9374 |
| diff2_35 | Expect students to think about other reasonable explanations from evidence | 26 | -0.3846 | 0.9829 | -2.00 | 0.0570 |
| diff2_39 | Require students to develop explanations using evidence | 26 | -0.2692 | 0.9190 | -1.49 | 0.1478 |
| diff2_55 | Construct explanations from evidence using a provided framework | 26 | 0.0576 | 1.0984 | 0.27 | 0.7910 |
| diff2_69 | Comprehend teacher presented explanations | 26 | -0.0384 | 1.0763 | -0.18 | 0.8569 |

Pretest: Outcome Expectancy
Feature 4: Learner Connects Explanations to Knowledge

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr15 | Independently develop explanations using known scientifically accepted ideas | 30 | 3.9333 | 0.8683 | 2 | 5 |
| pr24 | Recognize connections between proposed explanations & scientific knowledge | 30 | 3.7333 | 0.8276 | 2 | 5 |
| pr41 | Refine explanations using possible connections to scientific knowledge | 30 | 3.8333 | 0.9498 | 1 | 5 |
| pr61 | Use internet based resources etc. to further develop investigations | 31 | 4.2580 | 0.7288 | 3 | 5 |

Post-test: Outcome Expectancy
Feature 4: Learner Connects Explanations to Knowledge

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po15 | Independently develop explanations using known scientifically accepted ideas | 28 | 4.1428 | 0.6506 | 3 | 5 |
| po24 | Recognize connections between proposed explanations & scientific knowledge | 28 | 4.1785 | 0.8629 | 2 | 5 |
| po41 | Refine explanations using possible connections to scientific knowledge | 28 | 4.1428 | 0.8034 | 2 | 5 |
| po61 | Use internet based resources etc. to further develop investigations | 28 | 4.3214 | 0.6696 | 2 | 5 |

Difference Post-test – Pretest
Feature 4: Learner Connects Explanations to Knowledge

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff15 | Independently develop explanations using known scientifically accepted ideas | 27 | 0.1111 | 0.9740 | 0.59 | 0.5585 |
| diff24 | Recognize connections between proposed explanations & scientific knowledge | 27 | 0.5185 | 0.8931 | 3.02 | 0.0057 |
| diff41 | Refine explanations using possible connections to scientific knowledge | 27 | 0.2592 | 0.8590 | 1.57 | 0.1289 |
| diff61 | Use internet based resources etc. to further develop investigations | 28 | 0.0714 | 0.5394 | 0.70 | 0.4895 |

Difference: Delayed Post – Post-test
Feature 4: Learner Connects Explanations to Knowledge

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff2_15 | Independently develop explanations using known scientifically accepted ideas | 26 | 0.0769 | 1.0926 | 0.36 | 0.7226 |
| diff2_24 | Recognize connections between proposed explanations & scientific knowledge | 26 | -0.0769 | 0.9347 | -0.42 | 0.6784 |
| diff2_41 | Refine explanations using possible connections to scientific knowledge | 26 | -0.1153 | 1.1073 | -0.53 | 0.5999 |
| diff2_61 | Use internet based resources etc. to further develop investigations | 26 | 0.2307 | 1.1421 | 1.03 | 0.3128 |

Pretest: Outcome Expectancy
Feature 5: Learner Communicates and Justifies Explanations

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| pr6 | Defend their newly acquired knowledge during group discussions | 31 | 3.5806 | 0.9582 | 1 | 5 |
| pr9 | Make the results of their investigations public | 30 | 3.6000 | 0.9684 | 2 | 5 |
| pr50 | Communicate & justify their explanations using broad guidelines | 31 | 3.8870 | 0.8337 | 2 | 5 |
| pr56 | Follow predetermined procedures when justifying their explanations | 30 | 3.4666 | 1.0742 | 2 | 5 |
| pr59 | Collaborate with me to construct criteria for critiquing explanations | 31 | 3.8387 | 0.9344 | 2 | 5 |
| pr60 | Share & critique explanations while utilizing broad guidelines | 31 | 3.6774 | 0.9087 | 2 | 5 |
| pr64 | Negotiate criteria for sharing & critiquing explanations | 31 | 3.6048 | 0.8892 | 2 | 5 |
| pr68 | Justify explanations using given steps & procedures | 31 | 3.7258 | 0.9818 | 2 | 5 |

Post-test: Outcome Expectancy
Feature 5: Learner Communicates and Justifies Explanations

| Item | Label | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| po6 | Defend their newly acquired knowledge during group discussions | 28 | 4.1785 | 0.8189 | 2 | 5 |
| po9 | Make the results of their investigations public | 28 | 4.0000 | 0.9428 | 2 | 5 |
| po50 | Communicate & justify their explanations using broad guidelines | 28 | 4.1071 | 0.9560 | 2 | 5 |
| po56 | Follow predetermined procedures when justifying their explanations | 28 | 3.5000 | 1.2619 | 1 | 5 |
| po59 | Collaborate with me to construct criteria for critiquing explanations | 28 | 4.1595 | 0.8700 | 2 | 5 |
| po60 | Share & critique explanations while utilizing broad guidelines | 28 | 4.0000 | 0.8606 | 2 | 5 |
| po64 | Negotiate criteria for sharing & critiquing explanations | 28 | 4.1071 | 0.8751 | 2 | 5 |
| po68 | Justify explanations using given steps & procedures | 28 | 3.9285 | 1.0515 | 1 | 5 |

Difference: Post-test – Pretest
Feature 5: Learner Communicates and Justifies Explanations

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff6 | Defend their newly acquired knowledge during group discussions | 27 | 0.5185 | 1.0141 | 2.66 | 0.0133 |
| diff9 | Make the results of their investigations public | 27 | 0.4074 | 1.1183 | 1.89 | 0.0696 |
| diff50 | Communicate & justify their explanations using broad guidelines | 28 | 0.1785 | 1.2488 | 0.76 | 0.4558 |
| diff56 | Follow predetermined procedures when justifying their explanations | 27 | 0 | 1.0000 | 0.00 | 1.0000 |
| diff59 | Collaborate with me to construct criteria for critiquing explanations | 28 | 0.3380 | 0.8724 | 2.05 | 0.0501 |
| diff60 | Share & critique explanations while utilizing broad guidelines | 28 | 0.3214 | 0.9833 | 1.73 | 0.0951 |
| diff64 | Negotiate criteria for sharing & critiquing explanations | 28 | 0.4642 | 1.0708 | 2.29 | 0.0298 |
| diff68 | Justify explanations using given steps & procedures | 28 | 0.1785 | 1.0904 | 0.87 | 0.3938 |

Difference: Delayed Post – Post-test
Feature 5: Learner Communicates and Justifies Explanations

| Item | Label | N | Mean | Std Dev | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| diff2_6 | Defend their newly acquired knowledge during group discussions | 26 | -0.0384 | 0.9583 | -0.20 | 0.8395 |
| diff2_9 | Make the results of their investigations public | 26 | -0.3461 | 1.2310 | -1.43 | 0.1640 |
| diff2_50 | Communicate & justify their explanations using broad guidelines | 26 | 0 | 1.4142 | 0.00 | 1.0000 |
| diff2_56 | Follow predetermined procedures when justifying their explanations | 26 | -0.1538 | 1.3473 | -0.58 | 0.5656 |
| diff2_59 | Collaborate with me to construct criteria for critiquing explanations | 26 | 0.0205 | 0.8734 | 0.12 | 0.9056 |
| diff2_60 | Share & critique explanations while utilizing broad guidelines | 26 | -0.0769 | 1.0926 | -0.36 | 0.7226 |
| diff2_64 | Negotiate criteria for sharing & critiquing explanations | 26 | -0.5000 | 1.1045 | -2.31 | 0.0295 |
| diff2_68 | Justify explanations using given steps & procedures | 26 | 0 | 1.2649 | 0.00 | 1.0000 |