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SCIENCE TEACHING ANXIETY: THE IMPACT OF BELIEFS ON TEACHER PREFERENCES OF INSTRUCTIONAL STRATEGIES

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by

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Dedication

Because education is not for the present but the future, I dedicate this work to two people who will determine the future of our family, Sloane and Marshall Veal. May your many gifts and talents grace this world for the short time you are present, and impact the generations of children you will have the opportunity to influence.

I pass this torch to you to continue the race, keeping in mind the family members who laid the road you will trod.

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ABSTRACT

The purpose of this descriptive, mixed-method study was to explore a possible relationship between teacher beliefs and their philosophy of teaching. A theoretical framework depicted connections among levels of science anxiety and science teaching self-efficacy, and their influences on elementary teacher instructional preferences for a traditional or inquiry-based model of instruction. A card-sorting methodology was adapted to create an interview protocol that examined teacher instructional practices within the framework of an inquiry continuum. Teacher groups were identified quantitatively with two existing instruments to examine science anxiety and science teaching self-efficacy. Subtests of both the Science State-Trait Anxiety Inventory (STAI) and the Science Teaching Efficacy Belief Instrument (STEBI) were administered through an online survey and completed by 86 elementary teachers of science in a large urban school district. From the survey data teachers were grouped by levels of anxiety and self-efficacy in order to further examine their beliefs. Results identified three groups of teachers meriting additional investigation - low anxiety and high self-efficacy, high anxiety and low self-efficacy, and high anxiety and high self-efficacy. From these groups, eight total participants were interviewed using a semi-structured protocol consisting of a science teaching scenario card sort and open-ended questions to classify groups of teachers as primarily learner- or teacher-centered, and preferring a traditional or inquiry-based method of instruction. Based on qualitative coding for levels of inquiry and responses to questions probing teacher beliefs and practices, all of the teachers were classified as preferring a primarily teacher-centered model of instruction, thus upholding the theoretical framework for the high anxiety groups. In contradiction to the expectations described in the theoretical framework, the low anxiety and high self-efficacy group stated one of the strongest preferences for traditional instruction. In conclusion the low anxiety group may have preferred a traditional approach in order to meet campus expectations of instructional strategies that promote passing scores on standardized tests. Implications suggest that explicit instruction is needed on the essential features of inquiry for teachers during the preservice and induction phase of their careers, and additional professional development support for practicing elementary teachers.

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Chapter 1: Introduction

Introduction

A former elementary school principal commented that her teachers scheduled science for the end of the day, and then prayed for a fire drill. Many elementary teachers can identify with that statement, yet the current accountability system demands that schools produce passing scores on high-stakes tests or face increasingly draconian consequences. Science anxiety and avoidance may be playing a more significant role in this scenario than is currently understood.

Background

The problem of elementary science anxiety and avoidance may be closely linked to teacher beliefs, attitudes, and instructional practices. Elementary teachers are more likely to describe negative or fearful attitudes towards science instruction (Van Zee & Roberts, 2001; Westerback & Primavera, 1992). Science anxiety may permeate a teacher's experiences as a student and teacher, inducing them to avoid taking science classes, attending science professional development, and even reducing the amount of science they teach in their elementary classes (Hodgin, 2008; Ramey-Gassert, Shroyer, & Staver, 1996). The demands of high-stakes testing within the current state and federal accountability systems may only serve to increase anxiety and avoidance behaviors. Yet one of the most widely researched and highly recommended approaches is an inquiry-based model of science instruction. Implementing inquiry as the foundation of a science program is an important aspect of systemic reform, and its implementation requires the support and buy-in of elementary teachers – not avoidance and resistance.

Despite the strong research background and curriculum support for inquiry-based science, its value is not commonly recognized in elementary schools. This is unfortunate because inquiry utilizes natural curiosity to engage students in thinking and processes that mirror authentic scientific inquiry (Bybee, 2011; NRC, 1996, 2000). Inquiry is an essential part of the National Science Education Standards (NSES) and the subsequent publication Inquiry and the NSES (NRC, 1996, 2000). Possible links between science anxiety, science teaching self-efficacy, and instructional practices are areas worthy of exploration in gaining a clearer picture of elementary science implementation. Science anxiety and self-efficacy may affect a teacher's beliefs and influence their philosophy of teaching (Tosun, 2000). Teachers with high science anxiety and low science teaching self-efficacy may not develop effective coping behaviors, and avoid inquiry-based instruction. If a teacher has experienced low science achievement, interest, or engagement, then this negative experience may drive more negative attitudes and beliefs. Teachers, who choose to persevere in the face of a problematic situation if there is a belief of eventual success, develop coping skills that reduce anxiety and increase self-efficacy (Bandura, 1977). When teachers engage in successful coping strategies (such as perseverance, risk-taking, or incremental desensitization) that produce positive science achievement, also known as a Performance Accomplishment, then self-efficacy is increased (Bandura, 1977; Tosun, 2000). So if the vicious cycle of science anxiety and low self-efficacy could be broken, elementary teachers might implement inquiry-based instruction, students would experience science full of curiosity, and a solid foundation for further studies in science would begin in the elementary school years.

PURPOSE OF THE STUDY

The purpose of this paper is to investigate a possible relationship between science anxiety, self-efficacy and instructional practices. Science anxiety is the frame of reference for many elementary teachers, and through reduced self-efficacy, may lead them to avoidance behaviors and to adopt a philosophy of education that supports teacher-centered instruction (Bandura, 1977; Bleicher, 2004; Bursal & Paznokas, 2006; Cady & Rearden, 2007; Enochs & Riggs, 1990; Ramey-Gassert et al., 1996). This study will also explore how anxiety and self-efficacy may affect teacher beliefs, their core philosophy of teaching, and implementation of an inquiry-based instructional. The National Research Council and the National Council for the Teachers of Mathematics have designated teachers as the key to implementation of national standards for both mathematics and science (NRC, 1996, 2000). Yet, if teacher beliefs are a barrier to the learner-centered philosophy supporting inquiry, exploring these beliefs and addressing them through teacher preparation and professional development are key to changing how elementary school students experience science.

PROBLEM

Teacher beliefs may be an important component in their philosophy of teaching and their choice of instructional strategies. Their levels of anxiety and self-efficacy may directly impact their preferred instructional strategies in science, and impact their philosophy of teaching. Anxiety and self-efficacy may drive teachers to adopt strategies based on relieving the stress they may feel when faced with teaching science (Bandura, 1977, 1982; S. Gibson & M. H. Dembo, 1984; Ramey-Gassert et al., 1996). Unfortunately, traditional science teaching strategies are frequently teacher-centered, (Cady & Rearden, 2007; Fletcher & McClellan, 2008) and these strategies may exacerbate the problem and create a vicious cycle that inhibits the implementation of an inquiry-based instructional model (Bandura, 1977; Bleicher, 2004; Bursal & Paznokas, 2006; Cady & Rearden, 2007; Enochs & Riggs, 1990; Ramey-Gassert et al., 1996). The purpose of this research study is to explore how teacher beliefs affect their educational philosophy that may in turn drive their preferences for an inquiry-based instructional model or a traditional model. Exploring this framework is crucial to investigating the link between science anxieties, science avoidance, and how inquiry-based instruction may provide answers to this problem.

CONTEXT FOR THE RESEARCH

The Theoretical Framework for this study takes place within a background of contemporary issues including accountability and the demands of high-stakes testing.

Existing issues of accountability are exerting pressure on teachers to produce acceptable test scores, supporting, rather than contradicting a teacher-centered model. One of the outcomes of the high-stakes testing may be an increase in science anxiety due to the demands on elementary teachers (Bandura, 1977, 1982; Ramey-Gassert, et al, 1996; Tosun, 2000; Westerback, 1982, 1984).

Elementary teachers cannot avoid teaching science unless they choose a non-tested grade, and creating their own lessons independent of standards is not an option as it was many years ago when teachers could simply pull out their Rainforest "love units" and teach science without any evaluation of effectiveness. Yet many elementary teachers have been able to justify spending little time on science instruction because standardized testing regimes (even for science) require a higher level of reading skills. This provides many teachers with a strong rationale for stressing a traditional model of instruction. Because teachers must prepare students to take a standardized test, this often reinforces teacher beliefs that a traditional model of instruction is most effective.

Another stressor on elementary teachers is an increased demand (especially by administrator) for more "hands-on" activities without real attention to inquiry-based instruction. This may push already strained low science teaching self-efficacy teachers to adopt a teacher-centered instructional model with a few "fluff and run" activities that are not based on inquiry (Cady & Rearden, 2007; Fletcher & McClellan, 2008; Hodgin, 2008). Finally, the current climate of testing and punitive accountability has created a culture that does not promote inquiry. When traditional strategies prove successful in raising test scores, they may create a false impression that elementary science is preparing students for more rigorous science courses.

RATIONALE

If teacher beliefs play an essential role in determining instructional strategies, then preservice and in-service professional development cannot neglect teacher beliefs if there is any expectation of reforming science education. A quantitative study done with teachers in England found that staff development that emphasized inquiry-based science promoted increases in positive teacher attitudes about their science instruction (Pell & Jarvis, 2003). Pre-service teachers who experienced content-based professional development that emphasized a constructivist approach gained confidence in science and mathematics teaching abilities (Lowery, 2002). These learner-centered strategies are powerful because they help develop the ability to learn from experiences, integrate knowledge, and think reflectively. Inquiry-based staff development can provide teachers with the opportunity to experience learner-centered instruction, and adopt these strategies as with their students (Daley, 2003).

If anxiety and self-efficacy determine their philosophy of teaching, inquiry-based instruction alone may not be sufficient to reform elementary science. Teacher-centered instruction may be contributing to science anxiety, thereby creating a vicious cycle of science avoidance in students. The problem of science teaching anxiety tends to be self-perpetuating and may contribute to this vicious cycle. Ironically, some of these same science anxious teachers mention these very "reading and memorizing vocabulary" strategies as the things that initially turned them away from science (Hodgin, 2008). The current background of testing and accountability may reinforce this vicious cycle.

An emphasis on traditional instructional strategies may actually raise test scores without improving science literacy. Even though many policy makers (and citizens) are wary of educational reform efforts, if given the choice they would choose to have their own children "engaged with the learning process - away from passive, isolated absorption of information and toward active or interactive approaches" (Fletcher & McClellan, 2008, p. 1020). The production of test scores may be having the opposite effect on elementary science and actually working to increase teacher-centered instruction while also increasing anxiety and avoidance.

RESEARCH QUESTIONS

The foundation of this study will be driven by the following questions:

1. Do teacher beliefs direct their personal philosophy of science instruction, and if so, how?
2. Is there a relationship between the levels of science anxiety/science teaching self-efficacy and the preference for a teacher-centered model of instruction as opposed to a learner-centered model? If so, what is the relationship?
3. How do teachers with low science anxiety and high science teaching self-efficacy compare with high anxiety, low self-efficacy and high anxiety, high self-efficacy

teachers in their implementation of a traditional or inquiry-based model of instruction?

FRAMEWORK

The Theoretical Framework for the study explores possible relationships and patterns between teacher beliefs, their psychological and philosophical underpinnings, and how they may shape their preferred instructional models and strategies. A theoretical framework is the structure that frames the research, and drives the review of the literature, the methodologies, and conclusions reached as part of a big picture analysis. See Figure 1.1.

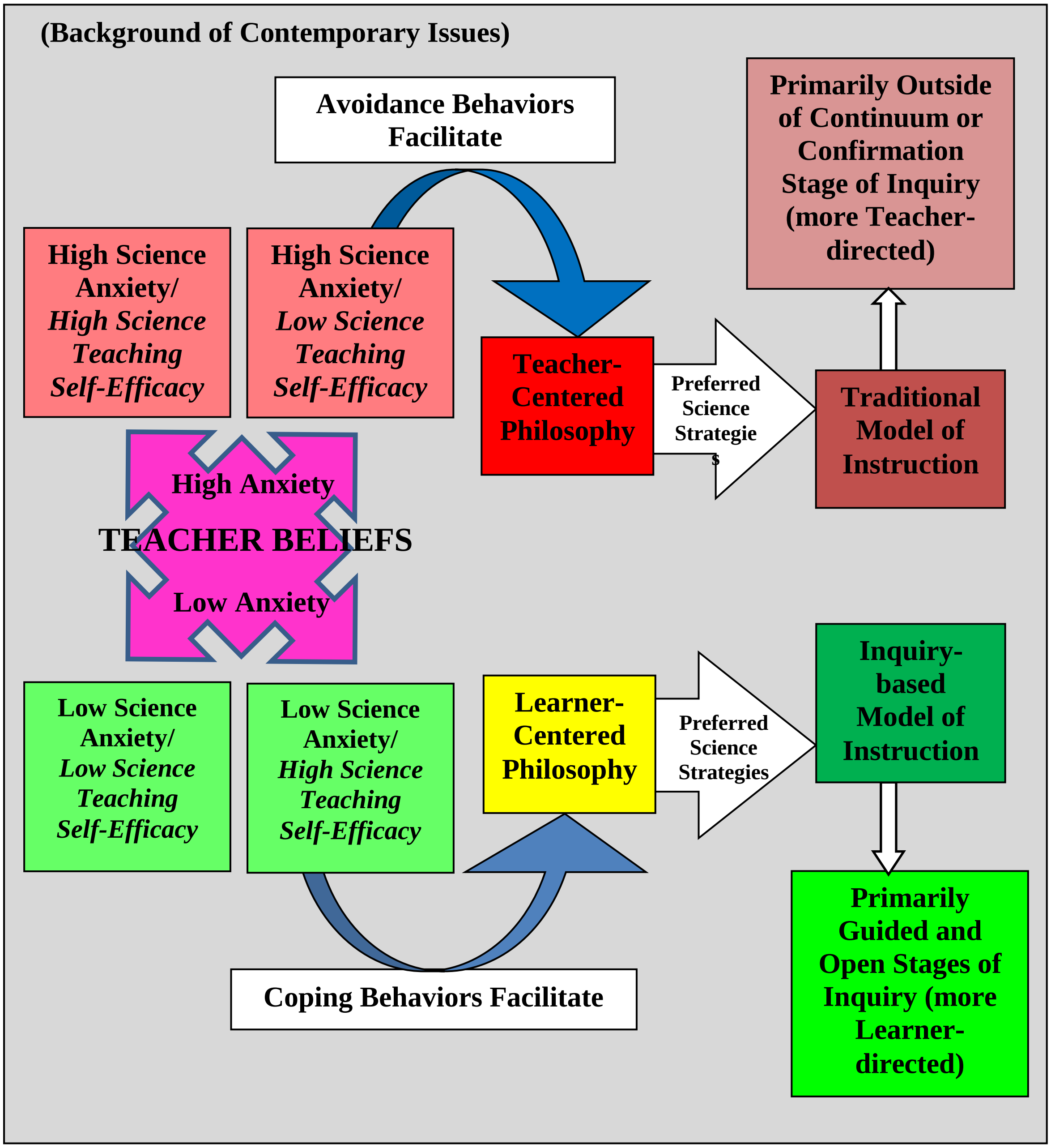

Figure 1.1: How do Teacher Beliefs Direct Models of Science Instruction?

Psychological Underpinnings

The psychological underpinnings of the theoretical framework are founded on the idea that teacher beliefs such as science anxiety are at the core of their instructional practices. The psychological basis for the framework is the examination of the role anxiety and the resultant self-efficacy play in a teacher's philosophy of teaching. Mallow defines science anxiety as a fear or aversion of science concepts, scientists, or science in general (Jeffry V Mallow, 1981). Westerback defines it as a transitory psychological state that is expressed by "feelings of tension, nervousness, worry, or apprehension" (Westerback, 1984). Her research adapted a generalized instrument for use in science teaching. Science Anxiety was measured during elementary science content courses using the State-Trait Anxiety Inventory (STAI) developed by Spielberger, and revised for use in teaching science (Spielberger, Gorsuch, & Lushene, 1970; Westerback, 1984). The authors changed the headings on the A-State scale (Anxiety-State) which is a measure of a person's current state of anxiety and may change over time to adapt responses to science teaching by asking preservice teachers to imagine that they were teaching science with the knowledge they currently possessed (Westerback, 1984). Both Westerback and Bandura researched the link between science anxiety and its relationship to self-efficacy (Bandura, 1982; Westerback, 1984; Westerback & Primavera, 1992). Self-efficacy is the belief that a person could act to solve a problem or deal with a situation, based on prior experiences (Bandura, 1977). Because self-efficacy may also play a role in science anxiety, research on self-efficacy was generalized to science teaching (Bandura, 1977, 1981, 1982; Westerback, 1984). In addition, self-efficacy can influence both the choice of behaviors avoided, and the associated coping skills (Bandura, 1977). The expectation of a positive or negative outcome when faced with an intimidating situation drives a person to adopt behaviors based on these expectations (Bandura, 1977). Bandura described the role of stress and arousal as an explanation for how anxiety and self-efficacy may facilitate avoidance of situations leading to the anxiety (Bandura, 1981). This becomes a vicious cycle as reduced self-efficacy increases avoidance, coping behaviors to help relieve anxiety are not initiated, and negative outcomes are expected (Bandura, 1977; 1982). Yet if coping behaviors that reduce stress and emotional arousal (such as anxiety) are initiated, then self-efficacy is increased, relieving anxiety (Bandura, 1982). During a study of science anxiety research, preservice teachers who experienced success in science had lower science anxiety (Czerniak & Schriver, 1994). Their success, and the resultant reduction in science anxiety, may result in increased science teaching self-efficacy.

Another driver in the theoretical framework is the role that anxiety and self-efficacy play in the development of a teacher's core philosophies. High anxiety and low self-efficacy beliefs influence behaviors such as avoidance of stressors and development of successful coping skills (Bandura, 1977). Factors that limit success in science courses may contribute directly to science anxiety (Westerback, 1984). Low personal self-efficacy is linked to science anxiety and a negative attitude about teaching science; the result is a reluctance to teach science (Ramey-Gassert & Shroyer, 1992). Preservice teachers report negative attitudes about science based on undergraduate courses that vary widely in their focus on inquiry, (Tosun, 2000) and these opinions may drive them to avoid taking science courses and teaching science (Brownlow & Jacobi, 2000; Hodgin, 2008; Pine, Aschbacher, & Roth, 2006; Ramey-Gassert et al., 1996; Tosun, 2000). There is also a strong link between science and mathematics anxiety (Jeffry V Mallow, 1981). An initial survey on mathematics anxiety showed 34% of elementary preservice teachers reported high levels of anxiety (Cady & Rearden, 2007). Quantitative research found a negative correlation between math anxiety and math teacher efficacy (Bleicher, 2004; Sloan, Daane, & Giesen, 2002; Swars, Daane, & Giesen, 2006; Trujillo & Hadfield, 1999). Preservice teachers identified as "high" math anxiety had low levels of confidence in their ability to teach elementary math (Bleicher; Bursal & Paznokas, 2006; Palmer, 2002; Sloan, et al., 2002; Trujillo & Hadfield, 1999). Other psychological issues specific to science teaching include the role of self-efficacy and avoidance (Dembo & Gibson, 1985; Gibson & Dembo, 1984; Ramey-Gassert & Shroyer, 1992; Ramey-Gassert, Shroyer, & Staver, 1996; Riggs & Enochs, 1990; Settlage, Southerland, Smith, & Ceglie, 2009; Tosun, 2000; Westerback & Primavera, 1992). The interaction of psychological influences may play a crucial role in science anxiety. In addition, mathematics anxiety is negatively correlated to confidence in science teaching among elementary preservice teachers ($r = -.417$) (Bursal & Paznokas). There was also a significant correlation at .01 level ($r = .549$) between math and science teaching self-efficacy (Bursal & Paznokas). The foundation for science self-efficacy research is grounded in the more generalized self-efficacy work of Bandura and a correlation between mathematics and science anxiety. Conversely, teachers who reported positive attitudes about science indicated that they had engaging science experiences as a high school and college student (Hodgin, 2008). These teachers reported that they did hands-on experiences such as labs and field work.

Although they did listen to lectures and take notes, these were not engaging for them, and did not inform their opinions about science instruction (2008). As teachers they tried to use as much inquiry as possible in their own classroom instruction (2008). However, teachers with negative attitudes about science indicated teacher-centered experiences in high school and college that were primarily lecture, notes and test-taking. They enjoyed hands-on, but experienced little of it. Because of their science experiences, they were unable to utilize inquiry as classroom teachers, perpetuating a vicious cycle of science avoidance and teacher-centered instruction.

Philosophical Underpinnings

A teacher's "philosophy of teaching" is the underpinning of their core beliefs, and may determine both their adopted frame of reference and preferred instructional strategies. At the heart of this research framework is the psychological foundation of constructivism, especially within the context of an inquiry-based instructional model. Constructivism is at the heart of a learner-centered classroom and a philosophy that honors authentic scientific investigation. Although educational research, national standards, and best practices in pre-service teacher education stress the importance of constructivism and a learner-centered philosophy of instruction, teacher-centered instruction is still widely practiced. Many teachers may not admit, or even realize that their core beliefs support a teacher-centered philosophy of instruction, and this may be related to stress and arousal stemming from science anxiety and low science teaching self-efficacy (Bandura, 1982). Avoidance behaviors resulting from this anxiety and low self-efficacy may also be important drivers in the philosophical beliefs and practices of elementary teachers. Although a significant number of preservice teachers described inquiry as important, the majority of the science lessons they wrote were teacher-centered (Cady & Rearden, 2007). Science anxious elementary teachers reported that because they lacked the background knowledge and skills to teach science, they utilized traditional, teacher-centered instruction such as reading and summarizing text about science content (Hodgin, 2008). Teachers low in science teaching self-efficacy may rely heavily on the textbook as a "safe" resource; these same teachers are reluctant to invest time into a new resource with unknown outcomes such as a lab or field-based activity (Ramey-Gassert & Shroyer, 1992).

Another strategy is to avoid taking science courses and to choose to specialize in non-science or mathematics areas such as English Language Arts or Reading. Preservice teachers high in history achievement, but low in science teaching self-efficacy were unwilling to do the extra work to master science content (Tosun, 2000). These choices lead to limited or less sophisticated PCK and science teaching skills. Teaching science as just another school subject by utilizing the traditional, teacher-centered strategies of reading the textbook, summarizing information, memorizing vocabulary and preparing for a standardized test may play a role in student and teacher science anxiety (Cady & Rearden, 2007; Lowery, 2002; Jeffry V Mallow, 1981; Ramey-Gassert & Shroyer, 1992; Sanger, 2007; Tosun, 2000). A teacher-centered philosophy of instruction promotes shallow comprehension and may lead to science anxiety, (Hodgin, 2008; NRC, 2000;

Webeck, Field, & Salinas, 2004) playing a significant part in killing the natural curiosity of elementary students.

Inquiry is a learner-centered model of instruction that focuses on putting students into the active role of a scientist instead of the passive role of a traditional student (NRC, 2000; Parker & Spink, 1997). In classes where inquiry-based strategies are the norm, students are reaching a deeper understanding of science instead of merely being told about science or reading about science (NRC, 2000). But what core beliefs drive teacher philosophies, especially the belief that learners should determine what the teacher does instead of the reverse? The theoretical framework suggests that teacher self-efficacy may hold the answer – if teachers develop coping behaviors such as risk-taking, and increase their self-efficacy, then the subsequent alleviation of stresses may allow them to relinquish sole control of the learning. In turn, less need to control instruction due to higher self-efficacy may promote greater success through learner-centered, inquiry-based instruction. Experiencing success will encourage people to persist in behaviors since they have an expectation of eventual success (Bandura, 1977). This reduces avoidance of science teaching, and with a learner-centered classroom, there is less pressure on teachers to know everything.

If the framework holds some validity, then a teacher's core philosophy and preferred model of instruction are driven by both psychological and philosophical underpinnings, driving teachers to choose either a learner-centered, inquiry-based model, or a traditional model of instruction. The traditional model is primarily based on a teacher-centered philosophy. It includes a heavy reliance on reading textbooks for information and “covering” material, and unfortunately may be reinforced by high-stakes testing. Teachers are being pressured to use more teacher-centered strategies in an effort to raise test scores. Teachers who do not deliver content, have students practice the objectives and then practice similar test questions would not be considered adequate teachers (Fletcher & McClellan, 2008). So a teacher who is already anxious about their ability to teach science is put under even more pressure and stress to raise test scores, and may feel no choice but to implement traditional strategies in an attempt to maintain some semblance of control over their classrooms and careers.

Another significant and stress-inducing barrier for elementary teachers is their limited Pedagogical Content Knowledge (PCK) or the ability to make specific content accessible to others (James Barufaldi, 1989; Clough, 2011; Pell & Jarvis, 2003). Inquiry-based science PCK demands both a deep understanding of the concepts to be taught, as well as mastery of the prerequisite knowledge so that a teacher can lay the foundation for the concept and assess for developing conceptions during instruction.

If a teacher can increase their science teaching self-efficacy and PCK, then they may adopt a philosophy of teaching with a marked preference for an inquiry-based science model of instruction. The learner-centered/inquiry approach is based on the premise that children learn actively, not passively. An important tenet of the constructivist paradigm that is the basis for learner-centered inquiry is that knowledge is created by the learner as a function of integrating new experiences with prior knowledge (Zion, Michalsky, & Mevarech, 2005). “In its essence, then, inquiry-oriented teaching engages students in investigations to satisfy curiosities, with curiosities being satisfied when individuals have constructed mental frameworks that adequately explain their experiences" (Haury, 1993, p. 3). Students are first introduced to concepts with hands-on, minds-on activities, and then guided through the processes of using scientific methods to discover knowledge, rather than being told answers by the teacher or a textbook. This learner-centered approach places the teacher in the role of a guide who leads students through experiments. Because the students are active learners, then "science content is covered in greater depth compared to a superficial traditional textbook approach" (Jorgenson & Vanosdall, 2002, p. 602). Inquiry-based instruction more closely matches scientific research than traditional, teacher-centered instruction. One of the features of inquiry-based science is the possibility of addressing science anxiety through generation of individual knowledge, engagement, collaboration, reducing assessment anxiety and fostering curiosity. It is based on the understanding of not only scientific concepts, but also methods and procedures of scientific thinking (NRC, 2000). It is not enough to simply increase self-efficacy if a teacher does not also attain a stronger PCK. The ability to implement inquiry-based standards is based on teachers possessing strong pedagogical content knowledge (Alake-Tuenter et al., 2012; Bransford, 2000; Stofflett, 1994). Therefore if the existence of a cycle that continues to produce elementary teachers who avoid science teaching is due to anxiety, then it is essential to research ways that strategies such as inquiry and learner-centered instruction may break that cycle.

Essential Features of Inquiry

Within the NRC's report Inquiry and the NSES is a continuum of five essential features of classroom inquiry (NRC, 2000). This rubric of variations of inquiry-based strategies will be used to rate teacher preferences of inquiry strategies. The continuum contains five essential features of classroom inquiry: it begins with a question; collects data as evidence; requires students to create an explanation based on data; asks students to compare their explanations to previous research; and requires students to communicate their findings (NRC, 2000). There is also a sliding scale that varies from the degree of teacher or materials-directed to the degree of learner direction. As a tool to evaluate both preferences for teacher- or learner-centered philosophical orientation and the degree of inquiry a teacher believes is appropriate, the continuum will be the primary structure for the theoretical framework. By holistically placing teachers along the Essential Features of Inquiry Continuum, teacher preferences for strategies can be classified by their positions relative to a teacher or learner-centered philosophy. By using a card-sorting task describing various instructional strategies that differ in the degree of essential features and the amount of teacher or learner direction, the primary choice of instructional strategy can be inferred for individual teachers. Their choice of strategies along several dimensions of the continuum (including outside the continuum) can be used to classify their preferred strategies as inquiry or traditionally based. This data can aid in the exploration of a theoretical framework that suggests teacher beliefs are the final determinant in a choice to deliver a primarily traditional model of instruction, or an inquiry-based model.

Definition of Key Terms

Science Anxiety - a fear or aversion of science concepts, scientists, or science in general

Science Teaching Self-Efficacy - teacher beliefs of their ability to teach science

Pedagogical Content Knowledge (PCK) - the ability to make specific content accessible to others

Essential Features of Inquiry Continuum – a framework of varying instructional strategies to support the implementation of an inquiry-based instructional model.

Inquiry-Based Model of Instruction - the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world

Traditional Model of Instruction - instruction is teacher-centered, and utilizes strategies such as reading from a textbook, memorizing vocabulary, and engaging in labs or activities with predetermined outcomes.

Learner-Centered Philosophy - that knowledge is created by the learner as a function of integrating new experiences with prior knowledge.

Teacher-Center Philosophy - traditional, expository method that focuses on delivering content based on student mastery of instructional objectives

Outside of Inquiry – a traditional method of instruction outside the levels of inquiry that is heavily dependent on text-based acquisition of knowledge.

Limitations of the Study

One concern of the limitations of the study is the Survey Instrument utilized. The Science Teaching Anxiety Inventory (STAI) is situation specific, and the levels of anxiety may be dependent on teacher duties at the time the survey is given (test preparations may increase anxiety, and it may be low during the summer). Results from a pilot study found exceptionally low science anxiety, but the survey was administered in June during the teacher's summer break. Another area of concern is establishing a relationship between anxiety and self-efficacy as measured with the Science Teaching Efficacy Belief Instrument (STEBI). Comparing STAI and STEBI results to find common grounds for classification of participants in either a high anxiety and low self-efficacy group or a low science anxiety high self-efficacy group will be a challenge.

All research studies possess some potential for bias, including the fact that myths about inquiry may drive teacher preferences. There has been a recent focus by educators (especially administrators) on "hands-on" activities based on increased student engagement, but without real attention to inquiry. Although teachers identify "hands-on" science as important, few wrote any of these lessons (Cady & Rearden, 2007). So teachers who have been pressured to use more hands-on strategies may simply pick strategies where students are manipulating materials, but without concern for the "minds-on" essence of inquiry. Another myth of inquiry is that the processes of science are more important than the product or content-specific goals. Teachers are often pressured to teach science process skills, sometimes in isolation, as students are tested on these skills.

Another limitation of the study is the revised card-sorting task. An existing interview instrument was revised to more closely reflect the Essential Features of Inquiry continuum. Revisions to reflect the inquiry continuum may confound results, since a small sample of elementary teachers were polled to validate the scenarios of card sorting task/structured interview instrument.

ORGANIZATION OF DISSERTATION

The dissertation proposal is organized into five chapters, with Chapter 1 an Introduction to the research study containing the Background, Problem, Rationale, Research Questions, and Theoretical Framework. Chapter 2 is a Literature Review including an Introduction, Purpose, Overview, Literature Review, Discussion, and Summary. Chapter 3 explains the research Methodology and contains the Research approach, Mixed Methodology, Research Questions, Instrumentation, Data Collection and analysis, Dissertation Timeline, and Summary. The 4th Chapter – Results and Analysis – reports and analyzes both the quantitative and qualitative data; and Chapter 5, Conclusions, is a discussion and summary of the research findings. The final sections of the dissertation are figures, tables and appendices.

Chapter 2: Literature Review

Introduction

The purpose of this exploratory investigation is to situate the study within the context of the body of research on anxiety, self-efficacy, and inquiry-based science instruction within the theoretical framework. One of the goals is to establish the research basis for the instruments chosen and the revision of an existing instrument. Examining possible relationships between science anxiety and science teaching self-efficacy as a framework for teacher beliefs that drive instructional practices may promote teacher preparation and professional development programs that address teacher beliefs as the core of a preferred instructional model.

Overview

The overarching question that this literature review will explore is “How do teacher beliefs affect their philosophy of teaching, choices of instructional models, and their judgments of the value of inquiry-based instructional strategies in science?” Much of the research on elementary science teachers and their practices have been devoted to the technical aspects of classroom instruction, rather than on the critical attitudes, beliefs, and assumptions that influence their practices (Kraft, 2002). Since teacher beliefs are at the core of the model, a review of science anxiety literature is the starting point. Science anxiety has historically been identified as a barrier in elementary science, and is a unique anxiety that perhaps cannot be measured or treated as another psychological disorder. Because teachers have a huge impact on the many students they teach, anxiety can have great influence beyond the individual experiencing the anxiety. It can lead to avoidance of science as a student and as a teacher, and become a starting point in creating a vicious cycle of science anxiety and avoidance. As such, science anxiety may be one of the first barriers to address in elementary science reform efforts. In order to measure science teaching anxiety, Westerback adapted Spielberger's State-Trait Anxiety Inventory (STAI) (Westerback, 1981, 1984; Westerback & Gonzalez, 1982; Westerback & Long, 1990; Westerback & Primavera, 1992; Westerback & Roll, 1982). Czerniak developed the Science Anxiety Questionnaire to provide another measure of science anxiety to be used with educators (C. Czerniak & Chiarelott, 1984; C. M. Czerniak, 1989; Charlene M. Czerniak & Schriver, 1994).

More commonly, the research has been conducted on teacher self-efficacy, perhaps because the concept of anxiety plays right into deficit thinking. Although anxiety and self-efficacy may be two side of the same coin, they are not the same thing. Personal confidence in a teacher's science content knowledge is directly correlated to their level of science teaching self-efficacy; a teacher with a strong science content background will possess a high level of self-efficacy, as well as the reverse. A teacher with a weak science content background will have a lower self-efficacy (C. M. Czerniak, 1989).

Situated within the literature, self-efficacy strategies may increase or reduce levels of stress and anxiety. Self-efficacy research was described within a generalized framework by Bandura (Bandura, 1977, 1981, 1982) He defined self-efficacy as the “judgment of how well one can execute courses of action required to deal with prospective situations" (Bandura, 1982, p. 122). Self-efficacy also plays an important role in both fearful and avoidant behaviors (Bandura, 1977). Specific to science teaching, self-efficacy also describes the role that avoidance behaviors may play in elementary science instruction (Dembo & Gibson, 1985; S. Gibson & M. Dembo, 1984; Ramey-Gassert & Shroyer, 1992; Ramey-Gassert et al., 1996; Riggs & Enochs, 1990; Settlage, Southerland, Smith, & Ceglie, 2009; Tosun, 2000; Westerback & Primavera, 1992). Beliefs about personal self-efficacy are directly influenced by coping behaviors. If people practice or even observe successful coping skills, they are more likely to believe they can perform a task and their self-efficacy increases (Bandura, 1982). People with strong beliefs in their ability to succeed will persist in a behavior much longer than those with weak expectations (Bandura, 1977).

Weak self-efficacy beliefs can lead to arousal and avoidance behaviors. "When presented with tasks in the weak self-efficacy range, most subjects promptly dismissed them as too far beyond their coping capabilities to even attempt" (Bandura, 1982, p. 139). Avoidance behaviors impede the development of coping behaviors that may permit an individual to be successful at a task and increase their self-efficacy (Bandura, 1977). However, avoidance behaviors that stem from high anxiety and low self-efficacy may have a profound effect on science instruction in the elementary school years. Teachers may not only avoid science, but may possess a naïve understanding of science concepts and inadequate scientific literacy.

Scientific literacy, or the ability understand authentic science practices (AAAS, 1989, 1993) has become a more essential goal for science education and science research endeavors (Eisenhart, Finkel, & Marion, 1996; Haury, 1993; Hodgin, 2011; Lowery, 2002; NRC, 1996, 2000). In the information age, a generalized understanding of the nature of science is essential to our modern, global, and technological life (AAAS, 1993; Abd-El-Khalick, Bell, & Lederman, 1998; Akerson & Hanuscin, 2007; Bencze et al., 2003; Hodgin, 2011) and an essential piece to promoting this literacy is inquiry-based science.

Inquiry-based instruction has been described as the "central strategy for teaching science," (NRC, 2000) and experts in science education have been active in writing science education standards that call for more inquiry-based science (AAAS, 1993; Hodgin, 2011; Sanger, 2007; Schneider, Krajcik, Marx, & Soloway, 2002). A distinct advantage of inquiry-based instruction is that it is written to more closely match scientific research methods. Typically, the research methodologies of scientists are defined as "scientific inquiry" (Akerson & Hanuscin, 2007; Jadrich & Bruxvoort, 2011; Schwartz, Lederman, & Crawford, 2004) and the strategies used to promote understanding of science and give students the opportunity to do science in the same way are called "inquiry-based science" (Jadrich & Bruxvoort, 2011; NRC, 1996, 2000). Yet, elementary teachers often have little experience with inquiry-based science as students or teachers. In fact, elementary science teachers frequently report negative experiences with science, citing high school and college courses that used primarily lecture, note-taking, memorization, and grades primarily determined from tests (Hodgin, 2008; Parker &

Spink, 1997; Sanger, 2007; Tosun, 2000). Therefore, it should come as no surprise that Westerback related that elementary teachers and preservice teachers report science anxiety (Westerback, 1982; Westerback & Long, 1990). This literature review will examine a possible link between science anxiety and inquiry-based instruction, given that limited experience with inquiry possibly drives continued anxiety and creates a vicious cycle where elementary teachers experience anxiety, feel incompetent or have low science teaching self-efficacy, avoid science, then pass this along to their students by practicing the very teacher-centered instructional strategies that turned them off from science in the first place!

REVIEW OF THE LITERATURE

Background

Teacher beliefs and the influence they may have on choices of instructional models in elementary school science is a problem that has not been fully explored or addressed. Despite the implementation of state and national standards, an accountability system, and more attention given to best practices, inquiry-based science is not widely implemented in elementary schools. In fact, elementary science is often cited as the "weak link in the continuum of K-16 science education (Hodgin, 2011). One of the reasons may be that the demands of inquiry-based instruction are rigorous, yet elementary teachers are usually prepared as generalists and lack the content and pedagogical expertise of secondary science teachers (Haefner & Zembal-Saul, 2004).

Given that elementary teachers have the ability to influence students, their attitudes about science are crucial to both instructional delivery and attempts to reform elementary science education (Cobern & Loving, 2002; Lumpe, Haney, & Czerniak, 2000; Pell & Jarvis, 2003). Teacher attitudes about science instruction are frequently negative and indicative of science anxiety. These negative attitudes about their science teaching are frequently reported by elementary teachers (Van Zee & Roberts, 2001). Elementary preservice teachers report being "frightened" of the prospect of teaching science (Westerback & Primavera, 1992). These attitudes about science influence their teaching, and teachers who had negative experiences with science as students, avoided taking science classes in college and teaching science in their elementary classes (Hodgin, 2008). The current climate of accountability and high-stakes testing may only exacerbate the problem.

Elementary school teachers frequently report a struggle to teach science in the face of high-stakes testing and increased accountability issues. Although teachers realize how important and interesting science is for children, anxiety and avoidance frequently drive actual instructional practices. Understanding the nature of science and how to use this as the foundation of an elementary science program is essential to promoting the systemic reforms needed to promote high quality science instruction. Inquiry-based strategies are the preferred model for most science instruction as they are the best match for authentic scientific research methodologies. Inquiry is defined in the National Science Education Standards (NRC, 1996) as a "set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories" (p. 214). Inquiry-based science instruction is a research-based approach that includes several essential features. The National Science Education Standards (NSES) (NRC, 1996) describes inquiry-based instruction as,

> a multi-faceted 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)

Yet many elementary teachers are not teaching science authentically, but traditionally in a teacher-centered model of instruction. Teachers may have little knowledge of inquiry-based science, or the desire to implement the strategies. Elementary teachers that participated in a 3-year project focusing on inquiry and the Nature of Science did not significantly change their beliefs or pedagogical practices (Bencze et al., 2003). And elementary teachers who do state preferences for inquiry-based instruction often equate "hands-on" activities with inquiry, confounding the student-centered essential features with "any physical manipulation of materials resulting in pre-determined results" (R. Pringle & S. Martin, 2005). The root of the problem may lie in teacher beliefs about science education.

Science Anxiety

Mallow defined "science anxiety" as fear or aversion of science concepts, scientists, or science in general, and can be characterized by a widespread avoidance of an area that is “beyond our ability to comprehend” Jeffry V Mallow (1981, p. 1). Science anxiety can be provoked by thoughts of ineptitude and fear of failure (Bandura, 1977, 1981; Czerniak, 1989; Mallow, 1981; Westerback, 1984; Westerback & Roll, 1982). Anxiety is an emotional and physiological arousal triggered by “fear-provoking thoughts” (Bandura, 1977, p. 199) and can be caused by the “inability to influence events and social conditions that significantly affect one's life” (Bandura, 1982, p. 140). Science anxiety is unique, and perhaps cannot be measured or treated in the same way that another type of anxiety may be treated. This distinctive type of anxiety may have a great influence beyond the individual experiencing the anxiety and even lead to avoidance of science as a student and teacher. Anxiety may be the starting point in creating a vicious cycle of avoidance and even failure. Science anxiety can be observed by an avoidance of science courses, the anti-science attitudes commonly found in society, and a stereotypical representation of scientists (Jeffry V Mallow, 1981). In addition, Mallow lists several “science skills” such as reading science textbooks, lectures, word problems, equations, graphs, and taking science tests that produce science anxiety (1981). One of the most important characteristics of science anxiety pertinent to the theoretical framework that Mallow describes is the experience of feeling frustration, then denying competence, and then finally avoiding science (Jeffry V Mallow, 1981; Jeffry V. Mallow, 2006). The research on mathematics anxiety may also provide insights into science anxiety, since the nature of science is very similar to mathematics. Trujillo and Hadfield have defined mathematics anxiety as “a state of discomfort that occurs in response to situations involving mathematical tasks that are perceived as threatening to self-esteem” (Trujillo & Hadfield, 1999, p. 219). These experiences play a key role in the description and possible measurement of science anxiety.

Measuring science anxiety is essential to understanding the factors influencing it and its effects on elementary teachers and students, yet few studies were published until 1977, and no instruments to measure science anxiety had been developed. Mallow was one of the first researchers to examine science anxiety within a clinic located at Loyola University (Jeffry V Mallow, 1978, 1981). Mallow described and treated science anxiety with traditional methods used in psychological treatments, describing it as unlike traditional psychological anxieties, and more closely related to fear of math than fear of flying (Jeffry V Mallow, 1978, 1981). This form of anxiety has a broader impact because science anxious students may become teachers who avoid science and thereby contribute to the vicious cycle of anxiety and avoidance (J. Mallow & Greenburg, 1983; Jeffry V Mallow, 1978). Little quantitative research on science anxiety had been attempted before Mary Westerback adapted the State-Trait Anxiety Inventory (STAI) to measure science anxiety (Spielberger, Gorsuch, & Lushene, 1970; Westerback, 1982). Building on the work at the Loyola Science Anxiety Clinic, Czerniak developed the Science Anxiety Questionnaire to measure science anxiety in preservice teachers (Czerniak & Chiarelott, 1984).

An important step in quantifying science anxiety was the creation of an instrument to measure general anxiety. Spielberger identified two aspects of anxiety, State Anxiety and Trait Anxiety in creating his instrument for measuring anxiety, the State-Trait Anxiety Inventory (STAI) (Spielberger, et al., 1970). State anxiety is described as a "transitory emotional state" that and may fluctuate over time (p. 3). Trait anxiety is more stable, and describes the "proneness" among individuals to experience anxiety. People with high trait anxiety should be more likely to experience high state anxiety at any given time, as well as the opposite (low trait anxiety should drive low state anxiety). Spielberger developed a self-administered instrument to measure both State and Trait anxiety, the State-Trait Anxiety Inventory (STAI). The STAI is a 40 question, Lickert scale instrument, with two sections of 20 questions each. One section measures State Anxiety and asks participants to evaluate how they feel "at this moment," (p. 20) and the Trait Anxiety section asks participants to rate how they "generally feel" (p. 21). The instrument was normalized on two sets of samples of university students; one group of 982 incoming freshmen and another group of 484 undergraduate students. The instrument was also normed with high school students, male psychiatric patients, general medical and surgical patients, and young prisoners (Spielberger, et al.). During subsequent use, it was noted that subjects with high State-Anxiety performed significantly lower on problem-solving tasks than subjects with low State-Anxiety. Yet Trait-Anxiety had no significant effect on performance (Meyers & Martin, 1974). This evidence helps to confirm the assertion that State-Anxiety is a sensitive measure of transient anxiety associated with a particular situation.

A more detailed description of science anxiety was built on the research of Mallow and Spielberger by Mary Westerback. Her description of science anxiety includes threats to self-esteem or achievement that are likely to increase state-anxiety (Spielberger, et al., 1970; Westerback, 1984). The Anxiety-State (A-State) is transitory and measures tension, nervousness, worry or apprehension, and may change over time. The A-Trait is a more stable measure of the proneness to anxiety. Finally, the A-State scale will increase when a subject perceives a situating as threatening (Spielberger, et al.; Westerback, 1982, 1984). Czerniak's definition of science anxiety is based on Mallow's definition, but in her description, anxiety is related to a threat to the sense of security, and not fear. Instead, fear is related to an actual physical threat, not a threat to a person's self-efficacy (Czerniak & Chiarelott, 1984; 1989).

Several methodologies for measuring science anxiety have been described in the literature. Westerback adapted Spielberger's STAI, with the author's permission and suggestions, for a series of descriptive studies (Spielberger, et al., 1970; Westerback, 1982, 1984; Westerback & et al., 1984, 1985; Westerback & Long, 1990). In a study published in 1984, four sets of preservice teachers participated in a study of science teaching anxiety for the duration of their one-year science content course (1977-78, 78-79, 79-80, and 80-81). The purpose of the study was to understand why elementary teachers may avoid science, and if there was a change in science anxiety over the course of a one-year science content course (Westerback, 1984). The first step was the adaptation of a standardized Instrument that would be used to measure science anxiety – the Science STAI (Westerback, 1984). Participant science anxiety was measured using the Science Anxiety State-Trait Anxiety Inventory (STAI), an instrument that measures anxiety at a "particular moment in time" (Westerback, 1984, p. 937). Westerback adapted the measurement for science anxiety by changing the headings in the A-State questions to match science teaching (Westerback). Westerback changed the headings by directing teachers to imagine that they were expected to teach science at this moment, with their current knowledge of science. She also used two forms of the STAI, the X and Y forms. Spielberger developed a second form of the STAI, the original form called the "X" form and the revised form the "Y" form. The purpose was to eliminate some of the measures of depression in the X form. Spielberger advised Westerback to use the revised Y form and it was compared to the X form during the 1980-81 study (Westerback). Over the course of the four-year descriptive study with preservice teachers, the Form X was used exclusively for the first three years (1977 – 1980) and the Forms X & Y were used for the last year, 1980-81 (Westerback, 1984). The A-State reliability coefficients for Form X ranged from 0.83 to 0.92, and Form Y was 0.95 (Spielberger, et al., 1970). The A-Trait correlations were 0.73 – 0.86 for the X form, and 0.92 for the Y form (Spielberger, et al.; Westerback). In a 1983 study, Sherwood and Westerback found the STAI to be a reliable standardized measure of science anxiety (Sherwood & Westerback). The science anxiety tests were given three times during the school year, at the beginning of the fall semester, near the end of the fall semester and at the end of the spring semester (Westerback, 1984). During the 1980-81 school years the tests were given six times in order to compare the X and Y forms of the test (Westerback).

The results of Westerback's study found a statistically significant reduction in preservice teacher science anxiety throughout the school year, although some of the patterns did raise some additional questions (Westerback, 1984). Westerback also found numerous cases in which the A-State was several points higher than the A-Trait, indicating science anxiety (Westerback, 1984). One of the criticisms of study and the possible use of the STAI is that the A-Trait should be a stable measure, yet there was a statistically significant drop in preservice teacher A-Trait from Dec 1980 to Jan 1981 [0.93 points with one course sequence, 2.32 points with the reverse sequence] (Westerback, 1984). Westerback was unable to offer an explanation for why there was a change in A-Trait since no answer from the data was available (Westerback, 1984).

In subsequent studies of science anxiety, Westerback continued to use the STAI, since it has been examined for reliability and construct validity and shown to be an effective instrument for measuring science anxiety (Westerback & Long, 1990). "The Science Teaching STAI is an easy to use, short, accurate, standardized measurement of teacher anxiety about science teaching" (p. 372). Over time, the norms for the Y-Form of the STAI were standardized with college students, working adults, and military recruits (Spielberger, et al., 1970; Westerback, 1982; Westerback & Long).

Because little research has been done on in-service teachers, Westerback and Long studied 95 teachers who participated in a National Science Foundation institute, the SSET (1990). The results of the study showed significant reduction in anxiety levels observed in practicing elementary teachers during an earth science course (Westerback & Long, 1990). From September to November the S-Anxiety (State-Anxiety) mean changed from 43.87 to 28.28 ($t = 7.234$, $N = 39$, $p<0.005$) (Westerback & Long). Two factors that possibly contributed to increased anxiety levels were grading on a curve, and the requirement of rote memorization (Westerback & Long).

For the SSET participants, the first mini-examination was very upsetting and some reported physiological responses to anxiety such as upset stomachs, hives, pacing and fidgeting (Westerback & Long, 1990). In addition, many participants reported increased anxiety and concerns about test performance (Westerback & Long). Westerback also compared achievement with STAI; there was an apparent relationship between raising scores on a science achievement test and lowering science anxiety (Westerback & Long). STAI scores for SSET teachers were also compared to a group of 18 elementary teachers not participating in the program who reported spending little time teaching science; however, these nonparticipants had a much lower mean (43.87 initial mean for SSET, 33.82 for nonparticipants) than the SSET teachers (Westerback & Long). This could be explained if the nonparticipants having no expectation to be teaching earth science, and therefore little anxiety about actually being required to teach science (Westerback & Long). During the course of the study, examination formats were changed to allow for take-home tests and corrections; and this may be what was responsible for some of the reduction in anxiety (Westerback & Long). Westerback and Long also ask the question “Is it possible that the expectation of teaching the subject is a factor in higher initial anxiety levels of teachers” (p. 371)? Teachers who are comfortable with studying science are more likely to teach it (Westerback & Long).

In a 1984 study, Czerniak and Chiarelott developed a Science Anxiety Questionnaire of 40 statements chosen to test four areas: "testing situations, laboratory/experiment situations, classroom/lecture situations, and science-related situations" (p. 17). Twelve Likert-like questions were developed for each category with responses that ranged along an attitude continuum from "very calm, fairly calm, neutral, a little nervous, and very nervous" (Czerniak & Chiarelott, 1984, p. 17). Seven individuals validated the instrument, including the teachers of students participating in the study. Modifications were made, and resulted in the final version of 48 questions (Czerniak & Chiarelott, 1984). Reliability was determined with the Cronbach Coefficient Alpha Formula, resulting in coefficients between 0.925 and 0.958 (Czerniak & Chiarelott).

Czerniak and Chiarelott examined science anxiety in students ranging from 4th to 9th grade and found that high levels of science achievement were correlated with low levels of science anxiety (Czerniak & Chiarelott, 1984). It was also found that science anxiety was significantly related to sex, with girls more anxious about science than boys, beginning as young as fourth grade (Czerniak & Chiarelott). Anxiety appears to be linked to the formal study of science as an academic subject, and anxiety about science appears early in a student's career (Czerniak & Chiarelott, 1984; Czerniak, 1989). Barufaldi found that elementary teachers had relatively high levels of anxiety about science teaching, and a strong tendency to avoid teaching science (J Barufaldi, 1982). While examining gender differences in science anxiety among college students, Brownlow found that students with high anxiety had lower SAT scores, took fewer science courses in college, and reported negative experiences with high school science teachers

(Brownlow & Jacobi, 2000). Based on her pilot study, students reported to Phillips that their science anxiety resulted from a hopelessness, a "lack of rescue" (Phillips, 2004).

She linked anxiety to poor performance in science classes, as anxious students used tricks to try and memorize material without a real understanding of the concepts. In addition, math anxiety is closely linked to science anxiety. Preservice teachers who were classified as “High” or “Moderate Math Anxiety” reported that they “Find it difficult to explain why science experiments work” (Bleicher, 2004). They are also less willing to be observed teaching science than their “Low Math Anxiety” counterparts, and compared to this group are less confident in their ability to “teach science effectively,” “have necessary skills to teach science,” and “know steps to effectively teach science concepts” (Bleicher, 2004). Finally, elementary education majors displayed the second highest scores (exceeded only by students enrolled in mathematics anxiety workshops) on the Mathematics Anxiety Rating Scale (MARS) (Bursal & Paznokas, 2006). Tosun found that preservice teachers report negative feelings about science content courses, even when they experience some success mastering content (Tosun, 2000). A comparison of two groups of preservice teachers with low self-efficacy scores - high achieving and low achieving in science content courses - found that both groups reported primarily negative descriptors of science; therefore low self-efficacy was a stronger factor than even science achievement (Tosun, 2000). Finally, in two separate studies, Udo found that non-science majors had significantly more acute science anxiety that science majors (M. Udo, Ramsey, & Mallow, 2004; M. K. Udo, Ramsey, Reynolds-Alpert, & Mallow, 2001).

Populations

The science anxiety research performed on various populations of participants in Westerback's study collected demographic data on the preservice teachers that participated in the four-year investigation, including age, sex, college standing, high school and college science and math background, and specialization in elementary or special education (Westerback, 1984). Although over 90% of the preservice teachers in Westerback's studies were female, there were no significant differences in gender for science anxiety or achievement (Westerback, 1982, 1984; Westerback & et al., 1984). In the various studies of undergraduates, (not only preservice teachers) approximately 60% were male, but no significant gender differences were found in science anxiety or science achievement (Westerback & et al., 1984). Gender was not mentioned in Westerback's study of elementary classroom teachers, presumably because all the participants were female (Westerback & Long, 1990). Czerniak found significant gender differences in science anxiety for students beginning in as early as the fourth grade (Czerniak & Chiarelott, 1984).

One of the demographics also collected were educational levels. In her studies with preservice teachers and other undergraduate majors, Westerback gathered information about the majors and classifications of students (Westerback, 1982, 1984; Westerback & et al., 1984). Data on the majors of students in order of frequency were: business, undecided, science and other unspecified non-science majors. In addition, most participants were freshman and sophomores (Westerback, 1982, 1984; Westerback & et al., 1984).

The professional status of participants is especially important, given the differences between preservice teachers and those actually working in classrooms. Westerback sought to describe how preservice teachers may change their levels of anxiety as they progress through a series of science courses designed specifically for their professional preparation program (1984). But anxiety levels were reduced in both studies of preservice and in-service teachers as they moved through a science content course.

Population factors may have a significant effect on the degree of science anxiety present in participants. One such factor is gender, and Czerniak and Chiarelott found girls to be more anxious about science than boys (1984). Beginning in the 4th grade, girls were already more anxious about science than boys, so science anxiety probably begins at an earlier age. It may be related to the study of science as an academic subject, but does not increase over time, so perhaps students are "checking out" of science even before middle school (Czerniak & Chiarelott).

There is also some evidence for reduction of science anxiety as more science is studied, indicating that levels of education may also play a role in science anxiety (Westerback, 1982, 1984; Westerback & et al., 1984, 1985). But most of the studies measuring anxiety on elementary teachers did not measure science content or correlate to number of courses taken (Westerback, 1982, 1984; Westerback & et al., 1984; Westerback & Long, 1990).

A teacher's professional status may play an important role in the measurement of science anxiety. The initial means of the A-State measures for preservice teachers was much higher than the initial means for female college students, indicating that preservice teachers experienced higher science anxiety than their fellow undergraduate non-education majors (Westerback, 1984). If fact, the initial means of A-State for preservice teachers most closely matched that of anxiety reaction patients, indicating an initial level of anxiety far higher than should be expected for their demographic (Westerback, 1984). Perhaps this is because they have an actual expectation of being required to teach science. Preservice teachers had the highest initial anxiety and nonparticipants in the SSET program had the lowest initial mean anxiety. In-service teachers participating in the SSET had the expectation of teaching science, but also had enough experience to evaluate their authentic expectations. Nonparticipants in the SSET probably had no expectation of having to teach science, and so therefore showed no anxiety. These variances in science anxiety may result because of the differences in studying and teaching science.

Science Teaching Self-Efficacy

The psychological underpinnings of self-efficacy research are grounded in Bandura’s social cognitive theory (1977). His definition of personal self-efficacy is, "judgments of how well one can execute courses of action required to deal with prospective situations" (1982, p. 122). Self-efficacy is the belief that a person could act to solve a problem or deal with a situation, based on prior experiences (1977). One aspect of self-efficacy is outcome expectancy, or the belief based on personal experience that a positive (or negative) outcome is likely (1977). Another aspect of self-efficacy is an efficacy expectation - the belief that a person could produce the given behavior in order to achieve the outcome (1977). One of the most important pieces of self-efficacy research is avoidance behaviors. Avoidance behavior occurs when people face situations that are intimidating and they believe they lack the skills to produce a desired outcome (1977). A key relationships described by Bandura was how changes in self-efficacy behavior are due to avoidant behavior (1981). The role of arousal and stress provide an important explanation for how anxiety drives self-efficacy. In turn, a person's perceived self-efficacy drives factors such as coping behaviors, outcome expectations and even career choices (Bandura, 1977; 1982), stress and emotional arousal (such as anxiety) are reduced by high levels of self-efficacy (1982). People view stress as an "ominous sign of vulnerability to dysfunction," (p. 127) and are more likely to expect success when they are not under stress such as anxiety (1982).

The relationship between self-efficacy, outcome expectations and avoidance behaviors is essential to understanding how science anxiety may operate in elementary teachers. Self-efficacy can influence both the choice of behaviors to avoid and the associated coping skills (Bandura, 1977). If there is an expectation of eventual success, than people may persevere if the rewards are sufficient (1977). The belief that a person can deal effectively with the cognitive, social, and behavioral skills needed to execute a course of action, is defined as perceived self-efficacy (1982). Efficacy expectations also vary in strength - people with strong beliefs in their ability to succeed will persist in a behavior much longer than those with weak expectations (1977). Performance accomplishments or the ability to achieve an expectation, increase an individual's self-efficacy. Basically, success breeds success, and failure breeds yet more failure (1977).

Self-efficacy also varies with the perceptions of accomplishment due to ability or effort (1977; 1981; 1982). People with low self-efficacy and low outcome expectation will give up easily if a desired outcome is not attained quickly (1977). The foundation for science self-efficacy research is grounded in the more generalized self-efficacy work of Bandura.

The special case of science anxiety and self-efficacy has been investigated to determine if the same kinds of relationships exist as do in generalized self-efficacy and anxiety. Science teaching efficacy is the belief that one can promote student achievement in science (Ramey-Gassert, et al., 1996). In a study of science self-efficacy by Tosun, two groups of preservice teacher participants classified as low-achievement in science used primarily negative descriptors of science, revealing the strength of low self-efficacy over high science achievement (2000).

Measuring science teaching self-efficacy and exploring how it relates to outcomes and beliefs has been examined with the Science Teaching Belief Instrument. The STEBI-B (Science Teaching Efficacy Belief Instrument-Preservice) is an instrument developed to measure science teaching self-efficacy (Riggs & Enochs, 1990). This instrument measures teacher beliefs of their ability to teach science, and results suggest that early detection of science anxiety is important in preservice teacher education (Enochs & Riggs, 1990; Riggs & Enochs). In 2004, the instrument was evaluated for reliability and validity (Bleicher, 2004). Bleicher examined the reliability and internal validity of the instrument and revised it to increase item-total correlations (2004). Comparison of means analyses showed that gender, number of science courses taken, and school science experiences had significant associations with Personal Science Teaching Efficacy or

PSTE (Bleicher, 2004). Ramey-Gassert, et al. described science teaching efficacy as the belief that one can promote student achievement in science (Ramey-Gassert et al., 1996). The two parts of science teaching efficacy are: PSTE (Personal Science Teaching Efficacy) and STOE (Science Teaching Outcome Expectancy). Personal science teaching efficacy (PSTE) is related to a teacher's belief in their ability to teach science, and both of these factors affect elementary science instructional practices (Ramey-Gassert & Shroyer, 1992; Ramey-Gassert et al., 1996). In this study PSTE and STOE were measured by two different subscales on the STEBI-A, the version of the test designed for in-service teachers (Enochs & Riggs, 1990; Ramey-Gassert et al., 1996). There was a significant ($p<0.05$) correlation between numerous factors (see Table 2.1) (Ramey-Gassert, et al., p. 290). Table 2.1 shows Personal Science Teaching Efficacy (PSTE) closely tied to: attitudes toward science – low PSTE is correlated to poor attitudes; educational degree level – low PSTE/low content preparation and choosing to teach science – low PSTE/don't want to teach science; and effectiveness in science teaching – low PSTE/ineffective teacher (Ramey-Gassert, et al.). STOE is significantly correlated ($p<0.05$) to: number of college science courses taken – more courses taken, higher the expectation of success; conversely, the fewer college science courses taken, the lower the expectation of successfully teaching science; and the choice to teach science (Ramey-Gassert, et al.).

Table 2.1

Spearman Rho Correlations for Data Variables with STEBI-A Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE) (N = 23)

	PSTE	STOE
PSTE	1.00	
STOE	0.261	1.00
Attitude toward science	0.850**	0.306
Years of teaching	0.206	0.066
Educational degree level	0.522**	-0.210
Number of college science courses	0.297	0.398*
Number of science methods courses	0.247	0.153
Number of hours spent teaching science per week	0.170	-0.043
Choosing to teach science	0.436*	0.357*
Self-rated effectiveness in science teaching	0.405*	0.127
Science-related professional development experiences	0.320	0.291

*significant $p<0.05$; **significant $p<0.01$.
(Ramey-Gassert, et al., 1996, p. 290)

This statistical analysis illustrates the significant relationship between science teaching self-efficacy, content knowledge background, and avoidance of science teaching (Ramey-Gassert, et al., 1996). A link between the science teaching self-efficacy, outcome expectation and avoidance behaviors can help to explain some of the aspects of elementary science teaching avoidance.

Science avoidance research is also closely tied a teacher’s experiences as a student, a preservice teacher, and an in-service teacher. As a science student, preservice teachers are often found to choose the minimum number of science courses required for their degree. When comparing course selection in high school and college, 97% of the preservice teachers in a study by Tosun, took Biology and Chemistry in high school

(2000). But this dropped to 66% for college Biology and 14% for college Chemistry. Physical sciences were 63% in high school, but only 29% in college; Earth sciences were 57% in high school, and 17% in college (2000). These preservice teachers avoided taking science in college; the numbers were higher in high school, but only because they were required to take these science courses (Tosun). This pattern carries over into classroom behaviors, especially if the teacher has no pressure from administration to actually teach science. Science is avoided in elementary classes due to negative teacher attitudes about their science teaching assignments as reported by elementary classroom teachers (Van Zee & Roberts, 2001). Avoiding science teaching in elementary schools is probably even more common than is being reported to researchers.

Science anxiety is arousal that leads to lowered efficacy expectations. Teachers may engage in avoidance behaviors that reduce anxiety, but also lower self-efficacy. If a teacher believes they cannot understand science then they are more likely to lower their efficacy expectations. “People who perceive their arousal as stemming from personal inadequacies are more likely to lower their efficacy expectations than those who attribute their arousal to certain situational factors” (Bandura, 1977, p. 202).

Elementary teachers are more likely to report high science anxiety and the subsequent low self-efficacy. Ramey-Gassert established a link between high science anxiety and low science teaching self-efficacy (Ramey-Gassert et al., 1996). During an interview as part of an ethnographic study, an elementary teacher responded that she experienced a great deal of science anxiety (Hodgin, 2008). When she began teaching, she attempted to address all of the content areas, including math and science, but quickly discovered that there were children who already knew more than she did (Hodgin, 2008). This realization contributed to an increase in science anxiety.

Teachers who have weak science content and performance accomplishments report negative attitudes that stem from their own experiences as a science student, especially in university science content courses that are difficult, yet provide little help in teaching science to children (Lindgren & Bleicher, 2005). They described themselves as uninterested and incompetent in science (Van Zee & Roberts, 2001). Many chose to relieve this anxiety by taking fewer or less rigorous Science courses and/or specializing in non-science and mathematics areas such as English Language Arts (ELA) (Hodgin, 2008). Unfortunately, these choices often perpetuate their science anxiety and low self-efficacy.

Elementary teacher science teaching self-efficacy and efficacy expectations are often lowered by negative performance accomplishments as a student. If the teacher had a poor science background in high school and college, they feel ill prepared to teach science. Many pre-service teachers report that their own experiences with elementary and middle school science consisted of reading text and answering questions; as a result they report apprehension and fear when faced with the prospect of teaching science (Lindgren & Bleicher, 2005). Elementary teachers are more likely to have experienced limited inquiry strategies experiences as a student. One pre-service teacher reported that "I had been taught by teachers my whole life (with the exception of a select few) who focused on details rather than concepts, answers rather than the search for answers, and test grades rather than true understanding" (Hodgin, 2011, p. 75). Teachers with poor science backgrounds may perceive their anxiety as stemming from an inability to comprehend or "do" science, and increase the chances that they will engage in science avoidance behaviors. One elementary teacher reported that, "When I first started teaching I went by the book (textbook) and I scheduled exactly the hours that were required. But then as the year went on, I realized that the very poor readers were not getting the science because they couldn't read the textbook." Since her background in science was not strong enough to be able to teach the content of the book, she began struggling in science, and because it was at the end of the school day, if anything took too much time, then science just got dropped. "By the end of the year, that was pretty much every day. Science went the way of the Ninja" (Hodgin, 2008). She also resorted to teaching what she was comfortable teaching – Reading. She justified this by stating that if students cannot read on grade level, then she would not be able to teach them any of the subject matter. So "Reading started taking up pretty much half our day" and she would teach some mathematics in the morning, and then finish up in the afternoon" (Hodgin, 2008). Elementary teachers with poor science backgrounds may have exacerbated their anxiety with continued avoidance behaviors and a low science teaching self-efficacy.

Reduced self-efficacy or the belief that one cannot perform the necessary tasks required of them may originate in a teacher's low Pedagogical Content Knowledge. Science content knowledge is also an important part of inquiry-based science and science anxiety. Teachers must have a deep Pedagogical Content Knowledge (PCK) in order to facilitate inquiry. Shulman describes pedagogical content knowledge as "knowledge … which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (Clough, 2011, p. 9). PCK is a deep understanding of both the concepts to be taught, and the prerequisite knowledge necessary for mastery of the concepts. Teachers must be able to continuously assess their student's progress along a continuum of development, while being aware of the possible alternative conceptions and how to challenge their student's thinking (Clough). Research indicates that elementary teachers have limited PCK or the ability to make specific content accessible to others (James Barufaldi, 1989). Teachers with little science experience may be fearful of being unable to answer student questions (Tosun, 2000). When teachers possess little Pedagogical Content Knowledge, then it becomes extraordinarily difficult for them to implement inquiry.

Elementary administrators and teachers frequently mention student engagement as an important goal in education. Although engagement alone does not guarantee learning, a lack of engagement in science classes is one problem described by high anxiety, low self-efficacy teachers. During interviews of elementary teachers who identified themselves as high science anxiety, low confidence, two teachers described almost identical experiences with science as a student and teacher. Both stated that their high school and college science classes were primarily lecture based, and they mentioned their own lack of engagement as a factor in their dislike and avoidance of science. Reading the textbook and answering questions was the primary activity in the science courses they took. One teacher could not remember any labs that were engaging - "we didn't even look at the sky, not one time in six hours of astronomy at UT" (Hodgin, 2008, p. 8). The other teacher did mention a high school physics teacher she loved who did the “egg drop, levers, pulleys and cars on ramps” (Hodgin, 2008).

These “teacher-centered” instructional strategies are discouraged by recent research in effective science instruction, such as the National Research Council’s study of inquiry-based pedagogy (NRC, 2000). Because many elementary teachers experience science with these teacher-centered strategies, they may not understand inquiry and the Nature of Science and how it differs from other academic disciplines. When an elementary teacher is put into a classroom and told to teach science, their poor background and lack of PCK may contribute to this vicious cycle of anxiety and avoidance. An elementary teacher who became an administrator seemed reluctant to talk about her experiences as an elementary science teacher, only volunteering that because of her poor background she “faked it. I’m not a science mind, so I’ve just stayed away from it” (Hodgin, 2008). She also reported feeling intimidated by the demands of teaching science. She described feeling a lot of apprehension, because “if they realize that I don't have what it takes in science they’re going to question everything that I teach. Then I'm not going to be the person in the room that knows the most about this” (Hodgin, 2008, p. 10). The problem of elementary science anxiety and avoidance is closely linked to teacher beliefs, experiences, and instructional practices, and a teacher is unlikely to adopt personal philosophy that causes anxiety and arouses feeling of low self-efficacy.

Teacher beliefs are a strong indicator of how the individual’s philosophy of education will drive their instructional model, so these beliefs may play a significant part in beginning the cycle of anxiety and reinforcing science anxiety, low self-efficacy and avoidance behaviors. Although there is not a strong direct relationship found in the literature between low science teaching self-efficacy and avoidance of science teaching, negative performance accomplishments as a student may lead to low science teaching self-efficacy. Teachers who held certain alternative conceptions (such as planets can only be seen with a telescope) also had low self-efficacy in science teaching (Schoon & Boone, 1998). The general research on science anxiety does establish a link with science anxiety, avoidance and negative attitudes towards science teaching, (Hodgin, 2008; Tosun, 2000; Van Zee & Roberts, 2001) so the link between generalized anxiety and self-efficacy creates some basis for stating that low self-efficacy teachers may avoid using an inquiry-based model of instruction. In an ethnographic study, Hodgin found that elementary teachers find many reasons not to teach science (Hodgin, 2008). These reasons include poor experiences in science courses and few experiences with inquiry (Lindgren, 2003; Tosun, 2000). If science is taught as a body of proven facts that must be memorized and "absolute truths readily communicated through texts and lectures, then students will come to regard science as a static body of knowledge" (Taraban, Box, Myers, Pollard, & Bowen, 2007, p. 2). If students are exposed to learner-centered inquiry, then they can come to realize that scientific knowledge is based on the interpretation of data and that meanings are negotiated through collaboration within the scientific community (Taraban et al., 2007). The lack of collaboration or climate of competition along with teacher-centered instruction can increase science anxiety and decrease science teaching self-efficacy. Due to the lack of engagement, emphasis on memorization, and other teacher-centered instructional strategies, Westerback reported one significant source of anxiety in their science courses were tests that included rote memorization and competitive grading on a "curve" (Westerback, 1984; Westerback & Long, 1990). In a preliminary study of elementary teachers, participants labeled as "non-confident" in their mastery of science, indicated a history of science course taking that were "not engaging" and that focused on memorization and reading from a textbook (Hodgin, 2008). For elementary teachers experiencing science anxiety and low self-efficacy, one option is to adopt a traditional instructional model. A traditional model of instruction is teacher-centered, and utilizes strategies such as reading from a textbook, memorizing vocabulary, and engaging in labs or activities with predetermined outcomes (R. L. Bell, Lederman, & Abd-El-Khalick, 2000; Bencze et al., 2003; Hodgin, 2011; Kelly & Staver, 2005). A traditional model of instruction provides an alternative to the demands of inquiry-based instruction, whether in teaching science or mathematics. Research on how mathematics anxiety affects instructional practices shows that teachers with this anxiety fail to implement inquiry-based techniques. They utilize more lectures, concentrate on basic skills, and neglect teaching concepts (Swars, Daane, & Giesen, 2006).

> These teachers devote more time to seatwork and whole-class instruction and less time to playing games, problem-solving, small-group instruction, and individualized instruction. Teachers with high mathematics anxiety avoid teaching mathematics, as well as perpetuate this negative attitude toward mathematics among their students. (Swars et al., 2006, p. 306)

Traditional instructional strategies also mesh well with English Language Arts instruction that may be more familiar to elementary teachers. The student takes on the role of receivers (and memorizers) of knowledge. This pedagogy consists of "…giving information and directions, asking questions, making and reviewing assignments, monitoring seatwork, giving and reviewing tests, assigning and reviewing homework, settling disputes, punishing noncompliance, and marking papers and giving grades" (Fletcher & McClellan, 2008, p. 1021). Traditional strategies are also the norm in the environment of high-stakes testing. The assertion is made that "A teacher in an urban school of the 1990s who does not engage in these basic acts as the primary means of instruction would be regarded as deviant" (Fletcher & McClellan, 2008, p. 1021). Incredibly, this is a common practice, despite research on best practices that contradicts these strategies.

When students are denied the opportunity to construct their own knowledge and must instead memorize the knowledge of others, this creates a situation where the locus of control is external – the teacher is at the center of instruction. The final judgment about the validity of a scientific idea is the textbook or a standardized test (AAAS, 1989, 1993). Teachers also are naïve in their own experiences with inquiry as a student. In a study by Cady and Rearden, preservice teachers wanted university professors to provide step-by-step directions for solving math problems, displaying an external locus of control where they expected the teacher instead of the learner to drive the instruction (2007). But teacher-centered instruction does provide a level of familiarity and does not require deep Pedagogical Content Knowledge, or PCK. Research conducted with pre-service teacher epistemic beliefs supports the view that teachers are content experts who provide "right-or-wrong" answers to student questions (Cady & Rearden, 2007). These same pre-service teachers "see their role as students as memorizing the right answers and giving them back upon request” (Cady & Rearden, 2007, p. 237). In many ways, these instructional strategies that perpetuate science and math anxiety continue in a vicious cycle. Elementary teachers sought the familiarity of instruction where the purpose was the pursuit of correct answers and the reward was a passing grade, instead of the unfamiliar territory inhabited by scientific inquiry. By forcing themselves into the role of teacher as expert, elementary teachers may actually increase their anxiety since they are both unaware of inquiry-based strategies and also lack the content knowledge of experts.

Teachers with high science teaching self-efficacy are more likely to adopt an inquiry-based instructional model. If they report more successful experiences with science, they are more likely to accept and implement the authentic nature of inquiry (Parker & Spink, 1997). Studies with pre-service teachers have shown that using inquiry-based methodologies can increase PCK. “…after engaging in an original science investigation, prospective teachers’ views of science and their explanations of doing science became more elaborated and data-driven” (Haefner & Zembal-Saul, 2004, p. 1658).

A teacher is participating in a collaborative, inquiry-based science program to obtain a Master’s degree described it as “by far the best experience I’ve had as a science student” (Hodgin, 2008). Scientific learning communities may play a significant role in collaboration and how it affects science anxiety. In inquiry-based learning, researchers and students work within the context of a team for entire project. Students are an active part of the learning process, as the individual uses social interactions to create personal meaning from sensory motor experiences (Lumpe et al., 2000). The student is also part of a larger community that can be used as resources and for peer-review. Science is a collaboration of many individuals working within the context of a scientific and learning community, (AAAS, 1989, 1993; NRC, 1996, 2000) and inquiry effectively mimics this collaboration. Perhaps the structure of a team helps to alleviate the anxiety of working as an individual to obtain a "correct" answer. Akerson and Abd-Khalick described a scenario in which a fourth-grade teacher, even with some knowledge of NOS, was unable to translate it into classroom practices (2001). It is hard to imagine a scenario that would create more anxiety than a teacher as the sole proprietor of knowledge. When students work within the context of teacher expectations, there is no larger community for review, but an isolated classroom experience.

The teacher with higher self-efficacy and lower anxiety is able to release control of the classroom with the confidence that they can be a facilitator of learning instead of the expert who answers questions, assigns grades, and prepares students to pass tests. High self-efficacy teachers display a willingness to take risks in using an instructional model with less teacher control. Czerniak reported that teachers with high self-efficacy were more likely to use a larger variety of instructional strategies than teachers with low self-efficacy (C. M. Czerniak, 1989). In addition, high self-efficacy teachers showed more "withitness" or the ability to monitor an entire class for engagement during small group activities (C. M. Czerniak, 1989). When elementary teachers possess a high degree of self-efficacy, they are more willing to release control of the instructional model to the learners and let questions instead of correct answers, and exploration instead of passing tests drive their basic instructional model.

Inquiry-based Science Instructional Model

The historical roots of inquiry-based science are based on the psychological underpinnings of social learning theory and constructivism. The origins of inquiry-oriented teaching are based on constructivist models of learning often referred to as "active learning" (Haury, 1993). Constructivist learning is based on personal experiences with scientific phenomena, (Haefner & Zembal-Saul, 2004; King, Heinrich, Stephenson, & Spielberger, 1976; Van Zee & Roberts, 2001) and maintains that learning results when students integrate new concepts into their existing frameworks in order to make meaning out of experiences (Daley, 2003; Haury, 1993). The neurological basis for constructivism was described by Lowery as the process in which our brains construct knowledge from hands-on experiences that provide sensory information that the brain then processes and stores (2002). "Constructivist educators strive to create environments where learners are required to examine thinking and learning processes, collect, record, and analyze data; formulate and test hypotheses; reflects on previous understandings; and construct their own meaning" (Zion et al., 2005, p. 958). Constructivist scientific inquiry is described as containing three stages – inquiry, analysis, and inference. During the inquiry phase students formulate questions and design valid experimental tests that are then analyzed. In the inference stage students modify theories based on collaboration and further inquiry (Zion et al., 2005). Constructivism is the most learner-centered of all philosophical underpinnings, and promotes deep conceptual understanding (Daley, 2003). Inquiry also includes a social learning component that recognizes the importance of group interactions (King et al., 1976). The constructivist foundation of inquiry-based science provides students with research-based best practices that support a learner-centered philosophy of education.

Authentic Science Instruction

A genuine solution to the issue of improving science education requires an approach that is in itself genuine. In order to draw parallels between learning and doing science, comparisons will be drawn between authentic scientific inquiry and inquiry-based science instruction.

For the purposes of this comparison, the term “authentic scientific inquiry” will be used to represent the kind of research that scientists actually perform. This kind of research is driven by a series of concepts and practices known as the Nature of Science (NOS). The NOS includes an empirical, tentative, distinction between observation and inference, and the role of subjectivity and creativity in science (Abd-El-Khalick et al., 1998). Although preservice teachers may recognize aspects of the Nature of Science (NOS), they seldom make these explicit to their students, (Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick, & Lederman, 2000; Akerson & Hanuscin, 2007; R. L. Bell, Lederman, & Abd-El-Khalick, 1998; R. L. Bell et al., 2000), depriving students of the ability to internalize a conception of how scientists actually DO science. Using instructional strategies that match authentic scientific research are recommended by both scientists and science educators (AAAS, 1993; Akerson et al., 2000; Howe, 1998; NRC, 1996, 2000; Sanger, 2007).

In inquiry-based instruction, students should be engaged by a scientific, investigable question; give priority to evidence that they observe; formulate explanations for the evidence; evaluate their explanations, especially alternative explanations; and communicate and justify their explanations (NRC, 1996). During the inquiry phase of an investigation students formulate questions and design valid experimental tests that are then analyzed. In the inference stage students modify theories based on collaboration and further inquiry (Zion et al., 2005). The National Science Education Standards describes some of the instructional strategies necessary for inquiry as

> 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. (NRC, 1996, p. 23)

Experience with authentic scientific investigations, understanding scientific processes goes far beyond memorizing steps in the "scientific method", or the meaning of terms such as "hypothesis." Students must have authentic experience with inquiry as a learner (NRC, 2000; Parker & Spink, 1997). But one of the most powerful aspects of inquiry-based instruction is that by placing the student in the role of a scientist, the lessons by nature are learner-centered. Inquiry-based science instruction is a learner-centered strategy that closely matches actual scientific research and covers fewer topics, but in greater depth (AAAS, 1989, 1993; Amaral, Garrison, & Klentschy, 2002; Daley, 2003; Hodgin, 2011; King et al., 1976). A recent report by the Governor's Business Council (Texas) entitled "Excellence in the Classroom" (Council, 2006) describes learner-centered instruction as a "faddish and unproven" pedagogy that is a "vague concept." By contrast, the "back to basics" movement is aligned with the more traditional expository methods often labeled "teacher-centered." Learner-centered instruction is neither new, nor faddish. Its roots can be traced to as early as 500 B.C. when Confucius taught that "every person should strive for the continual development of self until excellence is achieved" (Henson, 2003). Socrates stressed "know thyself" and his Socratic methods of teaching are still practiced as an excellent way to engage learners and assess their thinking continuously (Henson, 2003). Learner-centered strategies are powerful because they help develop the ability to learn from experiences, integrate knowledge, and think reflectively (Daley, 2003). Finally, with inquiry-based science, students are reaching a deeper understanding of science instead of merely being told about science or reading about science (NRC, 2000).

The larger implication is that inquiry is the antithesis of traditional, expository methods often labeled "teacher-centered" (Hodgin, 2011). Teacher-centered instruction diverges greatly from the real methods of scientific research. *The Benchmarks for Science Literacy* (AAAS, 1993) states that

> The usual high-school science "experiment" is unlike the real thing: The question to be investigated is decided by the teacher, not the investigators; what apparatus to use, what data to collect, and how to organize the data are also decided by the teacher (or the lab manual); time is not made available for repetitions or, when things are not working out, for revising the experiment; the results are not presented to other investigators for criticism; and, to top it off, the correct answer is known ahead of time. (AAAS, 1993, p. 9)

Teacher-centered strategies are anything by authentic and do not provide students with the background necessary to do science, much less understand it. Links between science anxiety and instructional practices are essential in understanding how science is being taught as an elementary school subject. Preconceptions about science may be based on prior experiences where the teacher is the "dispenser" of knowledge and students are the receivers (Cady & Rearden, 2007; Kahle, Meece, & Scantlebury, 2000). This belief puts a great burden on elementary teachers (as dispensers of knowledge) since they would have to be content area experts (Cady & Rearden; Lowery, 2002; Shulman, 1986). If a student asked a question they didn't know the answer to, then they could no longer fulfill that role (Cady & Rearden; Hodgin, 2008). This promotes a "teacher-centered" pedagogy that emphasizes memorization of facts, and may lead to anxiety and avoidance of science teaching (Cady & Rearden; Hodgin; Kahle, et al.). The problem of elementary science anxiety and avoidance is closely linked to teacher beliefs, experiences, and instructional practices.

Essential Features of Inquiry

The National Research Council describes several key aspects addressed by inquiry-based instruction that closely match authentic scientific investigations in the publication Inquiry and the National Science Education Standards: A Guide for Teaching and Learning (NRC, 2000). One of the attributes addressed by inquiry-based instruction is that questions drive the process. Inquiry based classrooms value student devised questions above the dictates of a traditional curriculum or textbook, (Lumpe et al., 2000) and employ instructional strategies that incorporate children's ideas and questions (Haefner & Zembal-Saul, 2004). Another focus of inquiry common to scientific research is that empirical data guides explanations and makes prediction, focuses additional questions, plan investigations - both empirical and descriptive - and uses modeling to create representations of phenomena (AAAS, 1993; NRC, 1996, 2000). An important characteristic of inquiry is that vocabulary is embedded and defined as part of the discovery process, similar to creating working definitions in science. One of the most difficult jobs a teacher has is to cultivate meaningful conceptual experiences for children by teaching them to understand concepts, not simply memorize vocabulary (Kraft, 2002).

An important aspect of authentic scientific research and inquiry is the explicit distinction made between observations and inferences as part of scientific investigations (AAAS, 1993; Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; NRC, 1996, 2000). From these observations and inferences, one or more tentative, alternative explanations are proposed and explored (AAAS, 1993; Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000; Lederman et al., 2002; NRC, 1996, 2000). Finally, the authentic strategy of evaluating evidence and confirming explanations based on prior knowledge may be used to evaluate explanations (AAAS, 1993; NRC, 1996, 2000; Van Zee & Roberts, 2001).

The NRC lists five "Essential Features of Classroom Inquiry", strategies that closely match authentic scientific research and provide a structure to plan, evaluate and implement a range of inquiry-based strategies (NRC, 2000, p. 25). Each feature also has varying degrees of structure that overlay with a range of teacher- to learner-centered orientations. The amount of structure for a particular lesson should be based on the needs of students as teachers move from a great deal of structure and guidance to less structure and more independence (NRC, 2000).

> Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations and communicating scientific arguments. (NRC, 1996, p. 105)

Inquiry-based instruction, like scientific research, begins with an investigable question. The first essential feature of classroom inquiry is based on answering a question or questions, so that “Learners are engaged by scientifically oriented questions” (NRC, 2000, p. 24). Questions may be generated by the student, teacher, resource, or combination of the above. Because questions must be investigable, (they are capable of being investigated by students without safety concerns, unreasonable amounts or time or money, and with data the students are able to access) teachers may need to guide students to ask questions within their scope of exploration. After deciding how to investigate a question, students can gather data and answer question based on their observations.

One of the essential features of inquiry is that evidence is the strongest priority for investigating question. “Learners gives priority to evidence, which allows then to develop and evaluate explanations that address scientifically formulated questions” (NRC, 2000, p. 25). Evidence consists of empirical observations and measurements that are repeatable and can be verified for accuracy, and is “subject to questioning and further investigation” (NRC, 2000, p. 26).

Another essential feature is that explanations are formulated based on the evidence collected. “Learners formulate explanations from evidence to address scientifically oriented questions” (NRC, 2000, p. 26). Explanations are based on reason and rules of evidence, and for students, this means adding to their own personal knowledge base. Having students conceive their own explanations helps them create new knowledge (for the student) and collaborate with other students.

After students create their own explanations for what they have observed, these explanations are compared to current scientific explanations. “Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding” (NRC, 2000, p. 27). “Evaluation, and possible elimination or revision of explanations, is one feature that distinguishes scientific from other forms of inquiry and subsequent explanations” (NRC, 2000, p. 27). Students should make sure that their developmentally appropriate explanations agree with current understanding of scientific phenomenon.

Finally, the results of their investigations are communicated and justified as an essential feature of inquiry. “Learners communicate and justify their proposed explanations” (NRC, 2000, p. 27). Like scientists, students should publish their findings to allow others to examine their methods and conclusions, and to provide opportunities to discuss alternate methodologies or explanations. This helps students to understand how scientists reach consensus, and promotes a skeptical review of scientific practices.

The Essential Features of Classroom Inquiry as described in Inquiry and the NSES (NRC, 2000) form the backbone for a continuum of inquiry-based strategies that scaffold or move students through ever-increasing independence with scientific investigations. The NRC describes these features as based on research by Joseph Schwab who argued that laboratory investigations should be conducted before typical classroom activities such as reading textbooks and answering questions (NRC, 2000; Schwab, 1960). Most importantly, he described three different methods for conduction labs (Schwab, 1960). The first was to utilize typical labs from manuals or textbooks; the second method suggested students perform labs with questions from the manual or text, but without methodologies or conclusions given; and the third was an open investigations with students determining question, methods, analysis and conclusions (Schwab, 1960). Herron rated instructional materials by a four point scale of "openness" based on Schwab (Herron, 1971). The NRC's Essential Features continuum of inquiry-based strategies has been an important element in creating and evaluating the level of inquiry that teachers choose to implement. The NRC describes an additional piece of the Essential Features is the continuum of varying teacher- and student-direction that exists within the continuum. The degree of "variations in the amount of structure, guidance, and coaching the teacher provides for the students" is categorized in columns but not specifically named on the chart (NRC, 2000, p. 28). The Essential Features includes a continuum of "More" to "Less" degree of "Learner Self-Directions," or "Direction from Teacher or Material" (NRC, 2000, p. 29). Basing their research on the NRC continuum, Bell, Smetana, and Binns wrote an article providing both lines of investigations for researchers, and practical advice for educators to assess the “inquiry level of classroom activities” (R. L. Bell, Smetana, & Binns, 2005, p. 30). For an activity to be inquiry-based, it must begin with a research question and include data analysis; if students are not analyzing data, then they are "merely summarizing the conclusions of others" (2005, p. 31). The addition of a categorization of types of lessons based on the five essential features provides teachers and teacher educators a structure to drive discussions, curriculum planning, and evaluations of inquiry-based instruction. One of the categories of lessons that provide the most teacher-directed structure is the Confirmation (Level 1) (2005). Level 1 is the simplest, and is a confirmation activity with the answer to the research question and the results known in advance. It can be a very useful starting point for students (and teachers) with little inquiry experience. The next level described is the Structured (Level 2). Level 2 does not give away the answer to the question, but in all other ways is the same as Level 1 – procedures, explanations and conclusions are known in advance (2005). A Structured inquiry lesson can be a next step after Confirmation in helping students to learn basic process skills in science, and provide practice as students become more comfortable with laboratory procedures. The Guided (Level 3) provides an investigable question (or allows students to select a question) and leaves the procedure up to the student (2005). Finally, the Open (Level 4) leaves questions, methodology, explanations, and conclusions up to the student, placing them in the role of scientist performing investigations that are as authentic as possible (2005). The following table overlays both the NRC’s essential features of inquiry with the categorized lessons described by Bell (R. L. Bell et al., 2005; NRC, 2000).

Table 2.2

Variations/Levels of Inquiry [a]

Essential Feature	Variations/Levels of Inquiry			
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 formulate 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
	OPEN – Students investigate topic-related questions that are student formulated through student designed/selected procedures.	GUIDED – Students investigate a teacher-presented question using student designed/selected procedures.	STRUCTURED – Students investigate a teacher-presented question through a prescribed procedure.	CONFIRMATION – Students confirm a principle through an activity in which the results are known in advance.

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

[a] NRC Inquiry Continuum Adapted by Bell, et. al., 2005

The degree of learner-centered to teacher-centered focus varies from confirmation (most teacher-centered), to open (most learner-centered). Levels 1 and 2 (confirmation and structured) are often called "cookbook" labs since all procedures and results are given ahead of time for only one possible outcome and explanation (R. L. Bell et al., 2005). Structured and confirmation labs give students little opportunity to practice creating their own methodology or drawing their own conclusions – they simply try to recreate results from a concept they have already studied. Although students do need to learn simple lab procedures, (such as using a thermometer or finding the mass of a liquid with a balance) the main goal for the student is to get a good grade on the activity. Guided and open inquiry is more learner-centered because students plan their own methodologies, draw their own conclusions, and then research what the scientific literature says about their question (R. L. Bell et al., 2005; NRC, 2000). Levels 3 and 4 inquiries allow students to take ownership of their learning and give them a chance to construct their own meanings, a concept at the heart of constructivism.

Assuming that students have experience with lab procedures and safety, the main goal for the student in an open or guided inquiry lab is to answer a research question, therefore giving the student greater ownership of their learning (R. L. Bell et al., 2005). Level 4 is most often seen as a science fair project, and the usual disappointing results illustrate that students need practice, beginning with Level 1 (confirmation) activities and moving through the levels to gain skills necessary to perform Level 4 (open) inquiry. If students have little experience with how to conduct, and then write their own procedures and explanations, then they are in no way ready for a Level 4 investigation (R. L. Bell et al., 2005). Inquiry is a continuum of levels and ideally students should progress through them throughout the course of a school year (R. L. Bell et al., 2005).

Traditional Instructional Strategies

One of the most commonly utilized types instructional strategies are the traditional approach, also known as the "transmission" approach – reading textbooks, providing explanations, answering questions, memorizing definitions, and taking tests (Hodgin, 2011; Jadrich & Bruxvoort, 2011; Lindgren & Bleicher, 2005). The traditional lesson cycle is described by Jadrich and Bruxvoort as "inform, verify, and practice. (Jadrich & Bruxvoort, 2011). Lessons begin with teachers providing an explanation or "preteaching" concepts and vocabulary. Students then perform confirmation activities to verify the information presented, and then practice either applying the information or answering test questions (Jadrich & Bruxvoort, 2011). Yet these strategies do not match authentic inquiry. For one, they are sadly lacking the essential features of classroom inquiry. By contrast, numerous aspects of inquiry are not addressed by these traditional, teacher-centered instructional strategies. First of all, instead of questions, instructional objectives drive the process. An instructional objective is a description of a goal, not a question, and is essential to writing a standardized test item. The objective is part of a process, skill, content, or combination of these. Many test preparation strategies and teacher-centered methodologies such as the pedagogy of delivering content followed by student practice, is highly favored by laymen and many policy makers (Fletcher &

McClellan, 2008). Test preparation obviously plays no part in scientific investigations, and therefore plays no role in inquiry or the nature of science.

Another way that teacher-centered instruction differs from inquiry is that investigations are devised to collect data that confirms objectives and predetermined explanations. When attempting to provide a hands-on experience, “educators frequently take steps to orchestrate students’ constructions in directions leading to conclusions of professional science” (Bencze et al., 2003, p. 287). Students may be asked to make predictions, but these predictions are sometimes wild guesses that students label as “wrong” if they do not match the given explanation, and data that does not match expected outcomes is ignored or labeled incorrect. Through such regulation of their thoughts and actions, students are denied access to realistic contexts of knowledge construction in science. Within a teacher-centered model of instruction there is a sense that teachers must prioritize delivery of content above training students to actually do science in a way that corresponds to the research of scientists (Bencze et al., 2003).

Another aspect of teacher-centered instruction that differs from inquiry is the emphasis on mastery of vocabulary before confirmation of phenomena. The mastery of vocabulary is essential to success on a standardized test, yet vocabulary-dense textbooks do not meet the NSES, (Hodgin, 2011) and understanding science is more than mastering a set of facts and their associated vocabulary (NRC, 2000), yet it is frequently taught in that manner (Jorgenson & Vanosdall, 2002).

Traditional, teacher-centered instruction does not attempt to distinguish between observations and inferences. In a study of preservice teacher, Bell found that even though they were able to articulate the differences between observations and inferences, their lessons treated the subject more as an exercise in vocabulary than as a key piece to student understanding of inquiry and the nature of science (R. L. Bell et al., 2000).

In a traditional science class, only predetermined explanations are explored. An explanation for the data is provided by the teacher as part of the textbook or curriculum, and alternative explanations are not explored. In fact, textbook or curriculum guide is often the sole source of information. In numerous studies, preservice teachers failed to explicitly address how more than one explanation can be found for a set of data (Abd-El-Khalick & BouJaoude, 1997; Akerson et al., 2000; R. L. Bell et al., 2000). Textbook based curricula are frequently not effective at helping students master difficult science concepts such as transfer of energy (Kelly & Staver, 2005).

Teachers practicing a traditional methodology of textbook-based instruction may lack knowledge actual scientific methodologies. Many teachers hold naïve views of the nature of science, including the belief that scientific truths are proven to be true and that scientific theories become laws from a preponderance of evidence (Abd-El-Khalick & Lederman, 2000; Lederman et al., 2002). In the teacher-centered practice of science instruction, students are expected to memorize and reproduce the steps in "the scientific method." Several researchers describe this as the "myth" of one single scientific method that is a "recipe-like" series of steps scientists follow (Abd-El-Khalick & Lederman, 2000; Lederman et al., 2002). These pedagogies may be cost efficient, and even improve test scores on basic competency tests. But these kinds of low-level instructional techniques do not prepare students for advanced courses in science or mathematics, nor do they prepare them for future jobs that will require problem solving (Fletcher & McClellan, 2008). Few teacher-centered strategies bear any resemblance to authentic scientific inquiry. In direct contradiction, the 2010 Texas Essential Knowledge and Skills, the Science standards for the state of Texas, describe three distinct methodologies and dispels the myth of one methodology used in all scientific research or classroom investigations (TEA, 2010; West, 2010). In fact, several myths about inquiry are described in "Inquiry and the NSES" (NRC, 2000, pp. 36 - 37) Many misconceptions about inquiry exist, not the least of which is that there is only one model that must be adhered to rigidly. In fact, inquiry exists along a continuum of strategies from the most guided to full inquiry that is the closest match to the way scientists perform authentic scientific research. In fact, inquiry represents a range of strategies that vary with the content, goals, and the learner's prior knowledge (NRC, 2000). Another myth is that all science lessons should be inquiry-based (NRC, 2000). There is no one method to teach every science lesson, and some topics such as safety or skills-based lesson (measuring mass with a balance or calculating speed) are not appropriate as an inquiry. A common misconception is that students must generate their own questions for inquiry to occur (NRC, 2000). Zion, Michalsky, and Mevarech found that people must be guided through the process, and research suggests that adolescents (and even adults) have difficulty formulating and testing investigable questions (Zion et al., 2005). A common misconception is that kit-based science easily promotes inquiry (NRC, 2000). Many school districts invested large sums of money in purchasing kits that promised "inquiry-based science." But a kit is only as good as the teacher who implements it, and without an understanding of inquiry, kit-based science often becomes a "recipe" for science, with teachers demanding step-by-step instructions that turn what could have been inquiry into a traditional model of instruction.

One of the most pervasive myths is perpetrated by administrators and teachers alike. The belief that "hands-on" instruction insures that inquiry occurs (NRC, 2000) is very common. Many educators who are unfamiliar with inquiry equate engagement in science with inquiry. Yet not all "hands-on" is inquiry, but using only this characteristic can be misleading because not all "hands-on" activities meet the pedagogy or rigor of inquiry-based science. In a report on inquiry for the Virginia Mathematics and Science Coalition, Bell discusses the myth of equating hands-on with inquiry.

> The primary question to consider when determining whether an activity is inquiry-based is: Are students answering a scientific question through data analysis? Many worthwhile hands-on activities traditionally performed in science classrooms do not involve students in these essential components of inquiry. For example, constructing a model of the atom, organizing a leaf collection, or building a soda-bottle water rocket can all be excellent instructional activities. However, unless these activities involve research questions and the opportunity to analyze data, they do not qualify as inquiry activities. (R. Bell, Maeng, & Peters, 2010, pp. 2-3)

Confirmation labs may be considered hands-on, but do not meet inquiry-based standards if it is formulaic, like following a recipe with predetermined results. Teaching "The Scientific Method" is hands-on yet does not meet the demands of inquiry to provide authentic research experiences (West, 2010).

Many elementary teachers are searching for "hands-on activities for the sake of fun" without any real attention to developing scientific thinking (Haefner & Zembal-Saul, 2004). These "fluff and run" activities do not meet the rigorous standards for inquiry set forth by many states and the National Science Education Standards (NRC, 1996). Yet principals may look for engagement during an observation, without noticing how much original thought the students are putting into an investigation. Therefore, using the simple presence of a "hands-on" experience is not a valid evaluation of the amount of inquiry occurring during a science class.

Finally, the myth that inquiry processes can be taught independently of content is all too common (NRC, 2000). Educators cannot simply state that the process skills are included in a lesson and be sure that students are receiving adequate time to meet the goals of inquiry-based investigations (Jadrich & Bruxvoort, 2011). This belief originated in the 1960s when the idea of inquiry was in its infancy, and science instruction was almost universally taught by reading, watching demonstrations, memorizing definitions and doing calculations. Moving towards the essential features of inquiry has meant moving away from a focus on direct teach, a traditional model of instruction.

Traditional instruction is often labeled as using a "direct teach" focus, the delivery of content to students with little interaction and the expectation that students will take notes and memorize information. During a preliminary investigation, a former elementary teacher lamented that her lack of science teaching preparation may have been responsible for her science lessons that lacked engagement. She mentioned that she was worried about how testing is driving teachers into doing boring lessons instead of doing creative lessons; "they're opening the teacher's edition and doing the canned lessons that are not engaging." This scares her because "our world is becoming very technical and we are not preparing our kids" (Hodgin, 2008). Science was being taught as an exercise in reading to memorize content, yet elementary teachers who indicated they disliked science because of rote memorization, indicated that they used this as a strategy in teaching elementary science because "we can memorize that – that'll give me something I can teach" (Hodgin, 2008, p. 10). A comparison of authentic scientific research, inquiry and traditional instructional strategies reveals some of the differences between the focus and activities in all three types of strategies. See Table 2.3.

Table 2.3

Comparison of Authentic Scientific Inquiry, Inquiry-Based, and Traditional Instruction [b]

Authentic Science Inquiry	Inquiry-based Instruction	Traditional Instruction
Research-Centered Philosophy	Learner-Centered Philosophy	Teacher-Centered Philosophy
Begins with a question	Begins with a question	Begins with an instructional objective
Empirical observations provide a closer look at the environment	Empirical observations provide a closer look at the environment; vocabulary is embedded and self-defined as part of process	Mastery of vocabulary is stressed before confirmation of phenomena is observed
Data gathered from observation provokes new and more focused questions	Data gathered from observation provokes new and more focused questions	Data that does not match expected outcomes/instructional objectives is ignored or labeled as mistaken
Distinctions evident between observation and inference	Distinctions made explicit between observation and inference	Little distinction made between observation and inference
One or more tentative explanations of the observed data is proposed	One or more tentative explanations of the observed data is proposed	Explanation for data is provided to students; alternative explanations ignored or labeled as mistaken
Prior knowledge is applied to evaluate explanations	If prior knowledge exists, it may be applied to evaluate explanations	Validity of alternative explanations are not explored; the textbook or curriculum guide is sole source
Explanation is confirmed with prior research literature	Explanation may be confirmed with prior research literature	No confirmation of explanation attempted; accepted at face value
Findings are published in peer-reviewed journals	Findings are published in teacher-reviewed formats	Findings may be published in teacher-reviewed formats
Public policy may be influenced by findings	Public policy is seldom influenced by findings	Public policy not influenced by findings
Curiosity is the driver for all aspects of inquiry	Curiosity is one of the main drivers of inquiry	Mastery of instructional objective in order to pass standardized test is the main driver
Internal Locus of Control – Knowledge is constructed by the scientist	Internal Locus of Control – Knowledge is constructed by the learners (Students and Teachers)	External Locus of Control – Knowledge of experts is memorized by the learners (Students and Teachers)
Collaboration – Scientists work with others as a team and within the context of a scientific community	Collaboration – Learners (Students and Teachers) work with other learners as a team, and within the context of a learning community	Cooperative grouping – Students work in groups to gather data, but produce individual results. No learning community; competition for grades and test scores
Assessment – Scientists use self-assessment and peer-review	Assessment – Learners use self-assessment, some peer-review and teacher assessment	Teachers are solely responsible for assessing student work; Teachers seldom use self-assessment
Role of subjectivity explicitly addressed by examining researcher bias within the team and the scientific community	Role of subjectivity may be explicitly addressed by examining researcher bias within the learning community	Role of subjectivity not addressed within learning community
Creativity recognized and rewarded	Role of creativity may be recognized and rewarded	Role of creativity discouraged, and acceptance of learning objectives supersedes individuality
Deep understanding of fewer concepts (expert knowledge vs. novice)	Conceptual understanding of fewer concepts (move beyond novice)	Shallow understanding of more concepts (mile wide – inch deep)

[b] (R. L. Bell et al., 2005; Hodgin, 2011; NRC, 1996, 2000)

DISCUSSION

Teacher beliefs such as their level of science anxiety and self-efficacy may be a primary determinant of teacher-centered or student-centered instructional focus. If science anxiety promotes a high or low degree science teaching self-efficacy, these beliefs may be vital to the implementation of inquiry-based instruction. If science anxiety is high, and a teacher has avoided science instead of using coping behaviors, then a vicious cycle of anxiety and avoidance may be created. Low self-efficacy associated with high science anxiety reduces the expectancy of a positive science teaching outcome. Teachers with high anxiety/low self-efficacy may be more likely to select a teacher-centered model of instruction that utilizes direct teach, and reading for content strategies. If science anxiety is low and self-efficacy high, a teacher may be more likely to select a learner-centered model of instruction. Teachers who have experienced learner-centered instruction are more likely to use these strategies (Daley, 2003; Garet, Porter, Desimone, Birman, & Yoon, 2001; King et al., 1976).

Even though elementary teachers reported that they reluctantly utilized teacher-centered instructional model, they often implement them because they do not demand knowledge of inquiry-based strategies or deep PCK (Bransford, 2000; Clough, 2011; Hodgin, 2008; Peterson, 1989). Teaching science as just another school subject may play a role in student and teacher science anxiety (Cady & Rearden, 2007; Lowery, 2002; Jeffry V Mallow, 1981; Ramey-Gassert & Shroyer, 1992; Sanger, 2007; Tosun, 2000). Many students and teachers hold an inaccurate view of inquiry and the nature of science, and see it only as a small set of laws, concepts and theories (AAAS, 1993; Abd-El-

Khalick et al., 1998; Abd-El-Khalick & BouJaoude, 1997; Akerson & Hanuscin, 2007; NRC, 2000). In addition, many teachers hold views of science that are not consistent with the authentic inquiry and the nature of science (Abd-El-Khalick & BouJaoude, 1997; Akerson et al., 2000). Understanding science is more than mastering a set of facts and their associated vocabulary, (NRC, 2000) yet it is frequently taught in that manner (Jorgenson & Vanosdall, 2002). The current climate of high-stakes testing and accountability is driving the push to emphasize Reading and Mathematics since these are the subjects tested the most frequently, and these practices threaten the creative and engaging practices supported by inquiry-based instruction (Jorgenson & Vanosdall, 2002; Webeck et al., 2004). Creating an artificial approach to science teaching is counterintuitive, but all too frequently, is the most common strategy. Instead focuses on familiar traditional strategies used in teaching English Language Arts, and a direct teach model that emphasizes preparation for tests over preparation to do authentic science. Science anxious elementary teachers may avoid engaging in inquiry-based science by including hands-on for the sake of engagement, and activities, instead of purposeful inquiry. Learner-centered instructional models demands more PCK and use of authentic inquiry-based strategies, and elementary teachers may not feel equal to the task of implementing inquiry.

SUMMARY

This chapter provides a review of the literature, focusing on Science anxiety, science teaching self-efficacy, inquiry-based instruction, and the role of a teacher-centered or learner-centered model of instruction. The research framework describing the Essential Features of Inquiry are described and lay the foundation for additional research to categorize the level of inquiry, as well as a learner-centered focus as a central piece of the theoretical framework.

Chapter 3: Methodology

INTRODUCTION

This chapter describes the methodology for the descriptive, mixed-methods research study, clarifies the questions that are the foundation of the inquiry, and describes the research design including instrumentation, data collection and analysis procedures.

RESEARCH APPROACH

I conducted a mixed-methods research study to explore the relationships between elementary teacher levels of anxiety, self-efficacy and their preference for a teacher or learner-centered model of instruction. These attitudes and beliefs may drive the type of science instruction they implement – specifically an inquiry-based or a traditional model of instruction. The investigation began with a survey of elementary teacher science anxiety and self-efficacy in order to identify groups of teachers with low and high science anxiety and self-efficacy using well-established instruments. I identified significant groups matching my research interests, and interviewed participants from each group to look at their preferred strategies and instructional models within a descriptive, semi-structured interview format. The interview centered on a card-sorting activity with each card describing a particular science teaching scenario based on the National Research Council's continuum of the five essential features of inquiry (NRC, 2000). By holistically examining a teacher's preferred strategies, I was able to place them along an inquiry-based teaching continuum that also includes the degree of teacher- or learner-centered instruction relative to the type of inquiry strategies implemented. These research strategies helped meet the purpose of this study - to examine a possible link between anxiety, self-efficacy, and core instructional beliefs and practices about elementary science instruction.

The design of my study used a mixed-methodology to support a theoretical framework that includes two possible orientations of teacher beliefs affecting their preference for instructional strategies that in turn drive the type of science practices they choose to implement. I began by administering an online survey to a large group of participants (86 elementary science teachers completed the survey) with two well established measures of anxiety and self-efficacy. Participants were grouped using quantitative data, the scores obtained by comparing relative science anxiety (high and low) to science teaching self-efficacy (low and high). A correlational analysis was used to compare participants with high anxiety and low self-efficacy, along with a group of low anxiety and high self-efficacy, plus other participants deemed interesting such as with high anxiety and high self-efficacy. From each group representative members were selected to interview using qualitative methods. I began each interview by asking teachers to describe a lesson they have recently taught that best represents their preferences in science instruction. This question was followed by a semi-structured interview protocol adapted from a research study designed to elicit a teacher's beliefs about best practices in science instruction (Friedrichsen & Dana, 2003). The Science Teaching Scenario Card Sort (STSCS) is the format for a structured interview with opportunities to follow areas of interest with additional scripted, probing, and open questions. By adapting the card-sort created by Friedrichsen and Dana to better match the five essential features of the inquiry continuum, data on teacher preferences can be placed along the inquiry continuum to holistically classify preferred instructional strategies and the degree of learner- or teacher-centered instructional focus (Friedrichsen & Dana, 2003; NRC, 2000). Qualitative analysis was conducted by coding for frequencies and percentages of scenario preferences describing the five essential features along the inquiry continuum, as well as terms describing teacher-centered and learner-centered models of instruction. Comparing the high anxiety /low self-efficacy group with the low anxiety/high self-efficacy group for preferred instructional models (teacher- or student-centered) and science instructional strategies (inquiry-based or traditional) investigated the research questions and explored the validity of the theoretical framework. The mixed-methods design of this research study examined possible relationships between science anxiety, self-efficacy and a preference for learner-centered, inquiry-based instruction, or the tendency to utilize a teacher-centered, traditional mode of instruction.

RESEARCH QUESTIONS

The framework of this study centers on the of role teacher beliefs in shaping their core instructional practices. The following questions are central to exploring the intersection of research and practice:

1. Do teacher beliefs direct their personal philosophy of science instruction, and if so, how?
2. Is there a relationship between the levels of science anxiety/science teaching self-efficacy and the preference for a teacher-centered model of instruction as opposed to a learner-centered model? If so, what is the relationship?
3. How do teachers with low science anxiety and high science teaching self-efficacy compare with high anxiety, low self-efficacy and high anxiety, high self-efficacy teachers in their implementation of a traditional or inquiry-based model of instruction?

MIXED-METHODS DESIGN

For this descriptive study, a solely quantitative or qualitative approach would not prove sufficient to investigate the questions. Quantitative data is required to measure teacher attitudes and group participants in order to investigate the role that anxiety and the resultant self-efficacy may play in their instructional orientation. Qualitative data is needed to dig deeper into the core beliefs teachers hold and to examine the link between their beliefs and practices, so mixed-methods research is the logical research framework.

Mixed-methods research utilizes characteristics of both quantitative and qualitative research within the framework of a study to address a broader range of questions (Frels & Onwuegbuzie, 2013; Johnson & Onwuegbuzie, 2004; Johnson, Onwuegbuzie, & Turner, 2007; Merriam, 1998; Plowright, 2011; Stake, 1995; Weiss, 1994). Mixed-methods research encompasses a broad definition of research designs and has been described as containing numerous elements depending on the individual researcher.

> Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration. (Johnson et al., 2007, p. 123)

Johnson, Onwuegbuzie, and Turner (2007) described mixed-methods research as dependent on both qualitative and quantitative methods, a third type of research paradigm that integrates the strategies of both (Johnson et al., 2007). Mixed research is most useful in answering questions that simultaneously investigate quantitative-based questions (such as descriptive, correlational, causal-comparative, and experimental) and qualitative-based (such as biography, history, ethnography, case studies, phenomenology, and grounded theory) (Frels & Onwuegbuzie, 2013). The coordination of both quantitative data collection techniques and the deep analysis available through qualitative methods allows a researcher to investigate questions that may correlate attributes of an issue, and also analyze how the correlation may affect their beliefs and practices. This makes mixed-methodology the most appropriate strategy for my research study.

Rationale for Mixed-Methods Design

The mixed-methods research paradigm integrates both quantitative and qualitative methodology to explore the correlation of the inquiry continuum within and among statistically defined groups (anxiety and self-efficacy). For my investigation, anxiety and self-efficacy are correlational, and independently quantified with two well researched instruments. Understanding how anxiety and self-efficacy may affect a teacher's core beliefs and practices is driven by grounded theory in both social cognitive and constructivism research. This research frame of reference is used to explore how science instruction may match a preference for a teacher- or learner-centered model of instruction. Therefore a sequential mixed methods design is best suited to first collect quantitative data to inform selection of participants for interviews, and analyze the data to determine if the two groups are significantly different from each other yet consistent enough in their core beliefs to be representative of the groups as defined by the theoretical framework. Qualitative data was collected to create a more complex picture of teacher beliefs and practices than available through quantitative methods. The complex picture that can be created using qualitative data helps investigate the research questions that seek to frame teacher beliefs and attitudes within their chosen philosophy and preferred instructional models. Quantitative methods that utilize existing tests to measure degree of teacher anxiety and self-efficacy were implemented to identify participants with particular beliefs that inform the exploration of the framework. The statistical analyses possible through quantitative techniques may classify teachers as relatively high or low anxious, and high or low self-efficacy, and inform significant differences that may exist among and between groups to create a focus for the interviews. Qualitative methods promote a deeper exploration of the more complex beliefs and practices of a few representative participants, and examine emerging themes within an established framework, the essential features of the inquiry continuum and the degree of teacher- or learner-centered instructional focus. This is significant because previous studies on teacher anxiety have not examined how it affects their actual instructional practices, and a mixed methodology will more fully investigate a framework in which core beliefs and philosophies are the driver of a teacher's preferred strategies.

INSTRUMENTATION

Science Teaching Anxiety Inventory (STAI)

An important step in quantifying science anxiety was the creation of an instrument to measure general anxiety. Spielberger identified two aspects of anxiety, State Anxiety and Trait Anxiety in creating his instrument for measuring anxiety, the State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1970; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The State-Trait Anxiety Inventory (STAI) was adapted by Westerback to measure science teacher anxiety by adding one sentence in the directions – "How do you feel about teaching science?" (Westerback, 1982, p. 607). The instrument contains 40 questions divided into two sub-sections, the State-Anxiety Inventory and the Trait-Anxiety Inventory (Spielberger et al., 1983). Each sub-section includes 20 questions graded on a scale of 1 to 4 with a "1" scoring the least anxiety, and a “4” scoring the most, and all questions are totaled for a possible range of 20 to 80. Several questions were reversed scored with statements such as *I feel calm* where low scores actually show high anxiety, and were scored according to the STAI Manual directions (Spielberger et al., 1983). For the State-Anxiety scale the possible choices are 1 = *Not at all*, 2 = *Somewhat*, 3 = *Moderately So*, or 4 = *Very Much So* (Spielberger et al., 1983). In the current version of the STAI, Trait Anxiety Inventory, the possible answer choices are 1 = *Almost Never*, 2 = *Sometimes*, 3 = *Often*, or 4 = *Almost Always*, and six out of twenty items were rewritten since Westerback’s original research (Spielberger et al., 1983; Westerback, 1982). The STAI is a well-established instrument, and the logical choice to quantify elementary teacher science anxiety.

Science Teaching Efficacy Belief Instrument (STEBI)

Another key instrument for examining teacher beliefs and attitudes about science instruction is the Science Teaching Efficacy Belief Instrument, the STEBI (Riggs & Enochs, 1990). The STEBI is a two part instrument with sub-sections Personal Science Teaching Efficacy (PSTE), and the Science Teaching Outcome Expectancy (STOE) (Riggs & Enochs, 1990). The entire STEBI consists of 25 questions, 13 addressing PSTE and 12 on STOE. Each question is a 5-point Lickert scale question with answer choices *Strongly Agree, Agree, Uncertain, Disagree,* and *Strongly Disagree* (Enochs & Riggs, 1990, p. 25). Scores of 1 were given to *Strongly Disagree* indicating low self-efficacy or outcome expectancy, and a 5 to *Strongly Agree* indicating the highest self-efficacy or outcome expectancy. All questions for each sub-section are averaged for a range of 1 to 5 for each sub-section. In addition, ten questions with statements such as *I generally teach science ineffectively* were reversed scored and coded with scores of 5 given to *Strongly Disagree* indicating high self-efficacy or outcome expectancy, and a 1 to *Strongly Agree* indicating the lowest self-efficacy or outcome expectancy. Results for both subtests and the entire tests are averaged to obtain the final score.

During a preliminary study, both STAI and STEBI data was gathered from two groups of 72 total preschool teachers, one group of 24 from participants in a National Science Foundation grant funded project, and two control groups of 48 teachers who did not participate in the professional development part of the project (one group received materials but no professional development; another group had no contact other than to complete the survey instruments). Teachers were asked to fill out an online survey, and participants were given the State-Trait Anxiety Inventory and the STEBI-A (Enochs & Riggs, 1990; Spielberger et al., 1983). While all 72 participants completed the STEBI, only 70 completed the STAI. The data were analyzed using the Statistical Package for the Social Sciences (SPSS), and their associated descriptive and inferential statistics were calculated. Because an older version of the Trait Anxiety measure was used, and the developers had revised the test, results were not calculated for this subsection of the survey (Spielberger et al., 1983).

The only test that showed a significant difference between groups was the Personal Science Teaching Efficacy Belief instrument (PSTE). The other part of the STEBI-A, the Science Teaching Outcome Expectancy test showed no significant difference between the two groups, nor did the State Anxiety Inventory. A possible reason for the low anxiety scores may be that the survey was given in June when teachers were on their summer break from school, therefore any anxiety they experience about teaching science may be relieved until they return to work in August. In addition, pre-K expectations for science teaching may be extremely low, since the most pressing directive for these teachers is to prepare English Language Learners and low-income students for Kindergarten. For these teachers, the focus is predominantly language, pre-reading, and academic skills that promote school success. Because science is not tested until 5^{th} grade, pre-K teachers may feel little pressure to meet standards or work towards mastery of science concepts. They may view science teaching as simply an opportunity for their students to interact with the natural world and increase their vocabulary and observational skills with engaging hands-on activities. Without the pressure to prepare for an eminent test, science teaching may present no real anxiety. Therefore the low science anxiety scores are not likely to represent the true picture of science anxiety in elementary education, especially given the strong body of research supporting high science anxiety in both preservice and inservice teachers.

Survey Instrumentation

The administration of the quantitative research instrument was an online survey with a combination of questions from the Trait Anxiety portion of the STAI and the PSTE part of the STEBI. Additional questions gathered some demographics, optional contact information, and required consent. If all subtests of the STAI and STEBI were used, the survey would have totaled 65 questions, plus additional questions necessary to facilitate consent, contact information needed to arrange interviews, and demographics. Therefore one concern over the length of the instrument was that using all subtests would have created a survey so long that many participants would not complete the entire instrument. Based on the pilot study, a minimum 100 participants were needed to identify at least two statistically significant groups for comparison. So the survey needed to be long enough to gather important data, but not so long that participants were more likely to give up and quit before completion. To reduce the length of the survey and create a more focused instrument, only one subtest from the STAI and STEBI were administered. In the STAI portion of the survey only the State Anxiety Inventory was used. Although the Trait Anxiety Inventory may be useful when studying generalized anxiety, its use in this instance may be of less value. In a study of undergraduate performance on problem-solving tasks, subjects with high State-Anxiety performed significantly lower than subjects with low State-Anxiety, yet Trait-Anxiety had no significant effect on their problem-solving abilities (Meyers & Martin, 1974). In addition, Westerback found a decrease in Anxiety Trait when it should have been stable, suggesting that science teacher anxiety may be more accurately assessed with the State Anxiety subtest of the STAI (Westerback, 1984).

The STEBI-B is the latest revision of the instrument, and only the Personal Science Teaching Efficacy (PSTE) was used to measure self-efficacy (Enochs & Riggs, 1990). The Science Teaching Outcome Expectancy (STOE) was not used, primarily based on the fact that no significant difference was found in the preliminary study between the experimental and the control groups. One reason for this may be that student success measures are tied to many confounding variables. Ramey-Gassert found that PSTE and STOE are not statistically correlated, as post-test interviews suggest that teachers believe they have little control over many aspects of achievement in science such as parents, administrators, policy-makers and even standardized testing issues (Ramey-Gassert et al., 1996). Teachers with a high or medium PSTE may have a low STOE because they believe external factors may have a greater effect over student achievement than their own instruction (Ramey-Gassert et al., 1996). By eliminating the Trait Anxiety and the Science Teaching Outcome Expectancy sub-tests, the length of the survey can be reduced to approximately 40 total questions. Finally, the survey instrument collected demographic data such as years of experience, teaching assignment, gender, highest degree, and area(s) of certification or expertise in order to permit additional data analysis or further research. See Appendix A, *Science Attitude Survey*.

Interview Instrumentation

The conceptual underpinnings of the interview instrument are based on a grounded theory orientation as the descriptive research framework (Merriam, 1998; Scholz & Tietje, 2002; Stake, 1995). The Science Teaching Scenario Card Sort (STSCS) is an instrument adapted from a version of an elementary card-sorting task created by Friedrichsen and Dana (Friedrichsen & Dana, 2003). The authors constructed a tool to engage teachers in a discussion eliciting their beliefs about teaching and learning. Teacher beliefs and orientations may be more sophisticated and complex than the literature has reported (Carrier, Tugurian, & Thomson, 2013; Friedrichsen & Dana, 2003; R. M. Pringle & S. C. Martin, 2005). The card-sorting task was used in Friedrichsen and Dana's research with pre-service and in-service teachers, and as a peer-to-peer interview as part of their teacher preparation coursework (2003). Teacher explanations of why they selected scenarios and their adaptations was "most useful in understanding his or her science teaching orientations" (Friedrichsen & Dana, 2003, p. 296). The researchers also observed that the card-sorting task was beneficial in helping teachers to clarify their own beliefs (Friedrichsen & Dana, 2003). A sample of two of the eighteen Elementary science teaching scenarios is shown below in Figure 3.1.

Number	Scenario
10	You, as a teacher, set up learning centers for a unit on Newton's Laws of Motion. Using resource books from your school's library, you select a variety of fun, easy-to-do activities.
17	You, as a teacher, place bird feeders outside your classroom window. You ask students to carefully and accurately record their observations in an electronic journal.

(Friedrichsen & Dana, 2003, p. 296)

Figure 3.1. Examples of the Elementary Science Teaching Scenario Cards

The card-sorting task is not without its caveats and limitations, including the admonition that the "card-sort presented here is not like the magical sorting hat of

Hogwarts School for Witchcraft and Wizardry…" (Friedrichsen & Dana, 2003, p. 301). They also advised that the card-sort was not intended to create profiles of teachers because their orientations and beliefs are complex and change over time (Friedrichsen & Dana, 2003). In addition, the card-sorting task is "culturally bound, reflecting typical science teaching practices that we have observed and read about" in addition to being "dependent on the skills of the interviewer" (Friedrichsen & Dana, 2003, p. 302). But the possibility of creating a semi-structured interview format to elicit core beliefs about best practices inspired me to create a revised version that can be used for qualitative investigation of the complex ideas that make up an individual teacher's approaches to science instruction.

Because the study is grounded in constructivist theory, the card-sorting task by Friedrichsen and Dana's was revised to more closely match the NRC's five essential features of inquiry along a continuum of most open to outside of inquiry that also aligns with the degree of teacher- or learner-centered model of instruction. For the revised card-sort only the elementary science teaching scenario cards were used since this study focuses exclusively on K-5 teachers. The original card-sorting task focused primarily on data collection, analysis, and explanation of scientific concepts, but was not a complete match to the NRC's five essential features of inquiry-based instruction: Question, Evidence, Explanation, Connection, and Communication (Friedrichsen & Dana, 2003; NRC, 2000). See Table 3.1.

Table 3.1

Inquiry Continuum of Essential Features

Essential Feature	**Variations/Levels of Inquiry**				
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	No question(s) explored
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	No data collected; isolated activity or process skill-based lesson. Learner given information by reading text or watching video.
3. Learner formulate **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	No learner explanation created. Explanations (with an emphasis on vocabulary) provided for the learner, or answers to isolated questions to show mastery of an objective.
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	Learner summarizes or otherwise communicates knowledge from reading for the purpose of assessment.
	OPEN – *Students investigate topic-related questions that are student formulated through student designed/selected procedures.*	**GUIDED** – *Students investigate a teacher-presented question using student designed/selected procedures.*	**STRUCTURED** – *Students investigate a teacher-presented question through a prescribed procedure.*	**CONFIRMATION** – *Students confirm a principle through an activity in which the results are known in advance.*	**OUTSIDE OF INQUIRY -** *Students follow a teacher-directed, isolated activity/skills based lesson heavily dependent on text-based acquisition of knowledge.*

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

Some of the features were absent in the card-sorting task, in particular the evidence and explanation portion of the NRC continuum, with little emphasis on beginning with a question, connecting to scientific knowledge, or communication of scientific explanations (NRC, 2000). To better fit the card-sorting task with the NRC continuum, it was revised from the eighteen elementary scenarios to focus on the five essential features of inquiry, purposely including or excluding some of these features within given scenarios (NRC, 2000, pp. 24 - 29). In the final revisions, some scenarios had none of the five features and were classified as “outside” the continuum. The “outside of inquiry” classification was the researcher’s attempt to better describe traditional teaching scenarios that did not include any features of inquiry and fell along the most teacher-centered end of the continuum. The descriptions for outside of inquiry along the five essential features of inquiry are based on a comparison of authentic science inquiry, inquiry-based instruction, and traditional instruction. (Figure 2.3, pg. 66) Some of these scenarios already contained aspects outside of inquiry such as no question, a single strategy or process-skills lesson such as a KWL (know, want to know, learned) chart, or an isolated activity. One of the caveats of the NRC inquiry continuum was to address several “myths” about inquiry-based instruction, so some scenarios were created addressing some of these “myths” (NRC, 2000, pp. 36 - 37). Other scenarios were designed to fit exclusively along one part of the continuum as defined by Bell, Smetana and Binns in their classification of inquiry strategies as confirmation, structured, guided, and open (R. L. Bell et al., 2005). Scenarios were also designed to be a blend of these strategies, and contained a variety of features from differing parts of the continuum. This was a purposeful decision, meant to evoke discussion about a teacher's conceptions of inquiry. For each scenario a classification scheme was created describing where each of the five essential features lay along the continuum, along with a general classification of the scenario such as "outside the inquiry continuum," "open for all features," or a blend of "guided for the question and structured for all other features" (R. L. Bell et al., 2005; NRC, 2000).

In order to establish additional data triangulation and validity of the scenario classifications, they were examined by three other research colleagues. Then the entire interview procedure was field tested with three teachers in order to practice the interview protocol, discuss the wording of the scenarios, and possible misconceptions that might arise based on the revised language. The teachers were very helpful in providing feedback on the description of the scenarios and their personal understanding of what each scenario was attempting to elicit. Finally, member-checking was performed by having the interviewer state what they believed the teacher's philosophy of teaching to be, and the teacher confirmed or revised the statement. In all three cases the interviewer stated the teacher's philosophy based on the beliefs elicited during the card-sorting task, and all three teachers agreed that the statements of their philosophy were accurate.

Piloting Interview Protocol

As with many new research instruments, the first interview initially conducted to gather data for the study revealed several issues with the structure and protocol of the card-sorting task. A revision of the card-sorting interview protocol was needed based on the excessive length of the first interview (more than 2 hours). This time exceeded the parameters specified in the IRB for the university and the school district. Both IRB documents stated that there would be 1-hour interviews, and there was some initial concern as the three teachers in the piloting of the interview averaged 1.5 hours. The protocol directions were edited slightly based on the piloting of the instrument to make the directions more clear and eliminate some procedural questions on the part of the teachers, and it was hoped that this would reduce the length of the interviews. But the length of the initial interview highlighted other research complications such as the time required for transcribing and coding the interviews. Although the initial two- hour interview was lengthy, it yielded little useful data. Too much of the interview could not be included in the coding structure as the teacher spent a significant amount of time discussing areas not part of the research study such as how the school district implements Science Fair, curriculum mandates, or with detailed descriptions of the characteristics of the campus student body. Another problem was that the teacher would focus on one feature of inquiry mentioned in a scenario, spending a great deal of time discussing the use of PowerPoint in presentations, or foldables and the time it took to implement them, without discussing preferred strategies for communicating their findings or collecting and analyzing evidence. Another problem with the initial interview was that the researcher did not probe for participant definitions or examples of education terms that may have individual interpretations such as “hands-on,” or “research.” Therefore, the initial interview protocol was deemed inadequate to capture data focused on a teacher’s preferences for science instructional strategies and individual beliefs that would help describe their philosophy of teaching.

A revised interview structure and protocol was created to reduce the number of structured questions and to add more areas that could be probed for additional details. The final number of selected scenarios was changed to twelve from the original eighteen. This was based on the goal of creating a balanced representation of all levels of inquiry and reducing the interview time while also focusing the teacher discussions on beliefs about science instruction. The twelve scenarios were selected to represent all five levels of the inquiry continuum - open, guided, structured, confirmation, and outside of inquiry, plus scenarios that contained a mixture of levels. This was also done to reduce the time participants spent talking about district policy and procedures (such as Science Fair) and instructional strategies not within the scope of inquiry. Some of the scenarios that were eliminated included those specifically added to investigate the "myths" of inquiry since this was not technically a part of the research model. The selection of twelve cards were cross-checked with the research team for agreement on representation of all levels of inquiry within scenarios, and removal of scenarios that most elicited data outside of the scope for this research project. All twelve of the card-sorting scenarios are in Appendix B, the research team classifications of the scenarios are in Appendix C, and a few examples of the final scenarios are shown in Figure 3.2.

5	You have students observe earthworms and generate questions about earthworm behavior. Each group designs and carries out their own experiment to test a hypothesis related to the group's questions and an explanation of how their data links to other resources. The groups communicate their findings in a presentation to other groups.
10	You design a science unit around the question, "What's in our drinking water?" Your district provides a science kit to teach this unit that includes all materials, instructions, data tables, ancillary materials, and lab report forms.
12	You want students to name and describe the phases of the moon. You ask your students to observe and make sketches of the moon each night for a period of one month. At the end of a month, students are given cards with photos of moon phases and then asked to place the cards in order and label with the correct names of the phases. Each student creates a foldable with the names and pictures of the moon phases.

Figure 3.2: Sample Elementary Card-Sorting Scenarios

The interview protocol was also altered by eliminating the ranking of best represents scenarios and instead having participants select their top 4 – 5 for comparison. This decreased the time needed in the interview to rank the cards when the essential questions were about their most preferred scenarios, and considerable time had been spent on comparing the top 2-3 or the rank with the bottom ranking cards. A list of probing questions was written to incorporate during the interview if a participant mentioned an education buzz word such as "hands-on." When a participant mentioned these terms, the interviewer remarked that in education we frequently use words where not everyone agrees upon the definition. They were then asked what the word means in terms of application, specifically "what would ________ look like if I visited your classroom and you were implementing _________." These probing questions were asked throughout the course of the interview if a participant used a term from the list of questions. They included expressions such as “research, experiment, hypothesis, testable question, scientific method, and hands-on.” Finally, if a participant used a term more than once that seemed to have an inconsistent definition within the interview, that term was also probed. By using the first interview as a pilot of the process, most of the successive interviews were closer to one-hour in length. See Appendix D- Interview Protocol Script.

Semi-Structured Interview Protocol

To achieve the research goals and best utilize the card-sorting technique, the structure of the interview can best be characterized as semi-structured. Merriam describes a continuum of interview structures ranging from “Highly Structured/Standardized” to “Unstructured/Informal” (Merriam, 1998). The final protocol was a blend of some structured characteristics such as the wording and order of questions being predetermined, and unstructured characteristics such as flexibility, some open-ended questions, and a conversational tone (Merriam, 1998; Weiss, 1994). Each interview began with a broad, open-ended question asking the teacher to describe a lesson they have recently taught that best represents their preferences for science instruction. This was a cross-check of teacher preferences before any scenarios were introduced that might influence how a participant described their preferred science instructional strategies. Then the participants were asked to read each of the twelve scenarios, and sort into three stacks: the stack that “Best Represents how I would teach;” the stack that “Does Not

Represent how I would teach;" and the stack for scenarios that they are "Unsure" about. During the initial sorting process, participants were encouraged to "think aloud" and offer any comments about the scenarios, but to also treat each scenario as a whole based on the entire description, not simply one aspect. The interviewer documented any scenarios that evoked a strongly positive or negative response, and areas to further probe. After all twelve scenarios were read and categorized, the participants were then asked to select the top 4 – 5 scenarios from the "Best Represents" stack. The interviewer encouraged them to select cards that "if I were to visit your classroom, which cards would be most like what I would observe?" After the participants selected their top 4 – 5 cards, they were then asked to discuss what they have in common and how they support their purposes and goals for teaching science. Participants were then asked to examine scenarios from the "Does Not Represent" or "Unsure" cards selected by the researcher based on individual participant responses. They were questioned about aspects of the scenario(s) that would need to be changed to place them in the best represents category. Based on other areas that the interviewer thought were worth exploring (if time permitted), two or more additional scenarios were selected for comparing and contrasting, or inquiring how the participant would change them to best represent their preferences. In addition, probing questions were asked throughout each interview if a participant mentioned terms frequently used in elementary science instruction such as "Hands-on," "Research," "Experiment," "Hypothesis," and "Testable Questions." Other areas included the role of writing and vocabulary in instruction, the use of kit-based science, and high-stakes testing. In order to perform member-checking of teacher preferences in science instruction, the interviewer described the participants teaching philosophy based on what they heard during the interview. The participant was asked to agree, disagree, and if necessary, revise the interviewer's statements describing areas they think are on target, and areas that were not accurate. To end the interview the researcher asked if there was any additional information not already discussed that the participant wished to add to the interview. Participants were then thanked for their time and given a $25 gift certificate.

Limitations

One of the greatest limitations of the study was the use of the card-sorting task to place teachers along a continuum. This violates the authors original intent of not creating teacher profiles, since science teaching philosophies can be complex (Friedrichsen & Dana, 2003). However, the original authors created this instrument to use as part of a teacher preparation program, and classifying preservice teachers who are not even engaging in their chosen profession cannot be helpful. This limitation suggests that the participants of the study, or at least the interviewees, should be experienced teachers beyond the induction phase (0 – 2 years of experience) of their career. Another limitation of the chosen methodology is self-reporting bias since teachers may wish to appear to support inquiry when they may not utilize inquiry-based strategies. Many school districts and campus administrators give lip service to inquiry or require teachers to engage in "hands-on" instruction without any real training or even understanding of what constitutes inquiry. There may also be self-selection biases since a science anxious teacher may opt out of the survey, skewing data towards those not science anxious. Finally, this instrument has not been widely used across various populations of elementary teachers and unforeseen consequences relating to teacher interpretation of the scenarios or classification of teachers along a continuum may not be accurate or reliable.

Discussion of Instrumentation

Although placing teachers on a continuum is a broad strategy, it is the initial piece in a descriptive study and may help teachers to examine their own practices to determine the degree of teacher- or learner-centered instruction that they actually follow. The marriage of the card-sorting scenarios to the NRC essential features of inquiry may provide both a research and a practitioner basis for exploring the inquiry continuum and its relationship to the degree of teacher- and learner-centered instruction. The strength of the revised card-sorting task is that the variety of scenarios provides opportunities to discuss strategies conforming to a range of inquiry, a blend of inquiry, and even completely outside of inquiry. This interview format provides opportunities for teachers to elaborate, alter, or eliminate parts or even entire scenarios to provide a more complex picture of teacher beliefs and practices.

DATA COLLECTION

The process of conducting this research study took more than one year from the IRB application submissions to the final data collection and dissertation report. The survey data was collected from a total sample of 112 teachers, finding 86 representative participants with results analyzed to identify groups with high anxiety and low self-efficacy, and low anxiety and high self-efficacy, along with a small group of high anxiety and high self-efficacy participants worthy of exploration. Participants for interviews were recruited based on these survey results. Of the 68 possible candidates, eight interviews were conducted with teachers representing various degrees of anxiety and self-efficacy. Tables 3.2 and 3.3 chart the study's research design.

Table 3.2

Mixed Methods Research Design Framework

QUAN	
Design Strategy	Online *Science Teaching Attitude Survey*, n = 86 elementary science teachers who teach Pre-K through 5th grades, completed the survey.
Purpose	To explore the relationship between levels of Science Anxiety and Science Teaching Self-Efficacy; identify specific groups of participants worthy of additional in-depth exploration of teacher beliefs.
Sampling	Self-administered online survey via email contact with all elementary teachers (with the exception of one campus) in a large urban school district.
Instrument	A combination of the 20-question State Anxiety sub-test of the State-Trait Anxiety Inventory (STAI) and the 13-question Personal Science Teaching Self-Efficacy (PSTE) sub-test within the Science Teaching Efficacy Belief Instrument (STEBI). There were 33 questions from the two sub-tests and 5 demographic questions for a total of 38 survey questions.
Measures	The STAI measures levels of Science Anxiety and the STEBI measures Science Teaching Self-Efficacy Beliefs to identify the relative levels of anxiety and self-efficacy.
Data Collection	Although all Pre-K through 5th grade teachers were invited to take the survey, only teachers who indicated that they taught Science were included in the final data set. Surveys were taken online through Survey Monkey and results downloaded for scoring as Excel files.
Data Analysis	IBM's Statistical Package for the Social Sciences to calculate descriptive and inferential statistics.

Note. Based on Dr. Lupita Carmona's (2010) table, "Alignment between research questions, research design, and conclusions."

Table 3.3

Mixed Methods Research Design Framework

QUAL	
Design Strategy	**Descriptive Interviews** (n = 8) of representative groups of teachers recruited to engage in a semi-structured card-sorting activity as the basis for eliciting teacher beliefs and preferences for science instructional strategies.
Purpose	Interviews used to create a detailed picture of individual teachers and groups of teachers with high or low anxiety and self-efficacy beliefs as preferences for levels of inquiry along a continuum (NRC, 2000), and holistic rating of teacher to student-centered learning.
Sampling	Interviewees selected as a **purposeful sample** from survey data to examine groups of low and high anxiety and self-efficacy.
Instrument	Revised Science Teaching Scenarios Card-Sorting (STSCS) strategy as a framework for a semi-structured interview (Friedrichsen & Dana, 2003). Additional probing questions to explore other factors and cross-check responses.
Measures	Essential features of inquiry, including percentages of interview coded as discussing these features, frequencies of references to the features, and additional factors influencing preferences for science instruction.
Data Collection	In person interviews with eight teachers selected from representative groups by levels of science anxiety and self-efficacy. A defined protocol of card-sorting for inquiry preferences drives a less structured interview strategy of probing for additional beliefs and factors affecting teacher preferences.
Data Analysis	Transcribed interviews coded for references to essential features and levels of inquiry along a continuum. Individuals were placed along the continuum to holistically classify their preferences for science instruction as primarily teacher-centered or learner-centered. Groups of teachers compared by levels of anxiety and self-efficacy.

Note. Based on Dr. Lupita Carmona's (2010) table, "Alignment between research questions, research design, and conclusions."

DATA SOURCES

Sources, Selection Criteria, and Setting for Survey Participants (QUAN)

The sources of the quantitative data comprise a subset (n = 86) of teachers recruited from a large urban school district in central Texas. IRB approval from the district was granted in April and from the university in May, 2013. Survey contact, assent, and administration were by email and through a link to Survey Monkey (See Appendix E). Before emails were sent to teachers, campus principals were contacted by email informing them of the study and giving them the chance to have their campus opt out. Only one principal chose to have no teachers participate, so those teachers were removed from the contact data set. From the contact information provided by the school district, 3277 teachers at 75 campuses were emailed the invitation to participate in the research study. This email contained the assent to participation documentation and the link to the survey. Although only elementary teachers beyond induction phase (3+ years of experience) were selected for interviews, all Pre-K through 5th grade teachers were contacted and asked to participate in the survey research portion of the study. Teachers who volunteered to participate were provided a link in the email in order to take the survey, and the informed consent form was embedded in the email, so by going to the survey they gave consent to participate in the research study. In order to encourage teachers to complete the survey and supply contact information, all participants completing the survey and providing their name and phone number were entered in a drawing for one of four gift certificates.

Demographics

Because a variety of demographic data may be useful as part of the analysis, the survey also collected this data for possible further research and to remove induction teachers from the interview participant pool. Data collected included gender, years of teaching experience, current teaching assignment, subject area specialization, degrees obtained, and major areas of study. See the demographic data for the quantitative question in Table 3.4.

Table 3.4

Demographic characteristics of Elementary science teachers – Quantitative

Demographic Characteristic		**Frequency**	**%**
Years Teaching	(participant did not provide = 5)		
0 – 2 years		8	9.9
3 – 5 years		10	12.3
6 – 8 years		16	19.8
9 – 11 years		15	18.5
12+ years		32	39.5
Gender	(participant did not provide = 11)		
Female		69	92
Male		6	8
Teaching assignment	(participant did not provide = 7)		
Self-contained class		60	75.9
Science (Departmentalized)		11	13.9
Special Ed Inclusion Support		6	7.6
Science/Other Campus specialist		2	2.5
Grade Level	(participant did not provide = 3)		
Pre-Kindergarten		14	16.9
Kindergarten		16	19.3
1st		6	7.2
2nd		9	10.8
3rd		8	9.6
4th		9	10.8
5th		13	15.7
Multi-grade		8	9.6
Self-described Area of Specialization	(participant did not provide = 6)		
Reading/ELA		24	30
Science/ELA		5	6.3
Math/ELA		2	2.5
Science		13	16.3
Mathematics		10	12.5
Social Studies		2	2.5
Bilingual/ESL		8	10
Special Education		3	3.8
All subjects		8	10

n = 86

Dataset – QUANT

After allowing five weeks for participants to self-administer the online survey, final data was downloaded. The STAI and STEBI data from Survey Monkey was downloaded as an Excel file, and they were scored by the researcher then analyzed using SPSS to calculate the mean and standard deviation of all participant data. Of the teachers contacted only 112 began the survey, with 86 completing the entire survey and teaching science. Because requiring contact information might have reduced the number of participants, it was an optional part of the survey, but necessary for inclusion in the random drawing for gift certificates. Participants were rank-ordered separately for the STAI and STEBI results, then grouped by quartiles above or below the mean. Examination of the STAI data by rank ordered scores, especially the first and fourth quartiles, identified two groups that could be interviewed to answer the research questions – a high and a low state-anxiety (STAI), and a third group with a mid-range level of anxiety. The same procedure was used with the STEBI data to identify two groups of high and low scores.

By grouping the teachers by scores on the STAI and STEBI it was possible to look at the direction and strength of the correlation within the theoretical framework for two different systems of teacher beliefs.

Sources, Selection Criteria, and Setting for Survey Participants (QUAL)

The sources of the qualitative data comprise a subset (n = 8) of elementary science teachers recruited from a pool of 86 teachers who participated in the quantitative survey, were not still in the induction phase of their careers (3+ years of teaching), and part of a group defined by levels of anxiety and self-efficacy worthwhile as an exploration of the research questions. Of the 86 teachers who completed the survey only 75 teachers provided contact information, and five of the teachers providing contact information had 0 – 2 years of experience so were excluded from the final data set to be contacted for possible interviews. Finally, two of the teachers had participated in the preliminary study, leaving a subset of 68 possible teachers to recruit as interview participants.

In order to explore the research questions fully, teachers from the low anxiety/high self-efficacy and the high anxiety/low self-efficacy groups were contacted first by telephone and then by email to recruit as interview participants (see Appendix F). By October, 2013 only five teachers in the two groups had been interviewed, so the pool of possible participants was expanded to include teachers with medium anxiety/high self-efficacy since some of the anxiety scores had little variance. This yielded only one additional participant, so a group that was not a focus of the theoretical framework but was worthy of study, participants from the high anxiety/high self-efficacy group were contacted. Two additional participants were recruited from this group for a total of eight teachers interviewed for the qualitative portion of the study. Interviews were conducted in the teacher’s classrooms after school or on a parent-teacher conference day. All interview participants received a gift certificate in appreciation of their time.

Demographics

A small subset of eight teachers from the original 86 participants was represented in the qualitative interviews. Demographics for interviewees are shown in Table 3.5

Table 3.5

Demographic characteristics of Elementary science teachers – Qualitative

Demographic Characteristic	**Frequency**	**%**
Years Teaching		
3 – 5 years	1	12.5
6 – 8 years	2	25
9 – 11 years	2	25
12+ years	3	37.5
Gender		
Female	6	75
Male	2	25
Teaching assignment		
Self-contained class	5	62.5
Science (Departmentalized)	3	37.5
Grade Level		
Pre-Kindergarten	1	12.5
Kindergarten	1	12.5
1st	0	0
2nd	1	12.5
3rd	1	12.5
4th	1	12.5
5th	3	37.5
Self-described Area of Specialization		
Science/ELA	1	12.5
Science/Math	2	25
All subjects	5	62.5

n = 8

Dataset – QUAL

Participant recruitment for the qualitative portion of the study began by contacting members of each of the two groups to recruit for interviewees. Survey participants who provided contact information were first called then emailed with follow up phone calls to determine a place and time to conduct face-to-face interviews. All interviews were conducted in teacher's classroom outside of school hours. Consent was obtained at the time of interview, including permission to audiotape. All participants who agreed to interview received a gift certificate.

Methods for Data Analysis

Quantitative data analysis procedures include methods of data organization and management, specifically sorting and analyzing individual scores separately on the STAI and the STEBI in order to identify two distinct groups described within the theoretical framework: the high science anxiety, low science teaching self-efficacy group; and the low science anxiety, high science teaching self-efficacy group. There were a significant number of participants who did not score high or low on one or both scales, but as these scores were outside the scope of the theoretical framework, these participants were not considered for further investigation in this study.

Statistical analysis procedures included using SPSS to analyze descriptive statistics to find three groups of participants based on their STAI – State-Anxiety totals and STEBI - PSTE means. First participants were ranked in order from highest to lowest

State-Anxiety by total score then compared by the highest and lowest quartiles to place into a low, high, or medium anxiety group. STEBI - PSTE data were analyzed in the same way as STAI data creating three groups – high, low, and medium self-efficacy.

In order to explore the theoretical framework, an intersection of common high and low scores to populate the two groups was attempted. Three particular groups of research interest were a high anxiety/low self-efficacy group, a low anxiety/high self-efficacy group, and a high anxiety/high self-efficacy group. After participants were rank ordered by their STAI and STEBI results (separately) then they were grouped into combinations of anxiety and self-efficacy by rankings. Although the majority of participants did fall into groups of medium anxiety and medium self-efficacy, the scope of the research focuses on the lowest and highest rankings. These groups provided the majority of participants for the qualitative portion of the research.

Qualitative data analysis procedures included audio recording the STSCS interviews, transcribing the interviews, and holistically classifying teachers along the inquiry continuum for preferred strategies, along with determining their focus as either teacher-centered or learner-centered instruction. The transcriptions were coded using the qualitative software package NVivo to identify common themes and patterns as teachers describe their preferred strategies for teaching science.

The first step in analyzing the qualitative data was to transcribe the audio recorded interviews using Dragon Naturally Speaking, a program designed to convert the audio recording of a person's voice into a Word document that was then analyzed by NVivo to help classify teachers by their responses to the STSCS. Each interview was first recorded again with the researcher speaking both parts so that Dragon could recognize speech patterns. Each recording was converted into a Word document by Dragon, and the numerous mistakes made by Dragon corrected to create a final transcript of the interview. Finally each interview was formatted to download into the qualitative coding software package NVivo.

To code each interview using NVivo, first each interview was imported as a separate source within one project. Then a coding structure was created based on the five Essential Features of Inquiry for each of the twelve scenarios written by the researcher. Each scenario has an identical coding node structure with the first sub-nodes as the 5 features of inquiry – Question, Evidence, Explanation, Connection, Communication, and the teacher's rating of each scenario as Best Represents, Does Not Represent or Unsure. At each of the first sub-nodes the coding structure contains all five levels of Inquiry – Open, Guided, Structured, Confirmation, and Outside of Inquiry. Additional nodes with the same coding structure were created for the first question in the interview, a description of a recently taught lesson that best represents the teacher's preferences. The same coding structure was also used for follow up questions asking teachers to compare their top 4 – 5 best represents scenarios, and changes to does not represent and unsure scenarios to place them within the best represents classification. The node for the question written to do member-checking was coded the same way as the other twelve scenarios and follow up questions. A final coding node contained additional items of interest such as the definition and examples of Hands-on instruction, the role of writing and vocabulary, science kits, and holistic classification of lessons. These nodes were coded only for references to the inquiry continuum, definitions of the terms, and use of the terms within a teacher's description of preferences for science instruction.

Each node was given a description to assist in accuracy and reliability of researcher coding, along with establishing criteria for another rater. The initial coding scheme was examined by a research team of two other graduate students who made a few suggestions for coding structures in the final node. Two interviews were coded by one research team member to check for inter-rater reliability. See Figure 3.3.

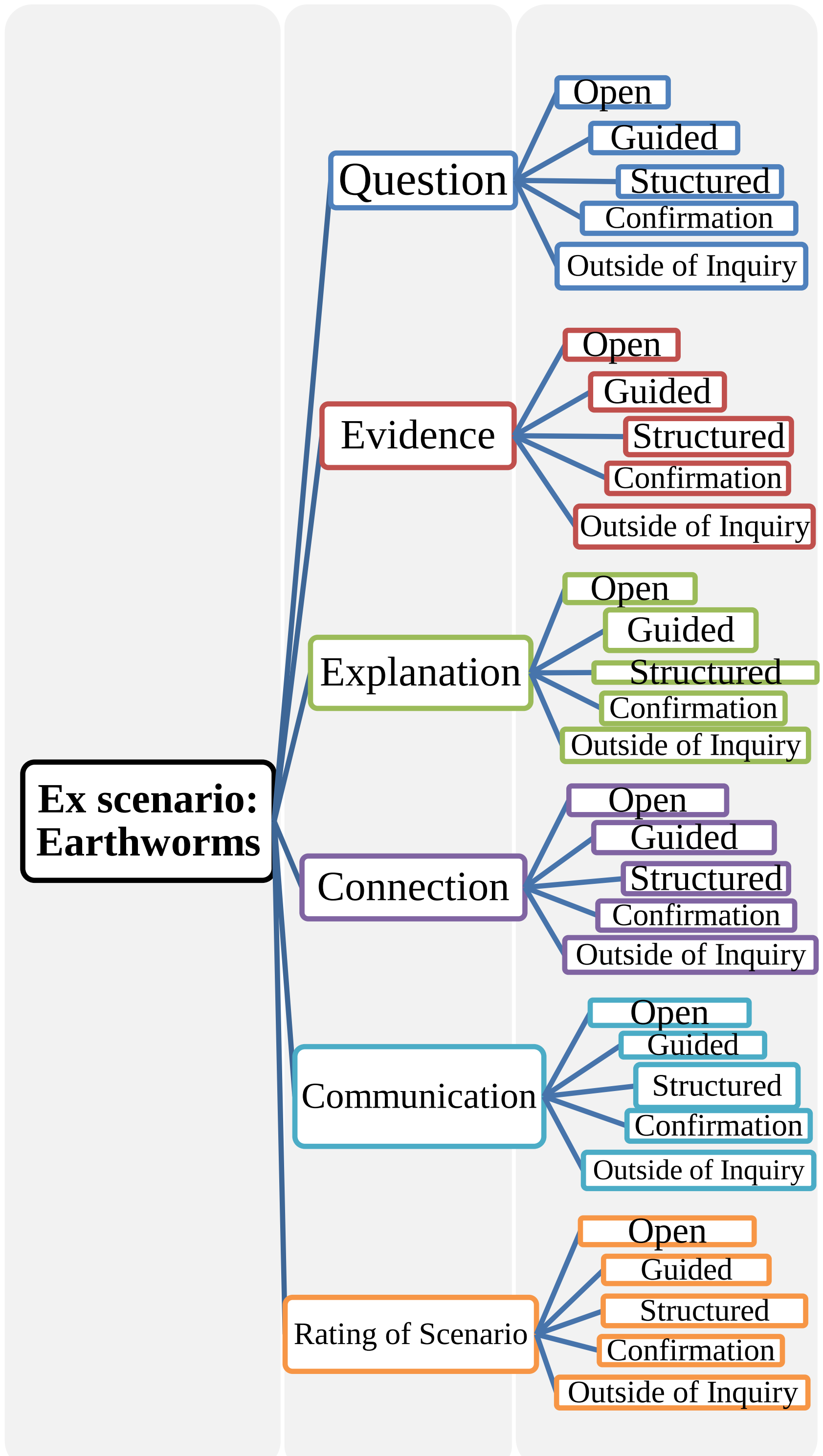

Figure 3.3: Interview Coding Structure for Science Teaching Scenarios Card Sort

After coding the interviews, the coding percentages for each participant were calculated within every scenario. NVivo calculates the percentage of the entire interview that is represented at each node, and the researcher entered that data into an Excel file along with frequencies of each code within a particular node. Not all nodes were coded since participants may not have discussed every essential feature of inquiry, but the terminal coding placed each node along the inquiry continuum as Open, Guided, Structured, Confirmation, or Outside of Inquiry.

Following calculating the total percentages for scenarios 1 – 12 for each participant, one graph was created for the total for best represents, the description of a recently taught lesson that best represents, and a comparison of the top 4 – 5 best represents scenarios. An additional graph was created for the changes to the does not represent and unsure scenarios. This graphed the total percentages and frequencies for changes to the does not represent or unsure scenarios selected by researcher to further examine during the interview. Finally, each participant answers to the final node structure were graphed for the coding in areas outside of the scenarios structure within a broad category of "Campus Culture Expectations." These nodes include percentages and frequencies of participant responses to terms such as "hands-on (the teacher's own definition of hands-on, and how it would look in their classroom); the role of vocabulary and writing in science; lesson cycle preferences (holistic classification of the lesson cycle as open, guided, structured, confirmation, or outside of inquiry); and other areas pertaining to the nature of science such as the role of research, experimentation, hypothesis, and testable questions.

In order to cross-check for validity of participant ratings of Scenarios 1 – 12, participants described of recent lesson they taught that best represented their preferences. The total percentages for coded references to open, guided, structured, confirmation, or outside of inquiry was graphed on the same graph as best represents scenarios selected from the twelve created by the researcher. The graph of an open-ended description compared to the best represents scenarios permits the researcher to do a cross-check to help establish the reliability of their responses.

Data organization and management strategies were used to first examine the transcripts and create graphs to place individual teachers along the inquiry continuum. By looking at the individual interviews holistically to describe patterns and trends that can classify teachers as primarily preferring open, guided, structured, confirmation, or outside of the inquiry continuum, individual and groups of teachers were examined to establish a primary preference for a level of inquiry. By overlaying individual teacher preferences on the NRC inquiry continuum chart, holistic strategies were used such as creating charts and arrows showing the direction teacher moved preferences for the twelve scenarios as compared to the initial classifications by the research team. Comparing the graphs of "best represents", "top 4-5 scenarios", and the "changes to does not represent" and "unsure" scenarios, along with placing teachers holistically along the continuum facilitated comparisons of all teacher placements to overlay on inquiry continuum for individual and groups of teachers. By examining all teacher preferences on the inquiry continuum chart, trends and patterns emerged between teachers at varying levels of science anxiety and science self-efficacy. This was accomplished by examining the ratings of teachers by preferred strategies, then creating the individual teacher graphs to place within the continuum based on the scenarios they described as “best represents” how they teach, “does not represent” how they teach, and the scenarios they are “unsure” about implementing. Using both the frequencies of coded terms and the teacher preferences graphs, the teachers were matched to the NRC’s continuum to classify them as using primarily a traditional or an inquiry-based model of instruction. These ratings also lie along the continuum, so it is possible to infer a teacher’s preferred model of instruction as teacher-centered or a learner-centered by using their placement along the continuum. Based on the research of Bell, the placement along the inquiry continuum can also infer a teacher’s preferred orientation of instruction as subscribing to predominantly a teacher-centered instructional model or a student-centered model of instruction (R. L. Bell et al., 2005). If teacher preferences are for more confirmation and outside of inquiry strategies then it also places them along the teacher-centered portion of the continuum. A learner-centered instructional model is inferred by teachers with more preferences for open and guided inquiry strategies within the student or learner-centered portion of the continuum. Placing teachers within the continuum was also based on additional coding structures such as lesson cycle preferences, the role of research, vocabulary, hands-on instruction, and explicit references to inquiry and teacher- or student-centered instruction. The transcribed descriptions of their teaching philosophy was compared to the description of a science lesson they recently taught that best represents their philosophy of teaching to cross-check for validity of their preferences and to examine the degree of self-reporting bias that may exist.

In order to answer the research questions, several comparisons were made across the quantitative and the qualitative data.

1. *Do teacher beliefs direct their personal philosophy of science instruction, and if so, how?*

2. *Is there a relationship between the levels of science anxiety/science teaching self-efficacy and the preference for a teacher-centered model of instruction as opposed to a learner-centered model? If so, what is the relationship?*

This question was studied by examining each of the interviewed participants. Each participant was classified as high anxiety/low self-efficacy, low or medium anxiety/high self-efficacy, or high anxiety/high self-efficacy and then holistically placed along the inquiry continuum by degree of preference for teacher-centered or learner-centered instruction. Emerging patterns suggested a complex relationship among the groups, including an interesting group, the high anxiety/high self-efficacy group.

3. *How do teachers with low science anxiety and high science teaching self-efficacy compare with high anxiety, low self-efficacy and high anxiety, high self-efficacy teachers in their implementation of a traditional or inquiry-based model of instruction?*

This question was examined by comparing the two groups of teachers classified as either high anxiety/low self-efficacy or low or medium anxiety/high self-efficacy (along with the high anxiety/high self-efficacy group) and their placement along the inquiry continuum by degree of preference for an Inquiry-based or a traditional model of instruction. Comparisons of the two groups were made by holistically rating both the frequencies and percentages of preferred strategies coded from the interviews, and the teacher placement graphs along the essential features of inquiry continuum.

Ethical Considerations and Trustworthiness

One of the major ethical concerns of this study is that of vulnerable participants, specifically teachers with high anxiety and low self-efficacy who may experience stress or discomfort when answering survey questions or during an interview. Eliciting their core beliefs and attitudes about science teaching may actually increase anxiety or lower a teacher's self-efficacy. As part of the consent to participate in the survey teachers were informed that they may withdraw consent at any time by exiting out of the survey. During the interview participants signed consent to participate in research forms at the beginning of the interview, and the researcher monitored their responses and levels of apparent anxiety. Although there is no deception in the survey or the interview process, teachers were not informed of the specific research questions or where they may be classified along the essential features of inquiry. In fact, no mention was made by the researcher of the terms "inquiry," "teacher-centered," or "learner-centered" unless first mentioned by the participant, and then only as part of follow-up questions.

Another area of consideration in the research methodology is the potential for participant biases. One such concern is that of a self-reporting bias, or the desire to present oneself in the best possible terms. Teachers are under more pressure to teach "hands-on" and "engaging" science lessons, especially to prepare students for standardized testing. Therefore, they may feel pressured to present themselves as using the strategies their district or campus administrator touts, rather than the strategies that are part of their own philosophy of education. Because of the perceived anonymity of the internet and contact information (identifiers) not collected until the end of the survey, teachers might have "forgotten" that they are not anonymous as they answer the survey questions. Of course, this may have reduced the number of teachers willing to provide contact information at the end, but the chance of winning a gift certificate might have been enough incentive for the participants to complete the survey and provide contact information. During the qualitative portion of the study the first question asked was to describe a lesson recently taught in order to compare their response to this question and their self-described philosophy of teaching. Reading science teaching scenarios may influence their description of their own teaching strategies, so gathering the description data upfront may have reduced self-reporting bias. Participant contradictions were noted in every interview, as they expressed a preference for a strategy, and then contradicted themselves within other parts of the interview. The cross-check question to determine veracity of teacher preferences was compared graphically to the best represents of the twelve scenarios, and the comparisons of their top 4 – 5. This question showed a consistent practice of stating preferences for the open end of the continuum in the scenarios written by the researcher, yet moving towards the confirmation and outside of inquiry end in their own practices.

A self-selection bias may create another concern for the trustworthiness of the data. Teachers with high science anxiety may have chosen to not take survey, skewing the results to appear that lowered anxiety is representative of the population of elementary science teachers. The possibility of winning a gift certificate might have overcome some of the teacher's anxiety and encouraged them to complete the survey. Since all interview participants received a gift certificate, perhaps this incentive also helped to overcome a self-selection bias. Even though some teachers undoubtedly chose not to participate, this may not have been a significant error because the study has a narrow focus, examining only teachers with relatively high or low anxiety and self-efficacy therefore a large sample may not have been needed. If additional research is pursued, a much larger number of participants would be preferable to overcome any participant biases.

DISSERTATION TIMELINE

The timeline for completing the dissertation began with the acceptance of the proposal on May 10, 2013. On April 5, 2013 I received approval of my research study IRB from the Austin Independent School District. During May each campus principal was contacted and only one declined campus participation. The UT IRB was approved on May 21, 2013 with an end date of May 21, 2014.

The collection of survey data from elementary teachers began on May 28, 2013 when the survey was mailed to all the elementary teachers still within the data set. Teachers were able to access the survey immediately, and results were collected through the site Survey Monkey. The site was checked every few days, and by June 28, 2013 no additional surveys had been completed for 10 days, so the final download was accessed as an Excel file.

During the summer the survey data was analyzed using SPSS. STAI and STEBI data was used to group participants, and contact group members to schedule interviews. The initial interview that was later used a pilot for the protocol and alteration of scenarios was conducted August 10, 2013. Subsequent interviews were conducted from August to November, 2013. Transcribing of interviews began as they were completed, and all transcriptions were finally completed by December 28, 2013. Data analysis of the interviews including creating coding structure creation began in November 2013 with charts for coding percentages and frequencies to classify teachers on the essential features of inquiry continuum completed on January 17, 2014. The data analysis tasks included coding interview data, creating charts and graphs to represent and analyze the data, and classifying teacher placement along the continuum. After classifying each interview participant for frame of reference and preferred model of instruction, the groups were compared to see if there is a relationship between anxiety, self-efficacy and a preference for inquiry or traditional methods, and a frame of reference. With data analysis completed in January, the month of February was devoted to editing Chapters 1 through 3 and beginning the writing process for the Results (Chapter 4), Discussions (Chapter 5), and other sections during the last week of February through March, 2014. Final edits and revisions were finished in March and the manuscript sent to the committee for review on March 25, 2014. The defense of the dissertation is scheduled for April 16, 2014, with the finished document submitted to The Graduate School by May 2, 2014.

SUMMARY

This chapter outlined the research approach for a study of elementary teacher science anxiety, self-efficacy and the possible relationship to their preferences for inquiry-based or traditional model of instruction. A mixed-methods research design was described, along with a rationale for using that methodology, including the instrumentation, data collection and analysis strategies. The chapter ends with a proposed dissertation timeline. The structure of the research methodology is designed to investigate the research questions found within the structure of a theoretical framework that may provide additional lines of research to investigate the phenomenon of teacher science anxiety and how it may affect actual classroom practices.

Chapter 4: Results

INTRODUCTION

The purpose of the chapter is to report the results of the study examining a possible relationship between science teacher anxiety, self-efficacy, and their philosophy of science instruction. A preliminary study found that teachers reporting high science anxiety were more likely to adopt a traditional model of instruction (Hodgin, 2008). The quantitative data collected for the study consists of results on the Science Attitude Survey of 86 elementary teachers who took anxiety and self-efficacy instruments to identify possible groups matching the theoretical framework. Qualitative data on eight teachers identified from the quantitative research were interviewed using a semi-structured interview based on a Science Teaching Scenario Card Sort (STSCS). Interviews elicited teacher preferences for levels of Inquiry in five essential features: Questions, Evidence, Explanation, Connections, and Communication. The purpose of collecting the data was to explore differences in teacher preferences for science instructional strategies based on anxiety and self-efficacy.

RESULTS

The central research goal of this study was to explore the role of teacher beliefs may play in their instructional practices. The following research questions were selected to help investigate how anxiety and self-efficacy may play a role in determining if a teacher prefers a teacher or student-centered model of instruction.

1. Do teacher beliefs direct their personal philosophy of science instruction, and if so, how?
2. Is there a relationship between the levels of science anxiety/science teaching self-efficacy and the preference for a teacher-centered model of instruction as opposed to a learner-centered model? If so, what is the relationship?
3. How do teachers with low science anxiety and high science teaching self-efficacy compare with high anxiety, low self-efficacy and high anxiety, high self-efficacy teachers in their implementation of a traditional or inquiry-based model of instruction?

Research Question 1 - *Do teacher beliefs direct their personal philosophy of science instruction, and if so, how?*

An analysis of the survey data consisting of a subtest of the Science Teaching Anxiety Inventory (STAI) and a subtest of the Science Teaching Efficacy Belief Inventory (STEBI) was performed as the initial step in reporting and interpreting the results. Descriptive statistics for the quantitative data were calculated using the Statistical Package for the Social Sciences (SPSS) for the 86 participants who completed the entire survey. The results calculated for the (STAI) test consisted of the frequencies of the mean, median, mode, standard deviation, and percentiles. The normalized mean for working adults who took the State-Anxiety Inventory (the sub-test used in the survey) was reported in the STAI Manual as 35.72 for males, and 35.20 for females (Spielberger et al., 1983). The mean of 32.24 for the survey participants is lower than the mean for the group of working adults, but still falls within the range of Medium anxiety group. See Tables 4.1 and 4.2.

Table 4.1

STAI Total - Descriptive Statistics

N	Valid	86
Mean		32.24
Median		31.50
Mode		33.00
Std. Deviation		8.76
Percentiles	25	25.00
	50	31.50
	75	36.25

Overall ranking by percentiles for all 86 participants established categories for science teaching anxiety groups. The percentiles were used to rank participants in order with scores at the 25 percentile and below placed in the low anxiety group, scores between the 25 and 75 percentiles were placed in the medium anxiety group, and scores about 75 percentile in the high anxiety group. Participants with low anxiety scored from 20 (the lowest possible anxiety score on the STAI) to 25; medium anxiety scores fell between and including 26 to 35, and high anxiety scores were from 36 to 59. The mean for both this study (32.24) and Spielberger's reported normalized means for working men and women (35.72 and 35.20) fall within the medium anxiety group (Spielberger et al., 1983).

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Table 4.2

Science Teaching Anxiety Groups by STAI Total Scores

STAI	**%**	**Mean = 32.24**
25 Percentile	20 to 25	Low Anxiety
50 Percentile	26 to 35	Medium Anxiety
75 Percentile	36 to 59	High Anxiety

N = 86

The descriptive statistics results were calculated for (STEBI) for frequencies of mean, median, mode, standard deviation, and percentiles. The mean for the PSTE subtest of the STEBI is 3.62 for a group of college students, as compared to 4.21 for participant teachers in this study (Enochs & Riggs, 1990). The mean for pre-service teachers is lower than even the 25 percentile scores of the teacher participants, but understandable that practicing teachers will have a higher self-efficacy than pre-service teachers. See Tables 4.3 and 4.4.

Table 4.3

STEBI Mean - Descriptive Statistics

N	**Valid**	**86**
Mean		4.21
Median		4.23
Mode		4.69
Std. Deviation		.60
Percentiles	25	3.92
	50	4.23
	75	4.69

Percentiles for all 86 participants STEBI scores were used to rank order them with scores at the 25 percentile and below placed in the low self-efficacy group, scores between the 25 and 75 percentiles were placed in the medium self-efficacy group, and scores about 75 percentile in the high self-efficacy group. Participants with low self-efficacy scored from a mean of 1 (the lowest possible self-efficacy score on the STEBI) to 3.92; the medium self-efficacy scores fell between and including 4.00 to 4.46; and the high self-efficacy scores were from 4.69 to 5.00. Table 4.4 below shows the specific scores for each group.

Table 4.4

Science Teaching Self-efficacy Groups by STEBI Scores

STEBI	**%**	**Mean = 4.20**
25 Percentile	1 to 3.92	Low Self-Efficacy
	4.00 to 4.46	Medium Self-Efficacy
75 Percentile	4.69 to 5.00	High Self-Efficacy

N = 86

The final number of participants in each anxiety and self-efficacy group were calculated by rank ordering all participants and classifying each by low, medium, or high anxiety and self-efficacy. Although there were groups of participants in the low and high groups for both tests, the majority of the sample fell within the medium levels for both anxiety and self-efficacy. The largest group, medium anxiety and with various levels of self-efficacy represents almost half of the survey respondents. (See table 4.5)

Table 4.5

Anxiety and Self-Efficacy Results for Survey Participants

Anxiety/Self Efficacy Groups	Frequency
Low Anxiety/High Self-Efficacy	12
Low Anxiety/Medium Self-Efficacy	11
Low Anxiety/Low Self-Efficacy	0
Low Anxiety Totals	23
Medium Anxiety/High Self-Efficacy	10
Medium Anxiety/Medium Self-Efficacy	21
Medium Anxiety/Low Self-Efficacy	8
Medium Anxiety Totals	39
High Anxiety/High Self-Efficacy	4
High Anxiety/Medium Self-Efficacy	5
High Anxiety/Low Self-Efficacy	15
High Anxiety Total	24

N = 86

Interview Participants

Identifying possible participants from survey data to follow up with interviews was accomplished by first creating a subject pool of possible participants to contact. Only 70 total elementary teachers provided contact information, and of those teachers 28 were classified as low anxiety/high self-efficacy, high anxiety/low self-efficacy, or high anxiety/high self-efficacy groups. After numerous contacts with teachers, the possible subject pool was expanded to include medium anxiety and low or high self-efficacy, and one additional participant was recruited for a total of eight participants interviewed. The majority of teachers (6) were identified as high anxiety, and the group was evenly divided between low and high self-efficacy. (See Tables 4.6 and 4.7)

Table 4.6

Interview Participant Frequencies by Anxiety and Self-Efficacy Percentile Rankings

Anxiety and Self-Efficacy	**Freq.**
Low Anxiety	1
Medium Anxiety	1
High Anxiety	6
Low Self-Efficacy	4
Medium Self-Efficacy	0
High Self-Efficacy	4

n = 8

Table 4.7

Interview Participant Frequencies by Anxiety and Self-Efficacy Groups

Anxiety and Self-Efficacy Groups	**Freq.**
Low Anxiety/High Self-Efficacy	1
Medium Anxiety/High Self Efficacy	1
High Anxiety/High Self-Efficacy	2
High Anxiety/High Self-Efficacy	4

n = 8

Their grade level teaching assignments ranged from the high self-efficacy teachers mostly teaching in the upper, tested grades (4^{th} – 5^{th}) and the low self-efficacy teachers mostly in the lower grades, with four in primary (pre-K – 3^{rd}). The high anxiety teachers were somewhat scattered, with all of the primary teachers (Pre-K through 3^{rd}) and two 5^{th} grade teachers within that group. Low and medium anxiety teachers were in the 4^{th} and 5^{th} grades, and since there was only one of each, they will hereafter be combined as low anxiety. The eight participants were very experienced with one teacher having 3 – 5 years of experience, two teachers with 6 to 8 years, two with 9 to 11 years, and three teachers with 12+ years of experience. Their STAI and STEBI results combined yielded three distinct groups – low anxiety and high self-efficacy; high anxiety and low self-efficacy; and high anxiety and high self-efficacy groups.

Table 4.8

Interview Participant Anxiety and Self-Efficacy Scores

Name [a]	**STAI Total**	**STEBI Mean**	**Anxiety/Self-Efficacy Group**
Daniel	23	5.0	Low Anxiety/High Self-Efficacy
Jane	33	4.77	Medium Anxiety/High Self-Efficacy
Nancy	36	4.92	High Anxiety/High Self Efficacy
Linda	37	3.46	High Anxiety/Low Self-Efficacy
Barbara	39	3.77	High Anxiety/Low Self-Efficacy
Randy	42	4.69	High Anxiety/High Self-Efficacy
Karen	55	2.54	High Anxiety/Low Self-Efficacy
Mary	56	2.0	High Anxiety/Low Self-Efficacy

Participant pseudonyms

After transcribing and coding the results from a semi-structured interview for each of the participants, a series of vignettes describing each teacher participant was created. Coding features included a description of their preferences for best represents scenarios, comparisons of their top 4 – 5 scenarios, changes to unsure and does not represent scenarios, along with a description of a lesson they recently taught that best represents their science instructional philosophy. Each teacher was assigned a pseudonym, and these vignettes are presented in this chapter.

In summary, the quantitative data from the STAI and STEBI questions within the Science Attitude Survey was calculated and compared to identify distinct groups of teachers most likely to contribute to some understanding of the theoretical framework. These vignettes paint a more detailed picture of teacher preferences and attempt to answer the question "Do teacher beliefs direct their personal philosophy of science instruction, and if so, how?"

PARTICIPANT VIGNETTES

Barbara

A description of Barbara's teaching assignment and demographics were self-reported during the online survey. Her current teaching assignment is at a low-income school within a large urban school district where she teaches in the PPCD (Preschool Program for Children with Disabilities). Her area of specialization was self-reported as Mathematics, and she has 6 – 8 years of teaching experience, with a BA in Applied

Sciences. Barbara's levels of anxiety and self-efficacy were measured in the same online survey by the STAI (State Anxiety sub-test) and the STEBI (PSTE sub-test). When compared to all the participants in the online survey, she ranked high in anxiety, and low in self-efficacy.

Best Represents Scenarios

A table and frequency histogram of the best represents scenarios, comparisons of her top 4 – 5, and her description of a lesson that best represents her preferences is shown below.

Table 4.9

Barbara: Preferences for Best Represents Scenarios

Essential Feature	**Level(s)**	**%**	**Freq.**
Question	Open	1.49	2
Evidence	Guided	0.93	2
	Confirmation	6.08	3
	Outside of Inquiry	6.47	6
Explanation	Structured	1.94	2
	Confirmation	4.67	2
	Outside of Inquiry	0.62	1
Connection	Guided	0.69	1
Communication	Structured	1.82	1
	Confirmation	0.64	2
	Outside of Inquiry	2.3	3

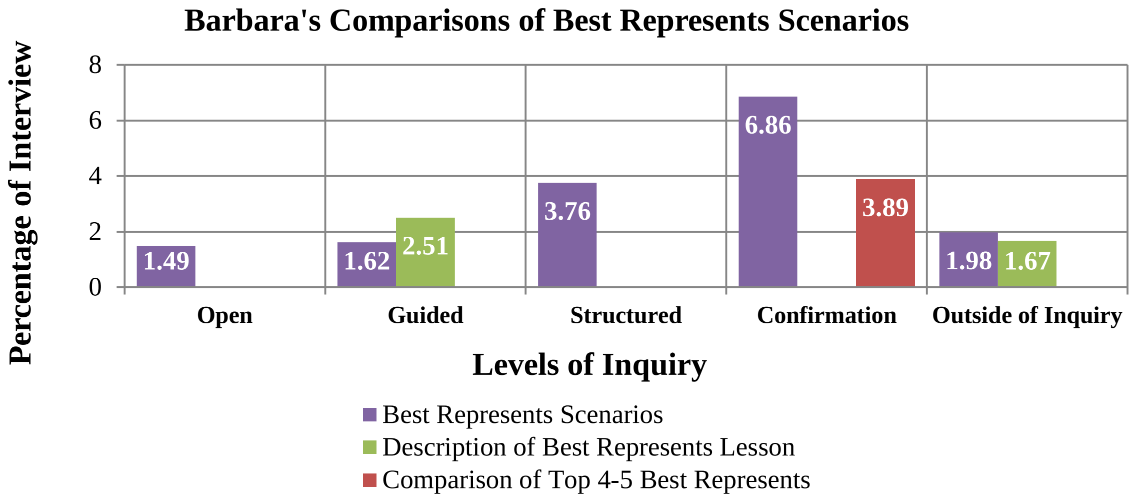

Figure 4.1. Frequency Histogram of Best Represents Scenarios

Based on her interview data, her preferred instructional strategies for best represent scenarios were coded by five essential features of inquiry. Her preferences placed her in the confirmation part of the continuum. For the vast majority of the interview, any explanations were provided by the teacher or resources such as, "The next day we can come back and when they've had a chance to look at other things, maybe they read the chapter in the book which deals with why it wouldn't have worked that way." For the communication feature, she preferred that students communicate their findings within a format provided by the teacher.

> Students write lab reports explaining what they learned. I like introducing that if I'm thinking fourth, fifth, grade - in my situation here in elementary school. And they test in fourth grade on writing and writing is everywhere. So why not have it be a very important piece of science as well.

As with many of the teachers in the study, she equated communication with practicing writing skills, particularly to prepare for high-stakes testing. This matches the outside of inquiry level where students summarize knowledge from reading and communicate this knowledge as part of an assessment.

Description of Recently Taught Lesson that Best Represents

Asking the teacher to describe a recent lesson that best represents their preferences for science instruction enabled the researcher to cross check the teacher's ratings of scenarios with their own lessons to determine the reliability of their scenario ratings. In Barbara's description of her recently taught lesson, no mention was made of question preferences. Although her lesson did begin with a question, it was procedural, not inquiry. Her description of a best represents lesson encompassed an isolated activity-based lesson that she described as integrating math and science because they were sorting beans.

> We were looking at the attributes of some different kinds of beans…And so the students were given a bag of mixed beans and the math portion of it is we are starting to sort it and lay it out on the table… and I gave them a larger index card and … then we glued the beans on.

Although she indicated she wanted students ask their own questions, but did not do this in her own best represents lesson, nor did she mention it as one of her goals and purposes.

Another method of holistically classifying her preferences was to examine areas matching her ratings of the twelve researcher-created scenarios with those of the research team. Two of her communication coded preferences matched the classifications from the research team, but all the other ratings diverged from the researcher ratings, with the other coding preferences moved towards the confirmation and the outside of inquiry end of the continuum.

Changes to Does Not Represent Scenarios

A frequency histogram of the total unsure, does not represent, and changes to does not represent scenarios are shown below in Figure 4.2.

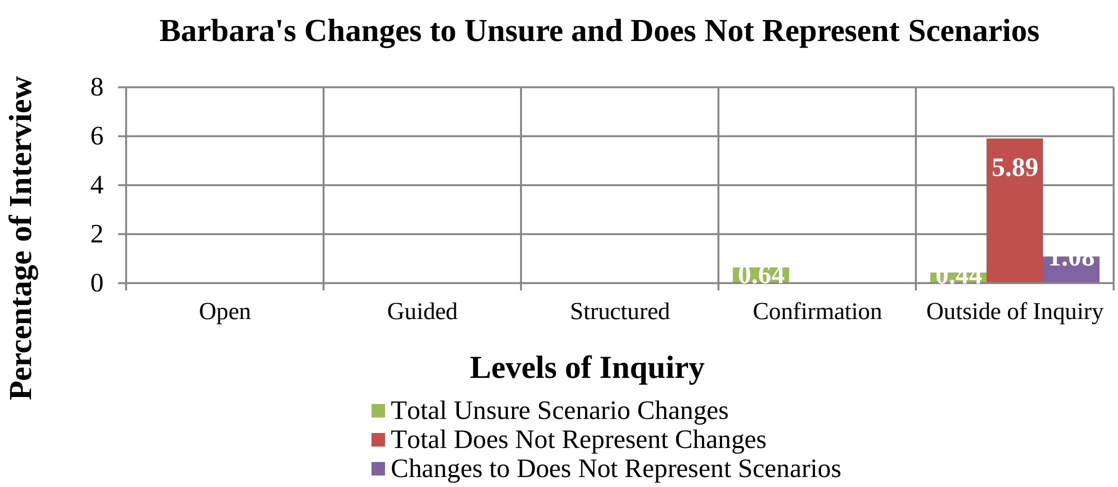

Figure 4.2.: Frequency histogram for changes to Unsure and Does Not Represent

Examining the changes she made to scenarios that did not represent her preferences revealed that she actually moved them more towards the outside of inquiry end of the continuum. Barbara described this when she improved a scenario that she rated as does not represent by having students create a diorama. “I like the idea of the diorama because then they could make the different kinds of clouds…maybe we would talk about pressures and the fluctuations, and what causes wind, and all that stuff.”

In scenarios inconsistent with researcher ratings, the majority of the scenarios she selected as unsure or does not represent were outside of inquiry, yet when asked how she would change them her descriptions simply added additional activities without moving the scenarios towards the open end of the continuum.

Campus Culture Expectations

Other questions elicited her definitions and applications of terms that may be part of a campus culture such as “hands-on” learning. See Figure 4.3 below.

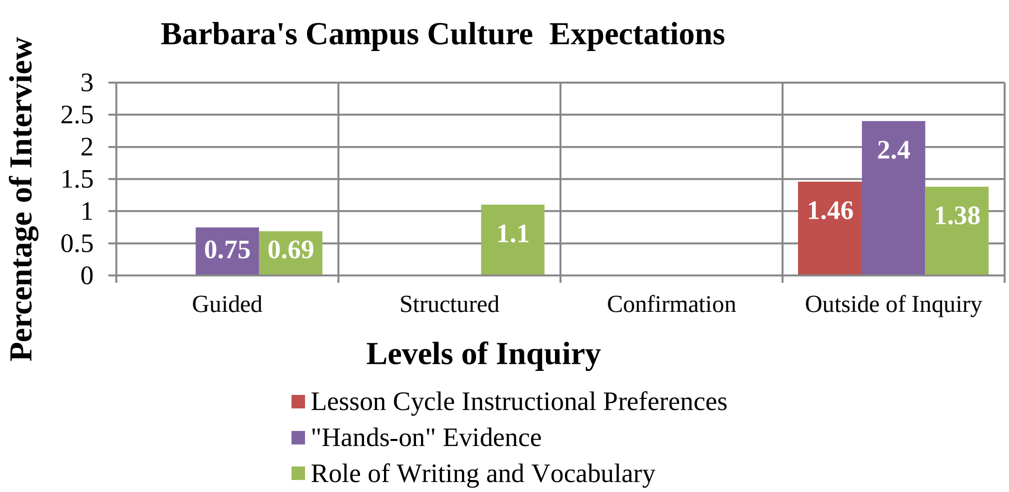

Figure 4.3: Histogram Frequencies for Campus Culture Expectations

Barbara’s references to hands-on included isolated activities designed to engage students but without the intent of collecting and analyzing data such as, “I like the hands-on approach. I'd rather have an activity than a worksheet any day.” Her lesson cycle preferences were primarily determined by her desire for students to gather data but without any mention of analysis. The role of vocabulary and writing was a skill apart from the purpose of scientific communication. “You want the students to write, whether it's writing in their journals, creating a formal lab report, or even just writing questions down, jotting things down on a Post-it note.”

Role of Experiments, Hypothesis, Research, and Testable Questions

Other areas include the role of experiments, hypothesis, research, and testable questions. See Figure 4.4 below.

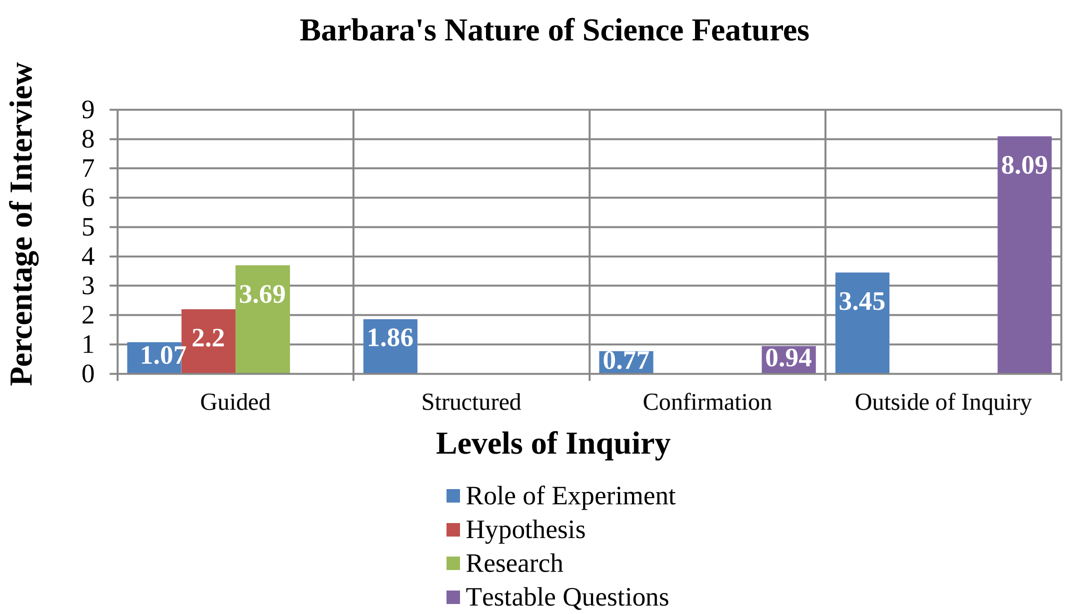

Figure 4.4: Histogram Frequencies for Nature of Science Features

Barbara's description of the role of research and other areas of the Nature of Science include her definitions and applications of hypothesis, research, experiment, and testable questions. Like many other teachers, she confounds hypothesis with prediction. When asked if she could think of an example of when the class created a hypothesis, she answered, "I mean we do weather every day. Children look out the window, and are making observations, and you know, what do you think? Let's make some predictions." Barbara (and many of the teachers in this study) view research or experimentation as based on a hypothesis, the process of data collection, and some representations such as graphs. When asked what research looks like in her classroom, she answered, "Making observations, recording it, trying to come up with some generalizations based on what we saw. Maybe we'll get to do a graph; maybe we'll get to look at different things." Her descriptions of experiments mirrored her preferences for students gathering their own data. "To gather some data, whether it's through observation, or their testing it, or they're doing comparisons – you know - side-by-side two different things…Being able to gather some data and understanding what that data means – that's the experimentation piece." Finally, when asked what she does when her students come up with questions that are not testable she replied,

> We would probably do it in class but maybe we would do the vocabulary first so they knew what they were dealing with, and maybe we would read a book or watch a video just so they could see it, and then maybe to stimulate some of that curiosity. And then by that time hopefully they would be able to come up with an idea - after the KWL and the video and the book – then maybe they would have an idea of what they would want to know.

Based on the data described in this interview, Barbara was placed on the teacher-centered portion of the inquiry continuum. Justifications for this placement include best represents lessons that show a marked preference for the confirmation level of inquiry, especially with evidence and explanation. Although she stated that student questions should drive the scenarios she altered, she provided no examples of how she would implement this, and did not do so in the description of her own lesson. Changes to her does not represent and unsure scenarios were almost exclusively outside of inquiry, with a small percentage of confirmation. Therefore, the holistic placement of Barbara along the essential features of inquiry places her close to the most teacher-centered instructional focus and the confirmation level of inquiry.

Daniel

Daniel's teaching assignment and demographics were self-reported during the online survey. His current teaching assignment is at a low-income school within a large urban school district teaching 4th grade Bilingual Math and Science. His area of specialization was self-reported as Math and Science, with 9 - 11 years of teaching experience, a BA in History; JD; and graduate hours in Elementary Education. His levels of anxiety and self-efficacy were measured in the same online survey by the STAI (State Anxiety sub-test) and the STEBI (PSTE sub-test). Ranking him among all participants put him in the low anxiety and high self-efficacy group.

Best Represents Scenarios

A table and frequency histogram of comparisons with the best represents scenarios, comparisons of his top 4 – 5 that best represent, and her description of a lesson that best represents his preferences is shown below.

Table 4.10

Daniel: Preferences for Best Represents Scenarios

Essential Feature	**Level(s)**	**%**	**Freq.**
Question	Confirmation	0.58	1
	Outside of Inquiry	1.58	4
Evidence	Open	2.03	2
	Guided	5.57	7
	Structured	0.72	1
	Confirmation	2.11	2
	Outside of Inquiry	10.78	11
Explanation	Structured	0.69	1
	Confirmation	0.94	2
	Outside of Inquiry	7.62	9
Communication	Structured	0.63	2
	Confirmation	1.43	2
	Outside of Inquiry	0.65	2

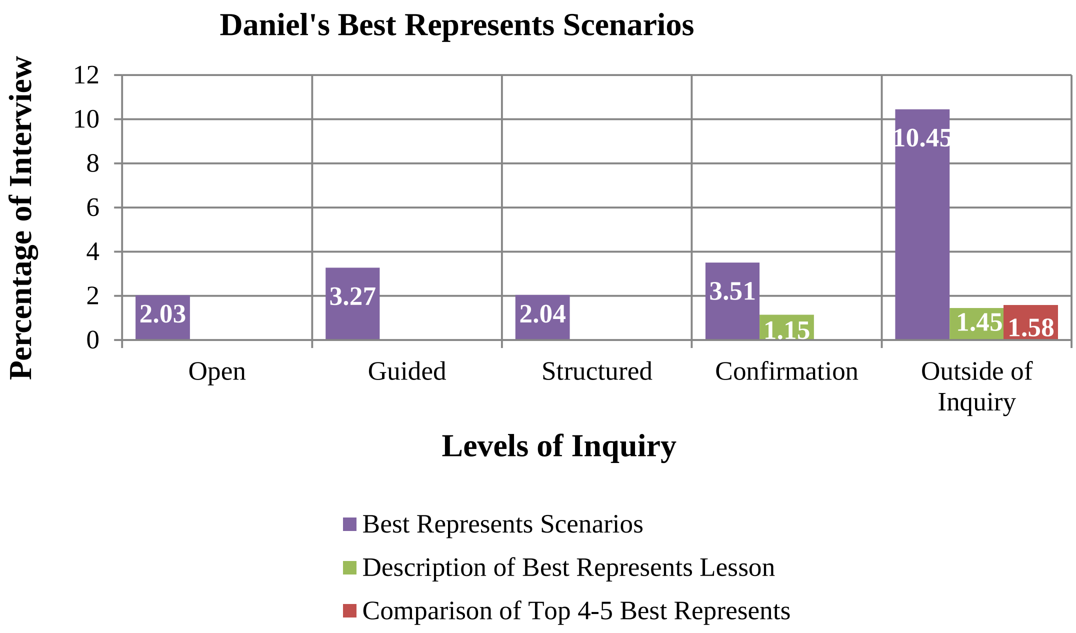

Figure 4.5: Histogram of Frequencies of Best Represents Scenarios

Based on interview data, Daniel's preferred instructional strategies for best represent scenarios were coded by five essential features of inquiry. The majority of his coding for scenario preferences fell within the outside of inquiry level. His ratings of questions were almost exclusively outside of inquiry, illustrated by statements such as, "We do teach electricity and we're going to be moving in the next grading period into energy and force and all that, and we had a little scientific investigation earlier about conductors and insulators." This describes his primary instructional preference – an isolated, activity based lesson that does not seek to answer a question or have students create their own explanations. But like many of the teachers interviewed, he did prefer that students collect data themselves, however mostly for the sake of engagement. For the essential feature of evidence in one of his best represents scenarios he described a guided level where "The kids have selected this - it's open-ended. Find ways to make this bulb work." Instead of students creating their own explanations, they are provided by the teacher or other resources. He describes this as, "Once the criteria for defining an insect has been met, then you could look and see if their graphic organizers actually correspond to the true definition of an insect." Finally, his preferences for communication fall within the confirmation level when he states, "…in this particular lesson the students are working together in groups to fill in sections of the poster and are going to present it to themselves. So you have student involvement in many different levels, and the teacher too."

Description of Recently Taught Lesson that Best Represents

Overall patterns of Daniel's description of a lesson that best represent how he prefers to teach science were predominantly situated on the confirmation and outside of inquiry end of the continuum. Areas consistent with his preferences in the twelve scenarios include references to confirmation levels in explanations and communication, along with outside of inquiry for questions and evidence. Areas diverging from preferences in twelve scenarios were almost exclusively for evidence coded as guided, given that the lesson he described was outside of inquiry for evidence. Students gathering data themselves was cited as important by Daniel (and many other teachers) especially as they mentioned their preferences for hands-on activities. References include statements such as "So I do like the fact that this investigation that they are observing and actually recording their data on their own.” This cross check of his scenarios reveals that although he may state a preference for the guided level of evidence, he may not practice this in his own science instruction.

Changes to Does Not Represent

A graph of his total percentages for unsure, does not, and changes to does not represent is shown below in Figure 4.6.

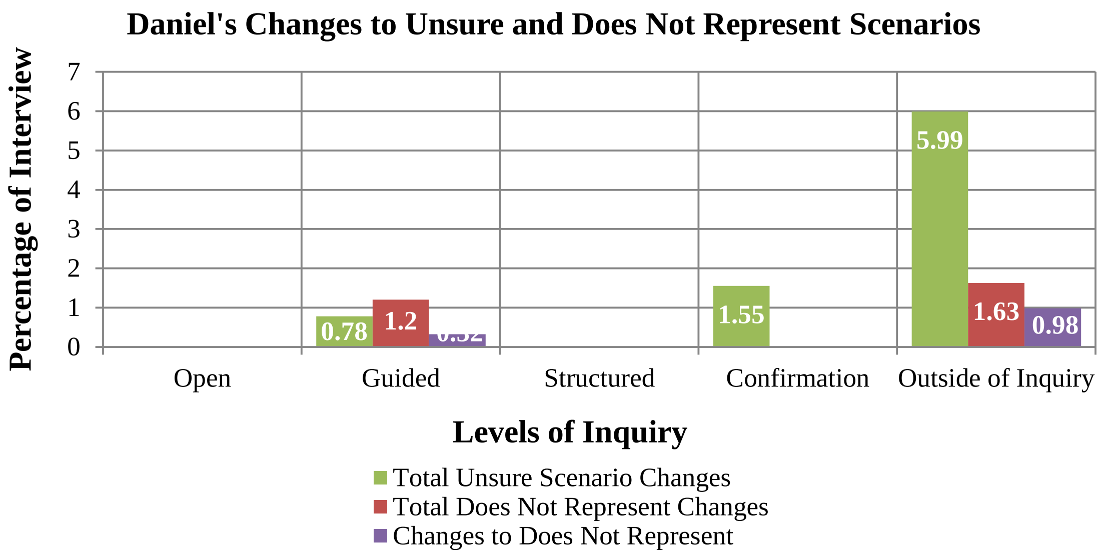

Figure 4.6: Histogram of Frequencies of Changes to Unsure and Does Not Represent

Daniel placed two entirely open scenarios as unsure or does not represent, and justified one of his preferences by stating,

> The reason why don't like it, is it’s very, very open. The group designs and carries out their own experiments…because of that I do not think that little

kids should be left to their own devices to come up with this sort of investigation.

He also took another scenario that was a mixture of levels, specifically guided for evidence and stated that he would improve it by actually moving it to outside of inquiry. “You look at the wealth of materials online - all the different science resources and videos and things like that - the books that are available, the TV programs that are out there.” In other scenarios he did diverge from his overwhelming preference for outside of inquiry but almost exclusively as guided for evidence. This level of Inquiry has students instructed to collect certain data themselves. Once again, this meets his preference for hands-on, and is illustrated by a reference that states, “…it is important that the students develop observation skills and learning about how their five senses are so very, very relevant in what they learn in school.”

Campus Culture Expectations

The histogram below shows the only area coded for campus culture expectations.

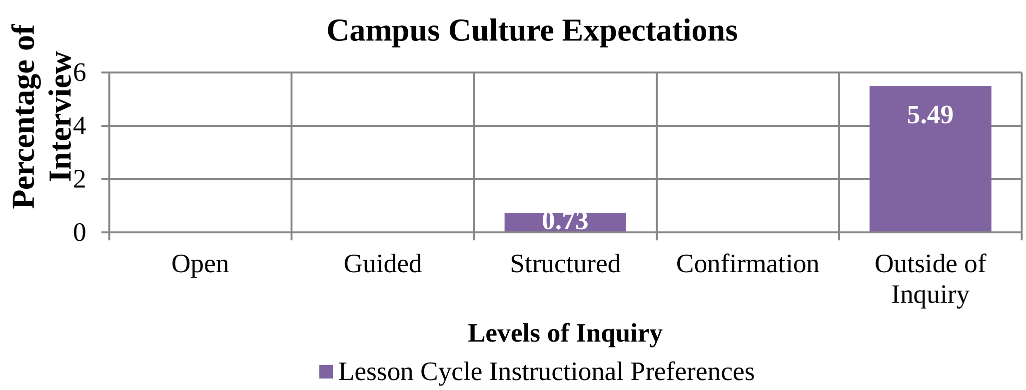

Figure 4.7: Histogram of Frequencies related to Campus Culture

Other aspects of Daniel's preferences for science instruction included his definition of "hands-on" instruction. He defined it as "doing hands-on, doing. I think that what it's about. You should be a guide or facilitator." Another area related to campus culture is the role of vocabulary in science instruction. "If you're using vocabulary building you could put an insect in and define it and draw pictures, give examples of what is or is not an example, what is not an insect." One of the ways to holistically place Daniel along the inquiry continuum was by his traditional, vocabulary dependent lesson cycle preferences.

> We can just read about it to understand the phenomenon – and the different cloud formations and what a high front and a low front is, but I want hands-on. You're gonna look at that weather map and you're gonna tell me what's happening based on the symbols on that weather map.

These additional areas provide more evidence that his preferences are for outside of inquiry.

Role of Experiments and Research

The histogram below shows Daniel's references to the role of investigation and research.

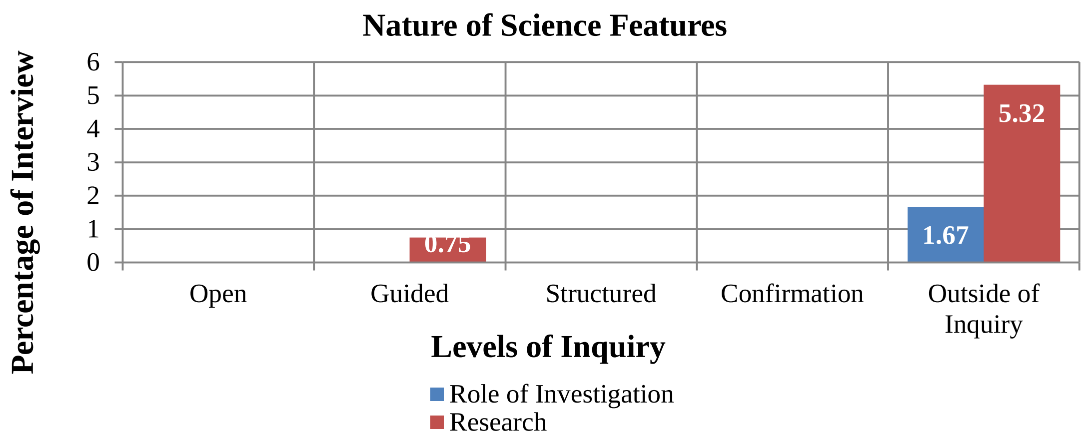

Figure 4.8: Histogram of Frequencies related to Nature of Science

When Daniel described aspects such as the role of research and experimentation, he shared many of the misconceptions common among the participants in this study. When asked about the role of investigation he stated that,

> I think that when you have a kid doing an experiment and they make their hypothesis and it didn't work out, sometimes kids give up and maybe do the experiment all over again, the exact same way. Okay you've got to learn that it's - maybe organized trial and error I suppose... And this gets kids to investigate and share why and why not. Variables - what did you do that we didn't do - those sorts of things. So I think in science you learn by your mistakes.

When Daniel described research in his classroom he interpreted it as an exercise in reading.

> Well I think research at the elementary level is not quite what it is in the other grades. We want them to develop reading for different purposes, and so we discuss about what books we want them to check out the library...

> Also we have computers and we get online and we get on different sites websites – I do have science books here too, and the kids have access to those in the classroom.

Another term he discussed was his interpretation of a common myth in elementary education – the idea that there is one “scientific method.

> You have the stereotypical method - you start out with a hypothesis and then your question and you do your investigation and get your materials; you collect data and you observe. You might have the variables and all that, and repeat the investigation or do it over time. Did you know what you're doing? Find out whether or not your hypothesis was correct, that sort of thing.

In conclusion, Daniel’s preferences for science instruction are overwhelmingly at the outside of inquiry end of the continuum. A holistic rating classifies him as preferring the most teacher-centered model of instruction. Justifications for placement include his ratings for best represent scenario preferences as confirmation and outside of inquiry, the changes to unsure and does not represent scenarios moving them to the confirmation and outside of inquiry end of the spectrum, and most especially the description of the lesson that best represents him as almost exclusively outside of inquiry.

Jane

Jane’s teaching assignment and demographics were self-reported during the online survey. Her current teaching assignment is at an elementary school within a large urban school district teaching 5th grade Math and Science. Her area of specialization was self-reported as Science, with 12+ years of teaching experience, a BS in Communication

Disorders. Her levels of anxiety and self-efficacy were measured in the same online survey by the STAI (State Anxiety sub-test) and the STEBI (PSTE sub-test). Ranking her among all participants put her in the medium anxiety and high self-efficacy group.

Best Represents Scenarios

The levels of inquiry for Jane are shown below in a table and histogram of her best represents scenarios, comparisons of her top 4 – 5 best represents, and a description of a lesson that best represents her preferences for science instruction.

Table 4.11

Jane: Preferences for Best Represents Scenarios

Essential Feature	Level(s)	%	Freq.
Question	Guided	1.99	3
	Structured	0.43	1
	Confirmation	0.58	1
	Outside of Inquiry	1.58	4
Evidence	Open	0.9	1
	Guided	2.21	3
	Confirmation	0.76	1
	Outside of Inquiry	10.69	7
Explanation	Guided	1.08	1
	Structured	1.23	1
	Confirmation	3.70	3
	Outside of Inquiry	8.4	10
Communication	Guided	1.09	2
	Confirmation	1.73	2
	Outside of Inquiry	4.47	9

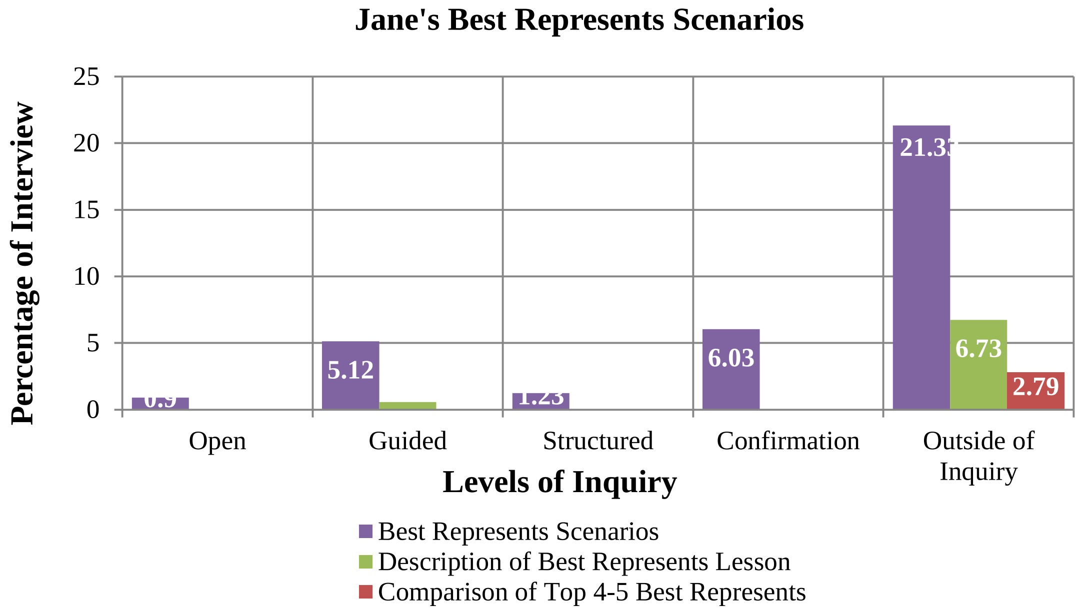

Figure 4.9: Histogram of Frequencies of Best Represents Scenarios

Jane's preferred instructional strategies were coded by five essential features of inquiry based on her ratings of the scenarios that best represents, comparisons of her top 4 – 5, and descriptions of her own best represents lesson. The overall percentages of her preferences placed her in the outside of inquiry part of the continuum. For the essential feature question, her chosen level of inquiry was primarily guided, with students selecting a question from ones provided by the teacher. She explains this by describing how she would, "definitely provide some type of probing or open-ended question… maybe add some of those questions in there. What time of day do birds seem to go to the feeders?" For the feature evidence, Jane expressed a primarily outside of inquiry approach, but with some preference for students gathering their own data. However, this was for the purpose of engagement and no analysis was attempted. “I would think they are hands-on. They’ve got the bread, they’ve got the water, the whatever, the petri dishes, they’re setting up things, they’re doing. They would enjoy that and they would learn more.” Her preferences for explanation were also outside of inquiry – an isolated activity that does not require students to create an explanation, but has them engaged in an activity.

> Again, since we can’t do a lot of hands-on with the moon… I think maybe they could use different materials to create the moon. You know, they could put little cereal pieces in their moon phases instead of just drawing it with paper and pencil or something.

Finally, Jane’s description of communication was also outside of inquiry, primarily as a tool for assessment. “You know, there’s that little assessment piece: here’s the phases, put them in order and label them. It doesn’t really matter where you start.”

Description of Recently Taught Lesson that Best Represents

Cross-checking for the validity of a teacher’s preferences for science instruction was accomplished by asking them to describe a lesson they recently taught that best represents how they prefer to teach science. Jane’s description of her lesson did not begin with a question, mistrusting her preferences for guided questions. Evidence was an isolated activity that was engaging but did not ask the students to analyze data. She stated that she would,

> Turn them loose in their small groups, you know, four, five at the most depending on the size of our class to work together and follow some procedures lined out on paper for them. Do this, do this, add this amount of liquid to this cup, put this amount of the diatomaceous earth or

whatever, you know, record your observations, how would you separate it?

Explanations were mainly an exercise in vocabulary memorization.

> But then the ultimate goal is understanding the difference between a mixture and a solution. We throw in vocabulary. We have mixture, solution, dissolve, invisible, solubility, solute, solvent, saturated… in their Science vocabulary spiral, they have the words with the definitions in there, you know, the textbook definitions and then the more common definition.

Holistic comparison of Jane's preferences in the twelve scenarios to researcher ratings showed a match to the researcher for only two references, and was divergent from preferences in the twelve scenarios for every other reference. Areas moved on the continuum showed all features of inquiry that she did move, were moved towards the confirmation and outside of inquiry levels. Her comparisons of best represents scenarios showed an overall pattern stating that her purposes and goals were predominantly outside of inquiry. Her comparison of her top 4-5 scenarios matched a preference for only two scenarios utilizing confirmation or outside of inquiry. But all the other areas she preferred were moved toward the outside of inquiry end of continuum.

Changes to Does Not represent

A graph of her total percentages for unsure, does not, and changes to does not represent is shown below.

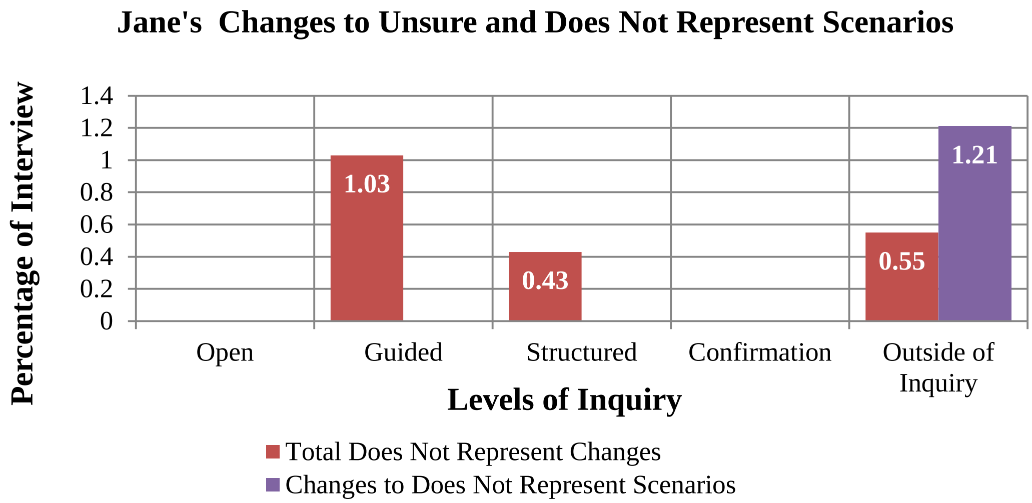

Figure 4.10: Histogram of Frequencies of Changes to Unsure and Does Not Represent

One of the scenarios she disliked was entirely open, and she added changes to provide more guidance from the teacher. She didn’t have many scenarios rated as unsure or does not represent, and the only changes she made were to move the most open scenarios to the guided level.

Campus Culture Expectations

The histogram below shows the only area coded for campus culture expectations.

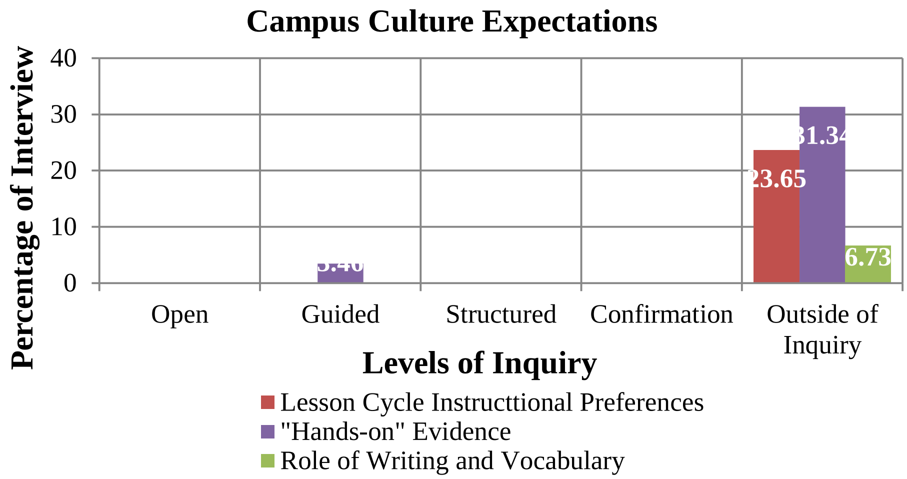

Figure 4.11: Histogram of Frequencies related to Campus Culture

One term mentioned by every teacher interviewed was "hands-on." When as how she defined the term, Jane stated that, "… to me hands-on is engaging because they're doing. They're an active participant, but they're actually doing. They're physically manipulating something, moving it or measuring it or something." She also described her preference for guided evidence as "hands-on, actively involved engaged sharing…you want students to be able to make the observations themselves, pull in some sort of tactile, kinesthetic activity where the students will be engaged and they're actually manipulating the materials themselves."

Another aspect of campus culture is the role of vocabulary in science instruction.

> Well, we start out with just basically giving them the list with the definitions. Rather than have them copy from the board, copy from the

overhead, it's pre-printed. We make copies for the kids, we trim it and we glue it in a spiral or we have holes punched and we put it in a folder.

In additions, lesson cycle preferences were coded for an overall teacher-centered model of instruction.

> I would need to perhaps give them materials or scenarios or questions that were a little more limiting, not completely limiting, but so hopefully they would end up after just maybe turning them loose on this at least close to where I want them to be or discovering something even if it's not the actual end, they're close to the end. Something like that - the end question or the end TEK or the end Science knowledge.

Role of Experiments and Research

Other areas include the role of research, and testable questions are shown in the histogram below.

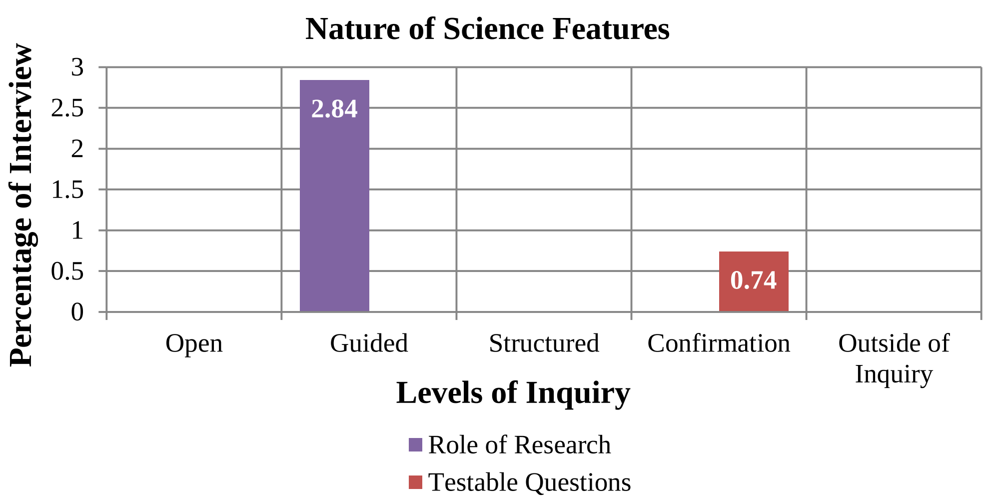

Figure 4.12: Histogram of Frequencies related to Nature of Science

Jane’s description of the role of research indicated a preference for guided evidence with students collecting their own data, such as “was field investigation; (she would) like the students to be able to do some of their own first hand observations.” Her definition of testable questions indicates this preference for guided levels of inquiry when she states, “Is it really a testable question? Who’s going to test it? And if we’re just looking up data that somebody else has gathered, we’re not doing the testing.” Content misconceptions are another area that help to holistically place teachers along the inquiry continuum.

> We do mention that we’re following the scientific method or state specifically that for this, you know, we’re definitely going to follow it step-by-step. We do some sample things that we take them through, piece by piece so they know.

Jane’s misconceptions about one “scientific method” help to determine her preference for a teacher-centered model of instruction.

Jane’s placement along the inquiry continuum is at the confirmation end of the spectrum, indicating a teacher-centered model of instruction. Justification for the placement is based on the fact that her best represents scenarios show a marked preference for outside of inquiry. In addition, her changes to does not represent and unsure were mostly guided, although she also moved almost every change she made in a scenario to the outside of inquiry level. Jane’s description of her best represents lesson was exclusively outside of inquiry, holistically classifying her as preferring a teacher-centered philosophy of science instruction.

Karen

Karen's teaching assignment and demographics were self-reported during the online survey. Her current teaching assignment is at a low-income elementary school within a large urban school district teaching Bilingual Kindergarten. Her area of specialization was self-reported as Reading, with 9 - 11 years of teaching experience, and an MA in Psychology. Her levels of anxiety and self-efficacy were measured in the same online survey by the STAI (State Anxiety sub-test) and the STEBI (PSTE sub-test). Ranking her among all participants put her in the high anxiety and low self-efficacy group.

Best Represents Scenarios

The levels of inquiry for Karen are shown below in a table and histogram of her best represents scenarios, comparisons of her top 4 – 5 best represents, and a description of a lesson that best represents her preferences for science instruction.

Table 4.12

Karen: Preferences for Best Represents Scenarios

Essential Feature	Level(s)	%	Freq.
Question	Open	3.35	3
	Confirmation	2.46	1
	Outside of Inquiry	1.07	1
Evidence	Open	0.44	1
	Guided	1.41	1
	Structured	1.98	2
	Confirmation	0.9	1
	Outside of Inquiry	13.9	4
Explanation	Outside of Inquiry	3.46	4
Communication	Open	0.69	1
	Confirmation	0.93	2
	Outside of Inquiry	1.93	3

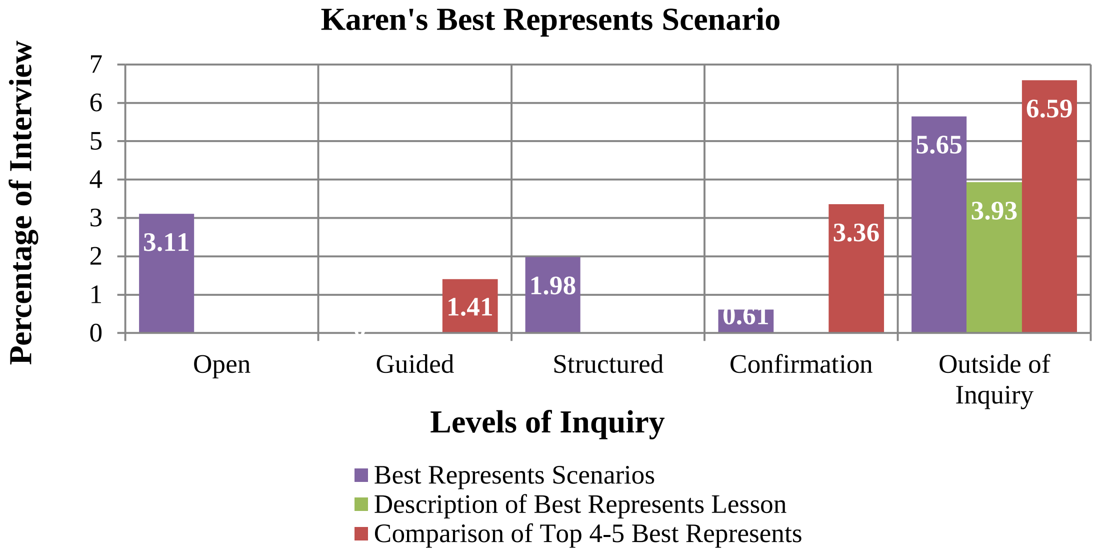

Figure 4.13: Histogram of Frequencies of Best Represents Scenarios

Based on her interview data, her preferred instructional strategies for best represent scenarios, comparisons of the top 4 – 5, and the description of their own best represents lesson were coded by the five essential features of inquiry. For the feature question, Karen stated a marked preference for the open level of inquiry. She described this by stating that, "I really like that the students are asking questions already; it was coming from them. I geared my lesson towards what they wanted. I like that." Her evidence preferences were structured and outside of inquiry, describing an isolated lesson that is not based on answering a question or analyzing data that is collected. "I really, really like this one cause they're going out there and observing – they're using their senses, and they're recording it. I really like the fact that they're recording it, in like a little journal." Her preferences for explanations were also outside of inquiry. She describes a summary of information, not an explanation by “they’re putting them on a graphic organizer. So they're using you know also vocabulary - I'm sure in this graphic organizer there's vocabulary.” The last essential feature, communication is also outside of inquiry, described as equating this area with assessment or summarizing an explanation provided to the students. Karen described her preferences by stating that “they organize their thoughts and comments on to a chart. I really like that.”

Description of Recently Taught Lesson that Best Represents

Cross-checking for the validity of a teacher’s preferences for science instruction was accomplished by asking them to describe a lesson they recently taught that best represents how they prefer to teach science. Although Karen stated a preference for open questions, she made no mention of any question preference in her best represents lesson. Her preferences for the feature evidence were outside of inquiry, and described an isolated, teacher-centered activity.

> So for example this week we’re investigating exploring magnets. So I went ahead and called different students to come up and use the magnets that were provided by the district. I only had 12, so I had to call them one by one.

The explanation feature also described a lesson where students summarized information. She described that “then kids go ahead and check the student’s answers, if they agree with it with thumbs-up or thumbs down. And then we go ahead and carry out a little experiment - you test it out.”

Comparing preferences in the twelve scenarios to researcher ratings, Karen only stated that two scenarios did not best represent her preferences. She moved the question feature towards the open end of the continuum, yet all the other features moved towards confirmation and outside of inquiry. In her comparisons of best represents lesson she described an overall pattern that was predominantly outside of inquiry, an isolated activity. She described having one student at a time come up front to test objects because the district sent her 12 magnets and she has 19 students. Although she moved the scenario questions to open, she did not practice this in her own lesson. Her comparison of her top 4-5 matches described a preference for students driving the questions and even explanation, but she contradicted herself later in the same question when asked about her lesson cycle. “It's usually direct teach, then if there’s time for an experiment or video or a whole group activity that's kind of like I started and then they can go off and do an independently or as a group or with a partner. And then they can go to the center and explore maybe with the magnets if we have magnets, or if we’re studying bugs maybe they can go and explore the bugs”

Changes to Does Not Represent

A graph of her total percentages for unsure, does not, and changes to does not represent is shown below.

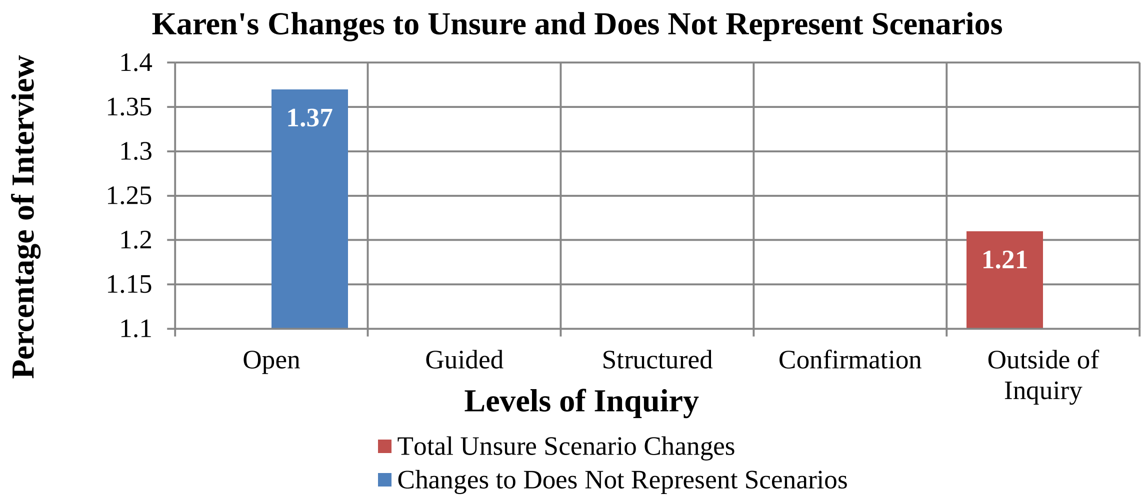

Figure 4.14: Histogram of Frequencies of Changes to Unsure and Does Not Represent

Karen's stated preference for students coming up with their own questions; but she also stated that "the teacher even provided the question, which is okay, maybe sometimes that helps students who are stuck coming up with questions. I know kindergartners are especially - they just stare at you - so having the questions already set can be good." The changes she made to evidence and explanation parts of scenarios that she did not prefer actually moved them more towards the outside of inquiry end of the continuum.

Campus Culture Expectations

The histogram below shows Lesson Cycle Instructional preference, the only area coded for campus culture expectations.

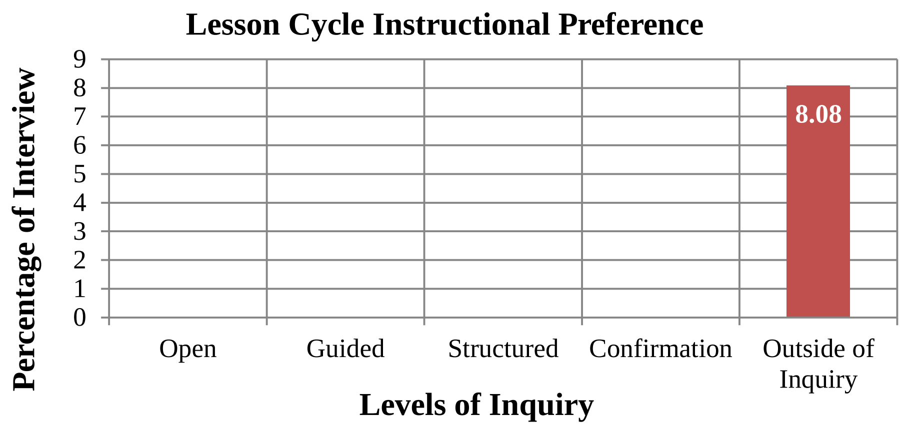

Figure 4.15: Histogram of Frequencies related to Campus Culture

The definition of "hands-on" instruction was mentioned by every teacher yet there was no consistent use of the term. Karen stated that,

> Hands-on would mean - for example - the magnet lesson that I gave. That's a little bit more hands-on because it's not just a paper and pencil thing that they do and they color. They're actually going and using an object and exploring with the classroom with their senses that's more of a hands-on.

The purpose of hands-on for her was for the sake of engagement and fun; described changing a lesson and turned it into an art project.

> But I would think that the students would also to like maybe create something with the moon, like maybe use clay, or play-doh, or materials that they have around. They can create it on their own, you know. Maybe

> something they create like with construction paper. A foldable is nice and it shows you the phases of the moon in the sequence. But I like the hands-on stuff for them, and it's good but I would prefer something else - a little bit of an extension like making with your hands, or with some construction paper, objects and stuff.

Her lesson cycle preferences were holistically coded as teacher-centered, as she stated,

> For science I start off my direct teaching usually at the very beginning, when I'm talking and explaining what we're gonna be studying, and I asked them a question to kind of start their brains spinning on the subject. I go over to my science wall, and just kinda go over the vocabulary that we're gonna be using, what they can be doing in the center when it's their turn to go to the center. That's what I do.

Role of Experiments and Research

Other areas include the role of investigation, research, and testable questions shown in the histogram below.

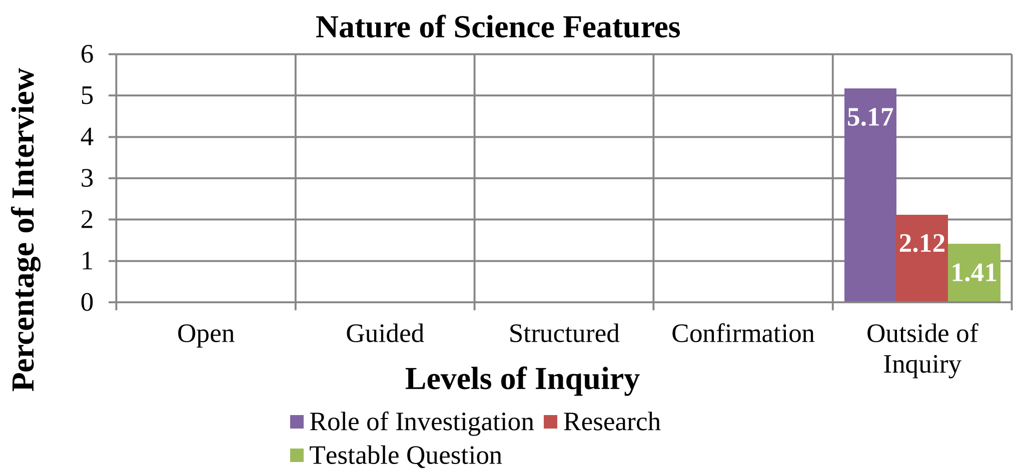

Figure 4.16: Histogram of Frequencies related to Nature of Science

Karen’s description of the role of research and other areas of the nature of science include her definitions and applications of investigation, research, and testable questions. For her, the role of investigation was primarily teaching the children to locate written references on a topic. When asked about what an investigation would look like in her classroom, she replied,

> I use it as much as I possibly can when it pertains to the lesson. Sometimes they don't have the books that we like, so we just find them online or just kind of make do with what we have already in the classroom.

Although she professed a strong preference for open questions, when asked what she does when kids ask questions that are not testable, she discussed it in terms of the scenario observing birds. I asked what kind of question students might ask that would not be testable, and she mentioned “What would happen if we put the parrot outside? Or another thing is we would research it - we would investigate it maybe online or in a book. We would find the answers you know.” All the references she made to the role of research in the classroom involved locating a written or online resource for the students to read.

Karen’s preferences for science instruction place her within the outside of inquiry portion of the continuum. Even though her best represent scenarios show marked preference for open questions, she did not utilize this in the description of her own lesson, instead choosing to use an isolated activity. In fact, although she didn’t have enough magnets for each student to use one, she could easily have them work in pairs, but instead chose to make her lesson even less hands-on by calling one student at a time to participate in a demonstration. The changes she made to improve scenarios that did not represent her preferences mostly moved them further into the outside of inquiry end of the continuum. Therefore Karen was holistically classified as preferring a predominantly teacher-centered instruction model of instruction.

Linda

Linda's teaching assignment and demographics were self-reported during the online survey. Her current teaching assignment is at an elementary school within a large urban school district teaching a 3rd grade self-contained class (all subjects). Her area of specialization was self-reported as Language Arts, with 12+ years of teaching experience, and a BS Elementary Education - Early Childhood with a minor in English. Her levels of anxiety and self-efficacy were measured in the same online survey by the STAI (State Anxiety sub-test) and the STEBI (PSTE sub-test). Ranking her among all participants put her in the high anxiety and low self-efficacy group.

Best Represents Scenarios

The levels of inquiry for Linda are shown below in a table and histogram of her best represents scenarios, comparisons of her top 4 – 5 best represents, and a description of a lesson that best represents her preferences for science instruction.

Table 4.13

Linda: Preferences for Best Represents Scenarios

Essential Feature	Level(s)	%	Freq.
Question	Open	1.92	4
	Guided	2.24	2
	Structured	0.74	1
	Confirmation	1.54	2
Evidence	Open	1.4	2
	Guided	3.14	2
	Structured	0.69	1
	Confirmation	0.61	2
	Outside of Inquiry	3.96	3
Explanation	Open	0.34	1
	Guided	0.63	1
	Structured	2.17	3
	Confirmation	2.74	2
	Outside of Inquiry	4.3	1
Communication	Structured	1.89	1
	Outside of Inquiry	6.14	4

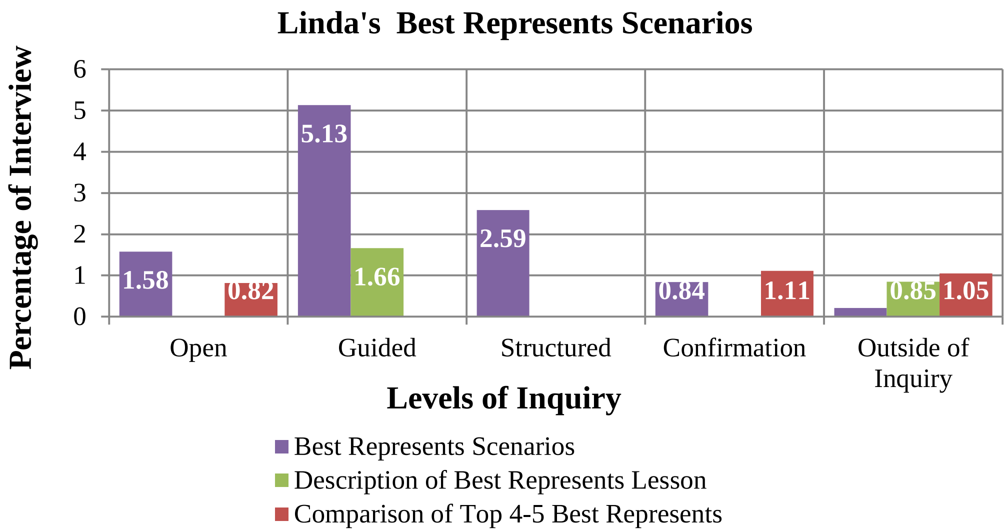

Figure 4.17: Histogram of Frequencies of Best Represents Scenarios

Based on her interview data, Linda's preferred instructional strategies for best represent scenarios, comparisons of the top 4 – 5, and the description of their own best represents lesson were primarily guided. Her question preferences were scattered across many levels, but with a strong preference for the open and guided end of the continuum. Her open preferences for questions were illustrated by the statement, "I think right here what I would probably change is have them come up with a question from what they've observed, then they may come up with a better question than what I have." She also indicated some preference for guided questions when she stated that "…of course if you need it, I'd leave this a little bit more open-ended, they could select a question from my list or if they had their own." In the evidence feature one preference was guided, but mostly for student engagement and not to collect and analyze data. "I like how they are able to observe, I think they would enjoy observing and making sketches because then it connects them a little bit more to a real-life situation because it's something that they have noticed." She also described some outside of inquiry strategies - reading activities where she confounded discussions about books with inquiry.

> Every time you would do it, you would do more of an inquiry-like thing - you would read the book, and then look at and discuss it – this book was about ladybugs, and this book was about spiders; why they the same and are they different?

Her explanation preferences were primarily confirmation, with information provided to students that guide them to an explanation. Linda continues to describe inquiry as reading to gain information.

> Then just start making a running list and then maybe when you're finished with two or three books, or however many books are going to read, that they would notice, "oh - all of these like the grasshopper all have the same amount of body parts, and all have the same amount of legs." More of an inquiry type of thing.

Finally, communication was also on the outside of inquiry level. Instead of students justifying their explanations, they summarize explanations provided to them. "So I'd rather give them a choice of how they present their information, it that makes more sense."

Description of Recently Taught Lesson that Best Represents

Asking the teacher to describe a recent lesson that best represents their preferences for science instruction enabled the researcher to cross check the teacher's ratings of scenarios with their own lessons to determine the reliability of their scenario ratings. Linda made no mention of basing her lesson on a question in her best represents lesson, even though she indicated a strong preference for open questions in her ratings of the scenarios. Her preference for guided evidence described students collecting data for the sake of engagement, yet no analysis. “So what they had was that each table had 2 cups of water; 1 cup was hot water and 1 cup was cold water. What they were doing was they were observing food coloring that was dropped in.” Linda’s explanation preferences matched the rest of her lesson as primarily outside of inquiry – an explanation provided to the students to summarize learning, and no justification of this explanation. She described the lesson as providing students with a demonstration “so they could see that in the hot water it would move faster and that heat makes the molecules move faster. And in the cold water they would see that it moved slower.” This activity is not appropriate for 3rd grade; it is not part of TEKS because it is too abstract and students have no foundation for understanding molecular theory. When comparing her preferences in the 12 scenarios to the researcher ratings, she matched all the researcher ratings for questions, and some for evidence and explanation. Areas that diverged from her preferences were where she moved explanation and communication towards the confirmation and outside of inquiry end of the continuum.

Comparisons of Linda’s best represents scenarios showed an overall pattern of preferences for the open questions along the inquiry continuum. Yet she asked no questions in her description a lesson that best represents lesson. When asked what aspects of the scenarios had in common, her statements indicated a preference for a structured level of inquiry. “Usually I tell them that that's a great idea, that's a great question. Then what I do is steer them into - you know like – why don’t we find out this, and this will help you find the answer.” In her comparison of her top 4-5 scenarios she prefers to guide students more than she indicated in her initial ratings for the twelve scenarios. “I think sometimes I have to kind of tell them - how I want to - some of the kids need - they don't how to present their information, so here's a PowerPoint.”

Changes to Does Not represent

A graph of her total percentages for unsure, does not, and changes to does not represent is shown below.

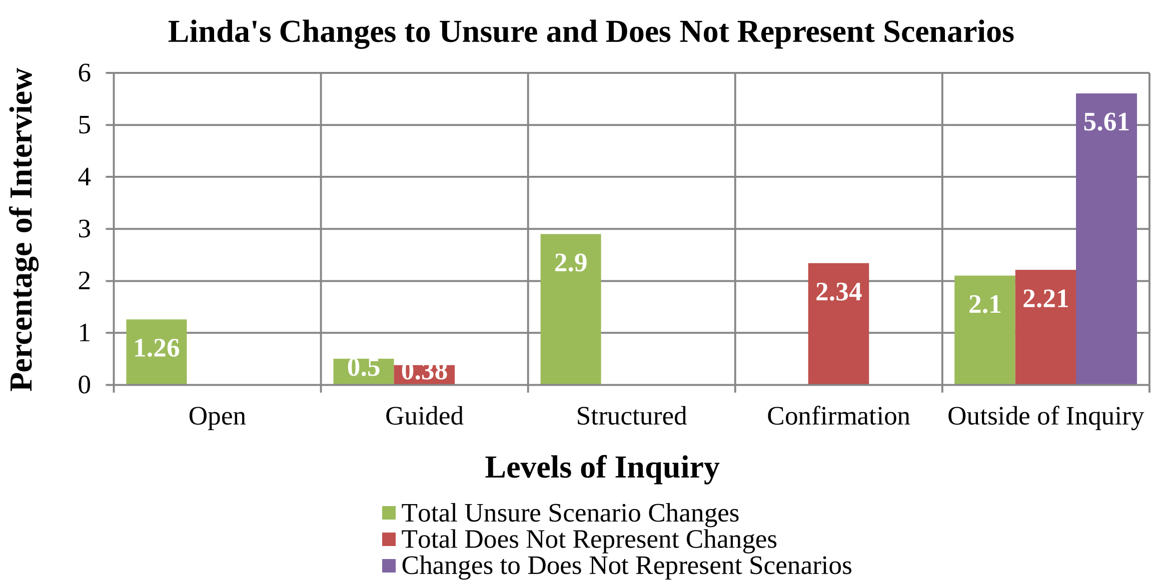

Figure 4.18: Histogram of Frequencies of Changes to Unsure and Does Not Represent

Linda made changes to unsure and does not represent ratings or scenarios coded for numerous levels of inquiry. But when asked specifically how she would change a scenario to place it into the best represents group, the changes she stated moved the scenarios to outside of inquiry. The changes she made to scenarios that she did not prefer or was unsure about indicated a preference for open questions and guided evidence, but also utilized many Language Arts strategies placing her science instruction outside of inquiry. One example was when she improved a lesson by commenting that,

> They're looking at nonfiction books, and I think that's fine. I think that's part of it; but I think they need to make more real-life connections like actually going outside and looking at the weather. Or you could even have a meteorologist come to the class and talk or something like that. I think more real-life application would be worth it. They would make a connection.

Her changes primarily described isolated activities or reading to gather and then summarize information.

Campus Culture Expectations

The histogram below shows coded preferences for lesson cycle, hands-on, and the role of writing and vocabulary as part of campus culture expectations.

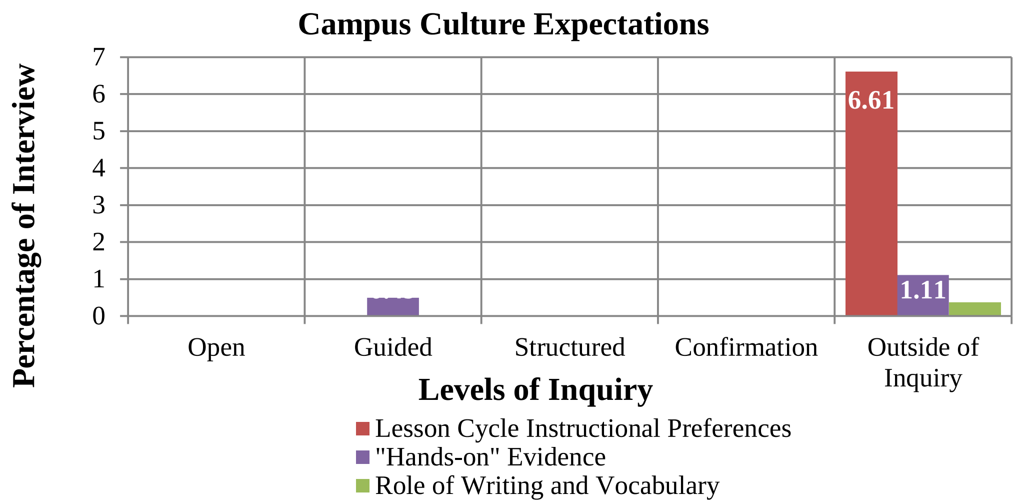

Figure 4.19: Histogram of Frequencies related to Campus Culture

The definition of "hands-on" by Linda was stated as,

> It's more student-centered. It's more the kids are doing more of the work; the kids actually have - instead of me doing the experiment up at my innovation station and them watching me. They've got the materials in their hands and they're actually doing them.

But she contradicted herself later in the interview by adding vocabulary to the application of hands-on. "Hands-on is also the students manipulating materials, they're using academic vocabulary - they are behaving like scientists. So they're talking like scientists." In fact, she describes both oral and written vocabulary as part of inquiry. "So a lot of academic talk - I would tell the "let's talk like a scientist, let's use our vocabulary words." For her, using vocabulary supplants students creating their own explanations.

> That they are using those basic science tools - that they are observing, they're collecting data - they're using the academic vocabulary to talk about - for example, with the heat energy that they were calling it thermal

> energy, and they were seeing that the molecules were moving faster instead of just saying the water was swirling around.

Linda's stated that a student-centered instructional model is her preference, but mostly for engagement rather than students driving the investigation and creating their own explanations. She equates a teacher-centered model with watching the teacher or direct teaching. "Although they might be collecting data on a worksheet, but they are actually working with the materials themselves, not watching me work with it, if that makes sense."

Role of Experiments and Research

Other areas include the role of investigation, research, and testable questions. See the figure below.

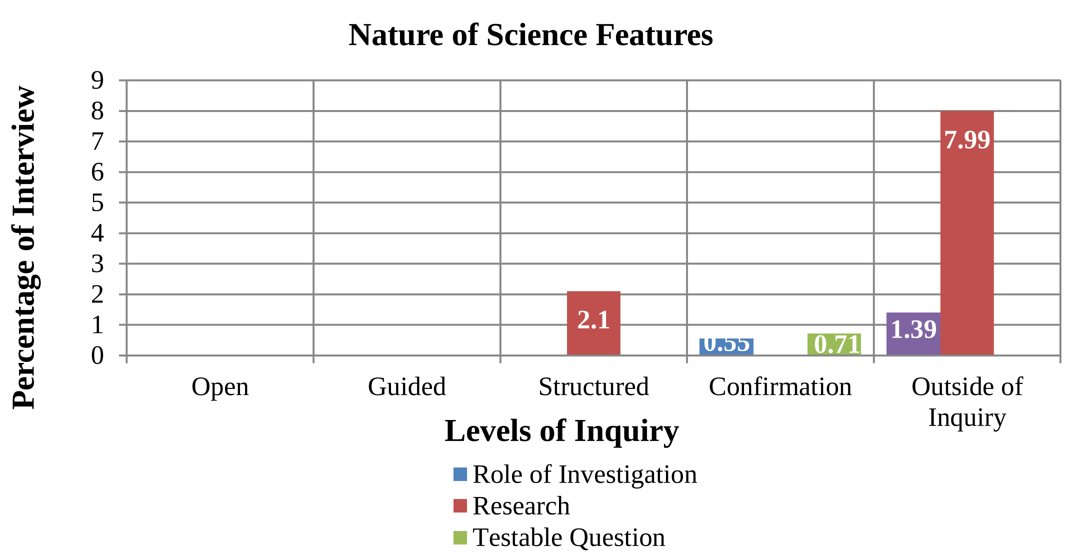

Figure 4.20: Histogram of Frequencies related to Nature of Science

When asked about the role of research and how an investigation would look in her classroom, she described a Language Art activity. She stated that,

> They're kind of noticing it through investigation, through all the reading, through watching me, through hearing the research, doing all that sort of stuff. Like for example, we were doing it right now with genres. I'll just put a whole bunch of biographies on their desks and I didn't tell them they were biographies - they just read them, and they figured out why is this book the same as this book.

Research is also a Language Arts study of how to find reading materials.

> We actually have just finished some research, and we're starting a new set of research. We use a third gradery website called "pebblego.com." It's down more to their level, but it's very kid-friendly. It reads things out loud to them, and that way I kind of know that they're not just putting Google in and going all over the Internet. So it's a little bit more directed and structured.

Even though she expressed a strong preference for open questions, she discussed how students were not able to do this, and needed support. "Sometimes they can't come up with anything at all, and I really have to kind of give it to them."

Even though Linda has a strong preference for open question and guided evidence, her placement along inquiry continuum is for mainly teacher-centered instruction. Her best represents scenarios may show a marked preference for open questions, but changes to does not represent and unsure scenarios were overwhelmingly outside of inquiry. In addition, her best represents lesson was divided between guided evidence and outside of inquiry for the other features. Although her best represents Scenarios are primarily guided, her changes to the does not and unsure scenarios place her closer to the confirmation part of the continuum.

Mary

Mary's teaching assignment and demographics were self-reported during the online survey. Her current teaching assignment is at a low-income elementary school within a large urban school district teaching a 1^{st} grade ESL self-contained class. Her area of specialization was self-reported as Reading, with 12+ years of teaching experience, and a BA in Liberal Arts; M Ed in Curriculum and Instruction. Her levels of anxiety and self-efficacy were measured in the same online survey by the STAI (State Anxiety sub-test) and the STEBI (PSTE sub-test). Ranking her among all participants put her in the high anxiety and low self-efficacy group.

Best Represents Scenarios

The levels of inquiry for Jane are shown below in a table and histogram of her best represents scenarios, comparisons of her top 4 – 5 best represents, and a description of a lesson that best represents her preferences for science instruction.

Table 4.14

Mary: Preferences for Best Represents Scenarios

Essential Feature	Level(s)	%	Freq.
Question	Guided	0.83	3
	Confirmation	2.34	2
	Outside of Inquiry	1.43	2
Evidence	Guided	2.28	2
	Confirmation	3.07	2
	Outside of Inquiry	10.22	7
Explanation	Guided	1.04	1
	Structured	0.71	1
	Confirmation	2.11	2
	Outside of Inquiry	17.99	9
Communication	Structured	2.02	1
	Confirmation	1.16	2
	Outside of Inquiry	1.27	2

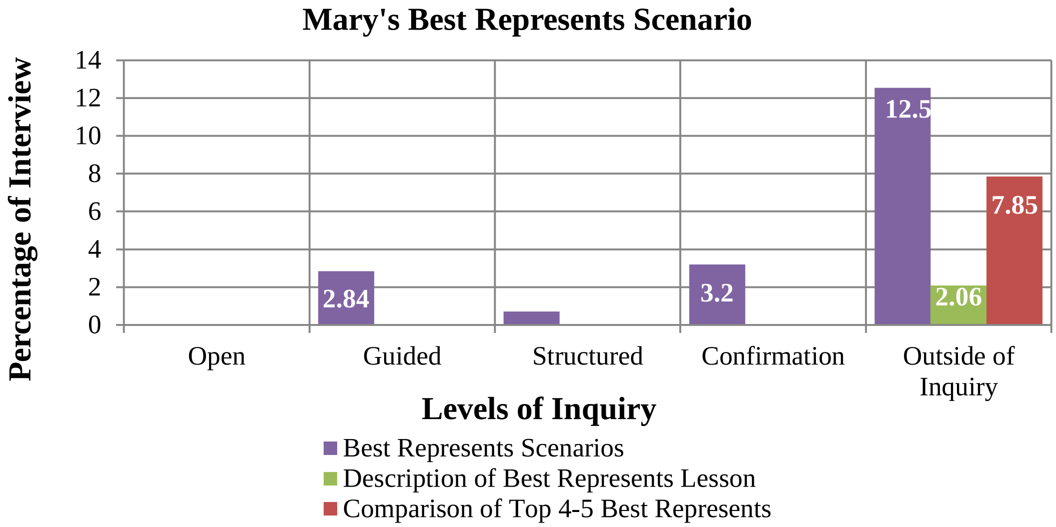

Figure 4.21: Histogram of Frequencies of Best Represents Scenarios

Based on her interview data, Mary's preferred instructional strategies for best represent scenarios, comparisons of the top 4 – 5, and the description of their own best represents lesson were primarily outside of inquiry. Her preferences for questions fell within the levels of confirmation and outside of inquiry, especially illustrated by her statement "They're coming up with questions that they may or may not be able to answer by whatever they devise. To me, this is way outside my comfort zone." Rating for evidence included some guided, but were also largely outside of inquiry.

> Again, this is pretty much how I would be very comfortable doing it, using text and the web resources. I would also probably bring in video. We have access to United Streaming - Discovery Learning so I would definitely put that in there as well.

Her preferences for explanation were overwhelmingly outside of inquiry with all explanations provided to the students.

> Apparently we're doing some other research because it says I guide them in researching birds. So to me that means that we're also going to go to the Internet or videos or non-fiction and from that research and further observations they are going to write to answer their question and explain how their observations prove their answers.

Finally, communication preferences were evenly divided between structured, confirmation, and outside of inquiry with her preferred goal to "have the students write their statement in their journal, their Science notebook okay. I would write it as a record, but I would also have them write it and illustrate it."

Description of Recently Taught Lesson that Best Represents

Asking the teacher to describe a recent lesson that best represents their preferences for science instruction enabled the researcher to cross check the teacher's ratings of scenarios with their own lessons to determine the reliability of their scenario ratings. Mary's description of a lesson she recently taught made no mention of a question preference, but was an isolated activity without any hands-on experience.

> We've been doing solids, working on matter, states of matter and so we did a solids activity where we discussed the definition of a solid, which was very hard to do at the first grade level. It was much easier… maybe I should talk about the lesson on liquids, because that actually worked.

Her description of gathering evidence was a discussion without even a demonstration.

> Because the liquid was easier to define in terms of taking the shape of the container and something that you could actually put your hand into and have you know, surrounded by liquid. I did not do a demo, all right, and I should have. That's what I figured out afterward.

For explanation and communication she preferred to provide what she thought was the correct explanation and then have students write a summary. “Well, one thing is using the non-fiction books and having the students do writing about what they’re learning as they’re learning it.”

Comparing her preferences for the twelve scenarios to researcher ratings found matches for scenarios that contained questions, two of them open, but with every other scenario her preferences diverge from the researcher ratings. For all other areas she moved them towards confirmation and outside of inquiry. Comparisons of the levels of inquiry for the lesson she described as best representing her showed an overall preference for predominantly outside of inquiry approach. Her comparison of her top 4-5 scenarios describes a lesson cycle that is the antithesis of inquiry – a reading lesson focusing on vocabulary instruction.

> Vocabulary is huge because they come in not equipped with a very wide vocabulary in terms of content area. So again, with the non-fiction reading and with me being very much at the helm, I’m sure that the vocabulary that’s related to the content is being delivered to the students and that the students are interacting and using it. That’s a very critical goal of the school, all right.

She prefers to pre-teach the explanation with an emphasis on students understanding all vocabulary before any evidence is collected.

Changes to Does Not represent

A graph of her total percentages for unsure, does not, and changes to does not represent is shown below.

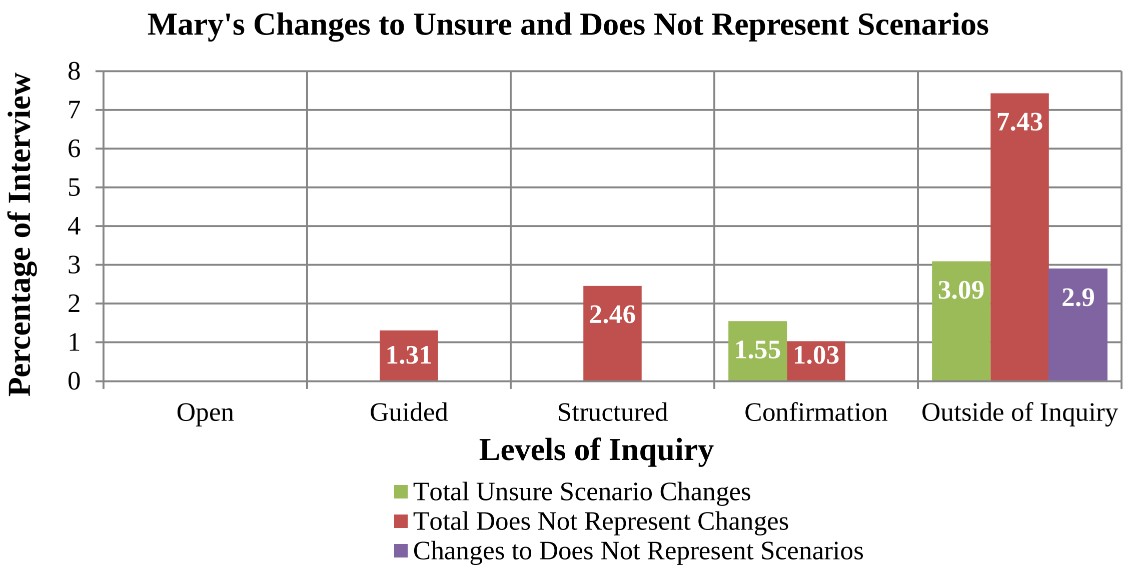

Figure 4.22: Histogram of Frequencies of Changes to Unsure and Does Not Represent

Overall the changes Mary made to scenarios that she did not prefer actually moved them more towards outside of inquiry. Her strong preference for controlling the direction of the investigations was illustrated by the comment,

> The group designs and carries out their own experiment. Okay, I might not have a problem with that if I had premade or preselected the questions that they were going to answer because hopefully from the questions I designed it would have a fairly obvious way for them to test it, to make the experiment.

Her changes in the scenarios she did not prefer for science instruction were almost exclusively outside of inquiry.

Campus Culture Expectations

The histogram below shows Lesson Cycle Instructional preference, the only area coded for campus culture expectations.

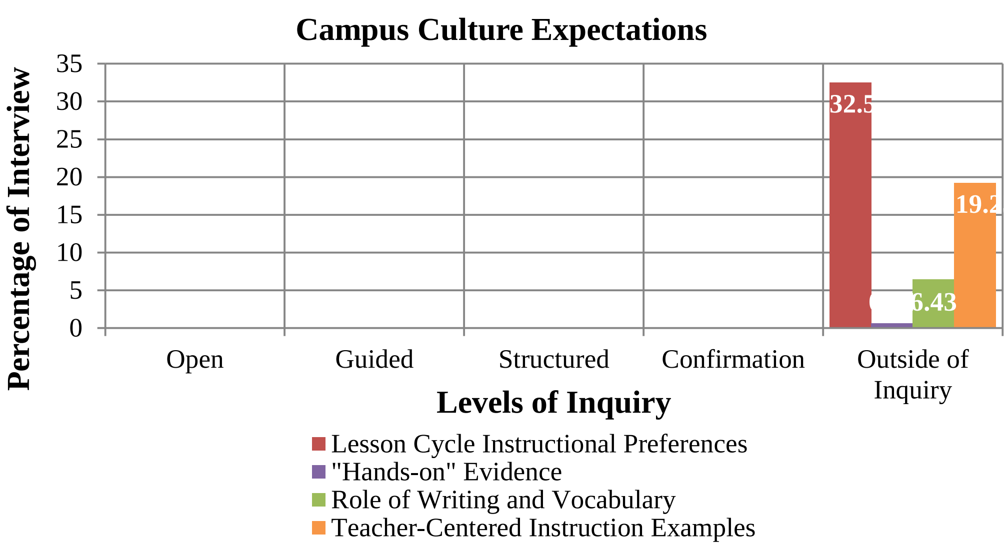

Figure 4.23: Histogram of Frequencies related to Campus Culture

Mary's definition of the term "hands-on," centered on students manipulating materials.

> Hands-on to me means that the children have manipulatives of some sort. In Math, they're pushing around blocks for counting, all right. In Science, they're actually interacting with the materials that we're talking about so I know in second grade we would go outside and gather different leaves so that we would come back into the room and do a sorting activity and the kids could sort them in whichever way they felt was the right way to sort. So they were actually interacting with the materials.

Unlike all the other participants interviewed, she did not have a strong preference for hands-on activities.

> I really don't like doing hands-on with first graders, that's a terrible thing to say, I know it. Okay, but I find that at least for me, it gets out of control much too quickly and I'm a pretty control freak and so I have a difficult time with hands-on Science.

Yet her preference for vocabulary and writing as a Language Arts skill was strongly expressed.

> What I would do is for Science words - I'm going to get them from the Internet because generally speaking, Science words are nouns, generally. I can find a picture to represent it. There's a picture, a gesture, a definition and so that's what school-wide we're adopting.

Lesson cycle preferences for Mary were the most teacher-centered of any participant. She explicitly stated that she wanted control the course of the lesson. "Yes, I think those are the two main things that I want to have control over - the probability of success. That is what I'm comfortable calling it, okay." She explained that her desire to use a teacher-centered model was to insure student success.

> I really do think that that's my job to make certain that I don't present a student with something that they can't possibly be successful at. Now there are varying degrees of success and varying reasons for that, but at very least, I think it's my obligation as the teacher to provide realistic goals for them. Again, that's another reason I am uncomfortable letting the students do that on their own because I'm not sure if that's a reasonable goal.

Finally, she voiced an open disdain for Inquiry or an inductive strategy taught to teacher many years ago called "Discovery Learning" NRC (2000).

> No, I would not let them - I'm not going to use discovery learning. It says encourage students to find ways to light the bulb. I'm not going to do that before they have a chance to look at books or Internet or a movie that showed how the materials were assembled in one way. Then I might encourage them to find a different way, all right, but I don't… I told you I do not like discovery learning.

Role of Experiments and Research

The role of Investigation was mentioned by Mary as only 0.77% of her interview with one reference. She spoke very little about the role of research in science instruction, with only one reference to creating a hypothesis. She did not like the idea of students creating one without substantial background information. "You know, you haven't done any background, all right, I'm wondering how they would come up with a hypothesis about the behavior."

Content knowledge was a very large concern for Mary, and she worried about not knowing enough science. "I might have to fill that in, I might not even know myself. Okay, so sometimes to me Science is a puzzle and has an inconclusive answer, all right?" Another example was when she viewed a scenario on moon phases as not being worth the time it took to complete. "I'm just not sure see, I just don't think that that's something that's so huge that it's worth thirty days of every night going outside and making a picture. This just doesn't seem like something that is that important."

Mary's placement along the inquiry continuum was the strongest preference for teacher-centered instruction of any participant. One of the justifications for this placement is that she openly acknowledged this preference.

> I really need to be the sage with my students and I do not like being in a position where they might come up with a question that I should be able to answer; I should be able to research and figure out, but I, for the life of me can't. That makes me a very unhappy teacher.

Her best represents scenarios show marked preference for an outside of inquiry model that begins with providing written or verbal explanations to master vocabulary. If a hands-on activity is provided it is for engagement only, and any explanation or communication on the student's part is for assessment. Changes to does not represent and unsure were primarily confirmation and outside of inquiry. Although she did prefer that students gather their own data, she did not do this in the description of her recently taught lesson. Her best represents lesson was entirely teacher-centered and outside of inquiry with no data collected and most of the activity was direct instruction, devoid of even a demonstration. She describes her preferences for instruction as entirely based on reading instruction.

> Okay, especially working with the population that I have, my primary goal is to teach these children to read because if they can't read, they can't do anything. At this age, first grade, they cannot read enough on their own to do Science. They are just not there yet. My students are not literate yet. So the time that I spend in Reading instruction bleeds over into every other subject that I teach because for me, reading means everything.

Nancy

Nancy's teaching assignment and demographics were self-reported during the online survey. Her current teaching assignment is at a low-income elementary school within a large urban school district teaching a 5th grade Science and ELA (English

Language Arts). Her area of specialization was self-reported as Science and Reading, with 3 to 5 years of teaching experience, and a BS in Advertising. Her levels of anxiety and self-efficacy were measured in the same online survey by the STAI (State Anxiety sub-test) and the STEBI (PSTE sub-test). Ranking her among all participants put her in the High Anxiety and High Self-Efficacy group.

Best Represents Scenarios

The levels of inquiry for Jane are shown below in a table and histogram of her best represents scenarios, comparisons of her top 4 – 5 best represents, and a description of a lesson that best represents her preferences for science instruction.

Table 4.15

Nancy: Preferences for Best Represents Scenarios

Essential Feature	Level(s)	%	Freq.
Question	Open	2.84	5
	Guided	0.41	1
	Structured	3.36	2
	Confirmation	0.54	2
Evidence	Open	1.21	1
	Guided	5.81	6
	Confirmation	1.15	2
	Outside of Inquiry	8.36	5
Explanation	Guided	0.81	3
	Confirmation	0.53	1
	Outside of Inquiry	6.91	5
Communication	Guided	5.04	3
	Structured	0.57	2
	Confirmation	1.41	2
	Outside of Inquiry	0.37	1

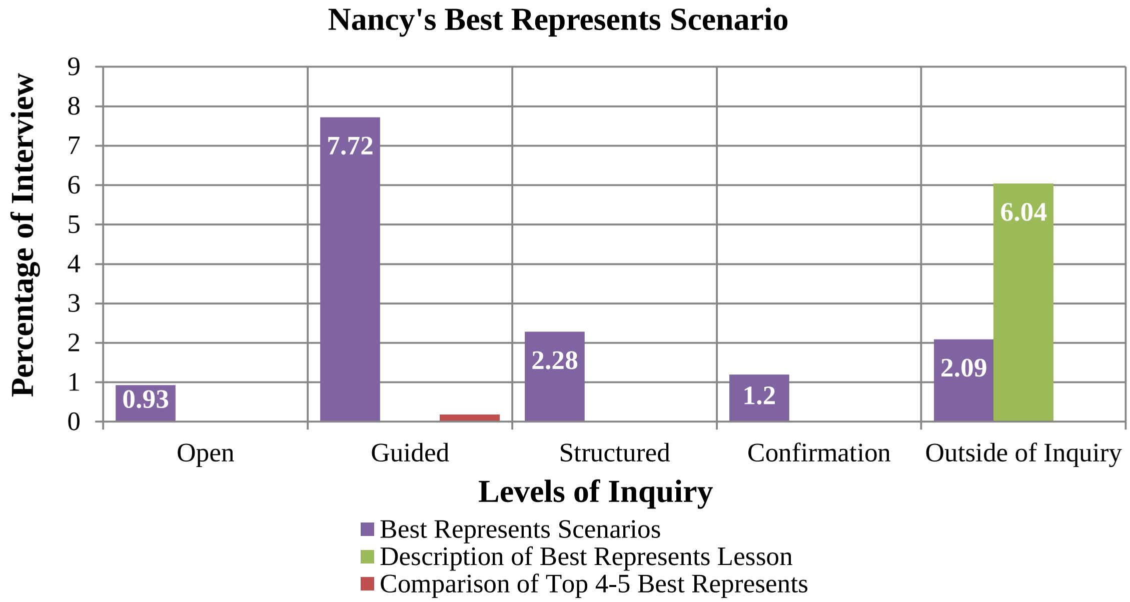

Figure 4.24: Histogram of Frequencies of Best Represents Scenarios

Based on her interview data, her preferred instructional strategies for best represent scenarios, comparisons of the top 4 – 5, and the description of their own best represents lesson were predominantly guided and outside of inquiry. For the question level Nancy indicated a structured preference.

> I find that their questions are kind of really out there, not as focused on something I could investigate, and they often have a hard time with a true science experiment with a hypothesis, procedures, variables you can change, and just a "I wonder what earthworms do?

An additional preference for open questions was indicated by the statement,

> The thing is I would want them to generate the questions. I wouldn't like – "here's your choices, pick one." Like for science fair, I don't pre-print a bunch of science fair experiments and say 'pick one.' Instead let's think about a question you can ask and be sure it has variables.

Her preferences for evidence were guided, as she described how she wanted students to collect their own data. “I feel like if they're gonna learn about insects, they need to have insects not just body parts of insects. So I might add the – like observe actual insects before and then re-create what they saw.” Yet she also stated a preference for an outside of inquiry lesson as an exercise in reading to obtain information.

> It says each day in the unit, you read to the class from a nonfiction book. For me, if the kids don't have it in their hands and they're not reading with me, they're not getting the information. I’m also a Language Arts teacher, so I want the literacy piece in there, so I would have every single kid with a copy of whatever I was reading, and mandatory that they're following along.

For explanation she also described an outside of inquiry based lesson that was reading to gather information.

> I will sometimes have them call out to me all of the vocab words they know about circuits, and put them on the board, then I say “okay, create the diagram and use 10 of these words.” Then I have the use that vocabulary on the diagram. I do almost this exact same thing.

Nancy’s preferences for communication were primarily guided based on her practice of having the students create a rubric with her to assess their work. “And I like that they’re presenting it. The only thing I would change is I would have them help me create a rubric.”

Description of Recently Taught Lesson that Best Represents

Cross-checking with a question describing a lesson they recently taught that best represents her preferences enabled the researcher to cross check the teacher's ratings of scenarios with their own lessons to determine the reliability of their scenario ratings. Nancy's lesson was outside of inquiry, beginning with no mention of a question except as a pre-assessment of prior knowledge on the topic. Her lesson described the evidence level as outside of inquiry, with an isolated lesson where students read information and watched a video then summarized that information.

> I had some picture cards and some actual objects - a mix. Then let's see - we also did read a couple of articles about the kinds of energy - one that day and one the next day. I sometimes let them partner read and repeat back what they heard so they can hear their partner read back aloud. One of the days they drew a little symbol or picture next to the paragraph to help them remember something they read about.

Her explanation continued the level, having students memorize vocabulary to prepare for assessment. "I usually like to offer a lot of opportunities for students to interact with the vocabulary - it's very vocabulary heavy, especially in fifth grade." When comparing preferences in the twelve scenarios to researcher ratings Nancy only selected four scenarios for best represents, and she matched the researcher ratings for all levels of inquiry on one scenario, and the communication level on another. In areas where she diverged from the researcher ratings, she moved the scenarios towards confirmation and outside of inquiry level.

The overall rating for Nancy's description of a lesson that best represents her is predominantly outside of inquiry. Her comparison of her top 4-5 matches only mentions that the lessons meet her goals because they are creating diagrams and writing explanations.

Changes to Does Not represent

A graph of her total percentages for unsure, does not, and changes to does not represent is shown below.

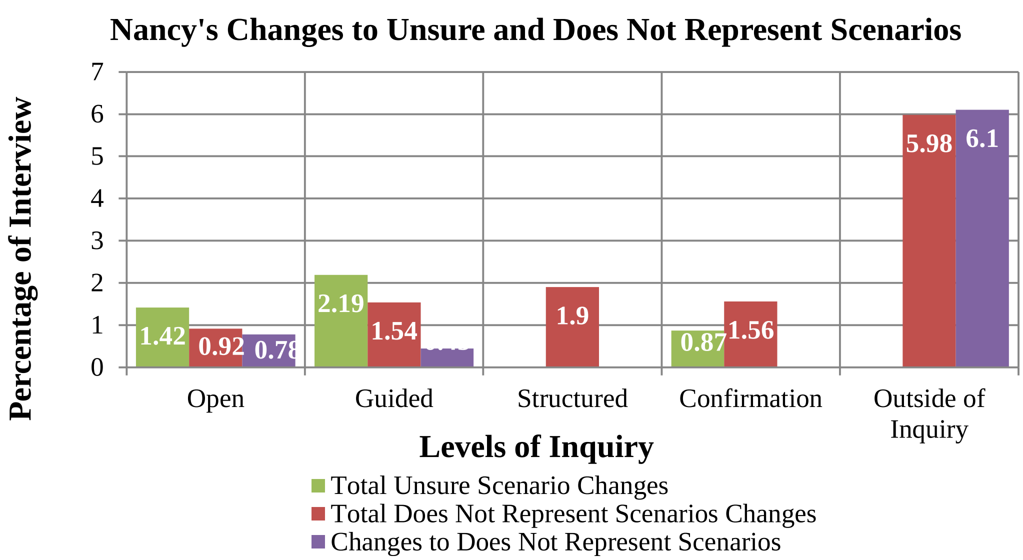

Figure 4.25: Histogram of Frequencies of Changes to Unsure and Does Not Represent

The changes she made to scenarios that she did not prefer actually moved them more towards the outside of inquiry end of the continuum. “I would pre-teach the phases of the moon. I typically take a week on it. I think I do moon phases and tides in the same week.” She also commented that in order to be successful on the STAAR assessment, “They have to know what comes next. This is what they are totally tested on, like which is the most reasonable." The majority of the changes she made to scenarios that did not represent her were to move them towards the outside of inquiry part of the continuum.

Campus Culture Expectations

The histogram below shows lesson cycle instructional preference, the only area coded for campus culture expectations.

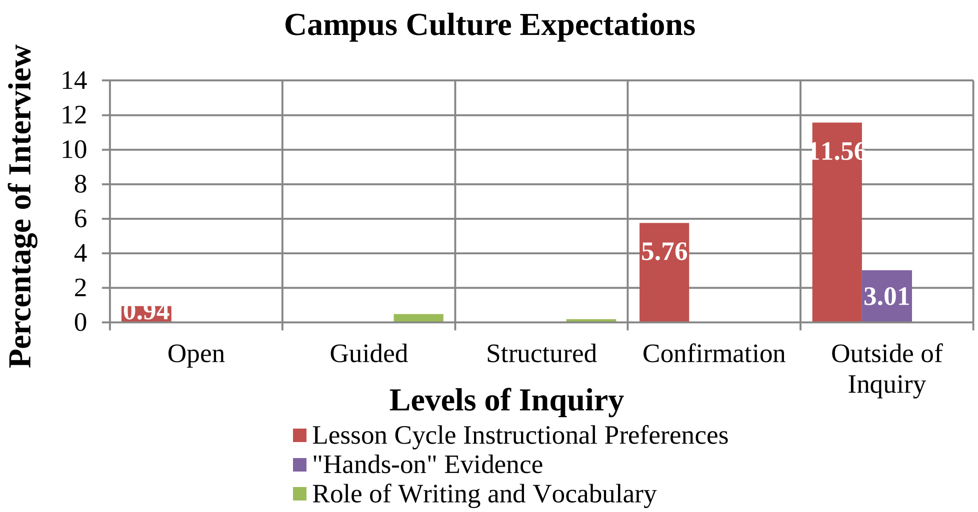

Figure 4.26: Histogram of Frequencies related to Campus Culture

Nancy's definition of hands-on described several strategies.

> They would have actual models in some way, and they were physically touching things. You can even be sorting cards because their hands are on something besides a notebook and paper. Hands-on, typically for me, means working together as well.

Overall, her lesson cycle preferences fell along the inquiry level of confirmation and outside of inquiry.

> We go through that routine every time, so it's always the same. And the hypothesis, and sometimes it's an "if-then" statement, but not every experiment applies to it. Then they come up with their hypothesis, and they identify what is the one variable that we're changing, what is the one thing we can change.

She described her best represents lesson as,

> First we talked about what they knew about energy before; and then we watched a video that had info about each of the five types they have to know…then they get two minutes to jot down everything they need to remember from the video. Then we watch it again, and see what they can add to the video notes. I had examples of different things like wind-up toys and flashlights and they sorted items based on the kind of energy they produced.

Her description of this lesson cycle was teacher-centered - an isolated activity based on reading text and watching a video to acquire information and then summarize it with notes.

Role of Experiments and Research

Other areas include the role of investigation, research, and testable questions. See the figure below.

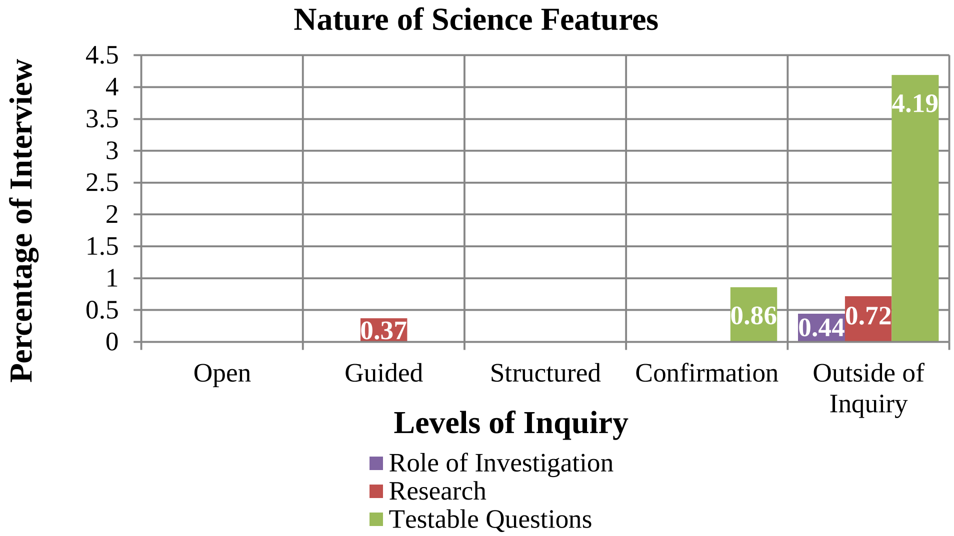

Figure 4.27: Histogram of Frequencies related to Nature of Science

Her description of the role of research was limited to reading strategies with almost no mention of scientific inquiry. “And the research could be a being books, it could be online, it could be some kind of source; yes, research is investigating a written thing.” Her definition of an investigation is interchangeable with research and also a reading exercise. “Investigate and research can have the same meaning if you're investigating something online - you are researching.” When asked about how she deals with students who ask questions that are not testable she replied,

> I would remind them that testable questions have an independent variable, something you can change. And then - my students know this - can I change more than one thing? No, everything else has to be the same, because I'm investigating that one thing.

Finally, she described the misconception of one scientific method.

> The scientific process is you formulate a testable question, and testable means there's a variable change you can change, you can create data, etc. So they create a testable question, come up with a hypothesis - and my

> hypothesis is very specific, like the question is always – it's up there on the wall…

Nancy's placement along the inquiry continuum holistically positioned her within the teacher-centered level of instruction closest to confirmation. Although her best represents scenarios show marked preference for structured and open, her changes to does not represent and unsure were primarily outside of inquiry and her description of a recently taught lesson that best represents her instructional preferences was entirely outside of inquiry.

Randy

Randy's teaching assignment and demographics were self-reported during the online survey. His current teaching assignment is at a low-income elementary school within a large urban school district teaching a 5th grade Bilingual self-contained class. His area of specialization was self-reported as Science, with 6 to 8 years of teaching experience, and a BS in Sociology, a Minor in Biology, and graduate work in Sociology. His levels of anxiety and self-efficacy were measured in the same online survey by the STAI (State Anxiety sub-test) and the STEBI (PSTE sub-test). Ranking her among all participants put her in the high anxiety and high self-efficacy group.

Best Represents Scenarios

The levels of inquiry for Jane are shown below in a table and histogram of her best represents scenarios, comparisons of her top 4 – 5 best represents, and a description of a lesson that best represents her preferences for science instruction.

Table 4.16

Randy: Preferences for Best Represents Scenarios

Essential Feature	Level(s)	%	Freq.
Question	Open	0.38	2
	Guided	0.54	1
	Confirmation	0.47	1
Evidence	Open	0.88	3
	Guided	6.77	9
	Confirmation	0.43	1
	Outside of Inquiry	0.67	1
Explanation	Guided	0.19	1
Communication	Guided	0.75	1

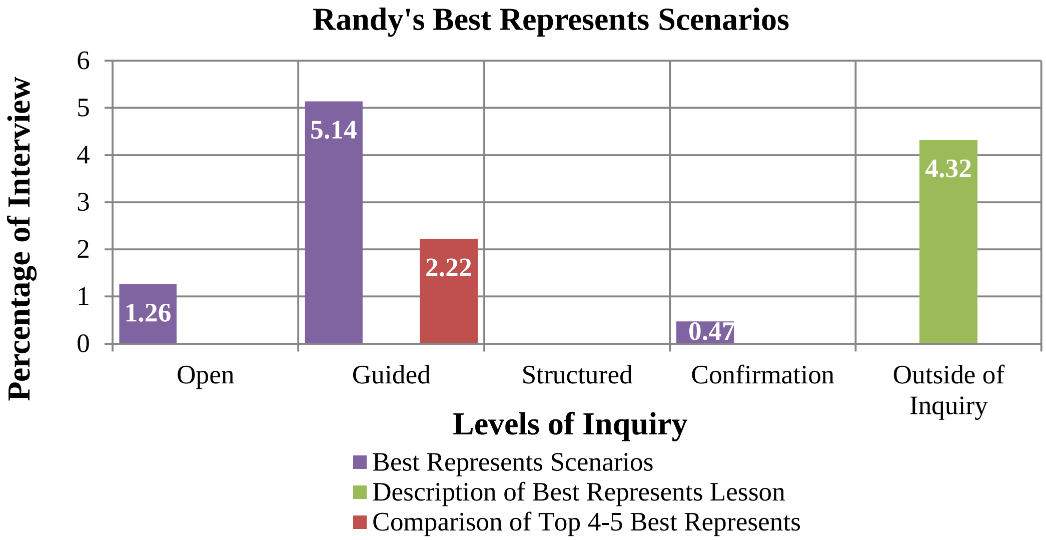

Figure 4.28: Histogram of Frequencies of Best Represents Scenarios

Based on his interview data, Randy's preferred instructional strategies for best represent scenarios, comparisons of the top 4 – 5, and the description of his own best represents lesson were divided among guided and outside of inquiry. He made few comments about the scenarios that he approved, but spoke more about the ones he was unsure of or did not represent his preferred model of science instruction. His scenario question preferences were scattered among open, guided, and confirmation. For guided questions he stated that students do need help with questions. "But then you helped the students with a set of questions you are selecting - a set of questions which you give them - which helps especially fifth-graders or younger kids too." His preferences for evidence were also guided, defined as asking students to collect certain evidence.

> What I would prefer here is that if their experiments are failures that we would talk about why there were failures, and perhaps redo the experiments. So that we would figure out you know - was the bag was sealed or did introduce the mold - or whatever the error was - because in science you have to be able to repeat your experiments and you have to learn from what doesn't work.

Randy made a small reference to guided explanations, explaining that, “You’re helping them with the researching birds - that's good.” For communication though he made no mention of communication preferences for his ratings of the twelve scenarios.

Description of Recently Taught Lesson that Best Represents

By cross-checking with a question describing a recent lesson that best represents their preferences for science instruction the researcher was able to compare their ratings on the scenarios to their actual practices to determine the validity of their scenario ratings. From Randy’s description of his own lesson, it was coded as outside of inquiry for all features. He made no mention of a question in his best represents lesson. Instead, it was an isolated, activity-based lesson focusing on a process skill. “We were working on the properties of matter. And I pulled out a number of different items that had different properties and we started by – I wanted them to focus on their senses and how to observe things.” His reference to evidence in the lesson was also outside of inquiry.

> They had to feel what was in the bag and write down what they felt, what they thought was in bag (these were paper bags so they couldn't see). I modeled that in front of the class with a big bag; then I gave them small bags in small groups. What they had to do was first do that part, then they got to reach inside the bag, but they couldn't look, so they use that sense. They had to feel the things and describe what they were feeling and break

> that down. Then they got to pull stuff out of the bag and describe what they now had in their hands. They were focused on one sense at a time.

Randy had no explanation since there was no question being answered, just a review of observation tools.

> Then we had some discussion about how we extend those senses with instruments. I had out various things we used to measure - the triple beam balance, and microscope, and I had the telescope out here. They could see these were just extensions of those senses.

Finally, his communication feature also fell within the outside of inquiry portion of the continuum as they summarized their experiences without justifying an explanation. “Then they had to write everything down. They’ve already been taught how to write things down in their notebooks and take notes - we practice that too – that was pretty much the lesson.”

Comparing preferences in the twelve scenarios to researcher ratings Randy matches four of his best represents scenarios to the researcher ratings. Areas where his preferences diverged from scenarios compared to researcher ratings were two of the open scenarios he moved to guided. In evidence, he moved from open to the guided end of the continuum, and in other areas he moved towards confirmation and outside of inquiry. The comparisons of his best represents scenarios were predominantly outside of inquiry. His comparison of his top 4-5 matches described no areas consistent with his preferences in the twelve scenarios, and he described a purely outside of inquiry lesson.

Changes to Does Not represent

A graph of her total percentages for unsure, does not, and changes to does not represent is shown below.

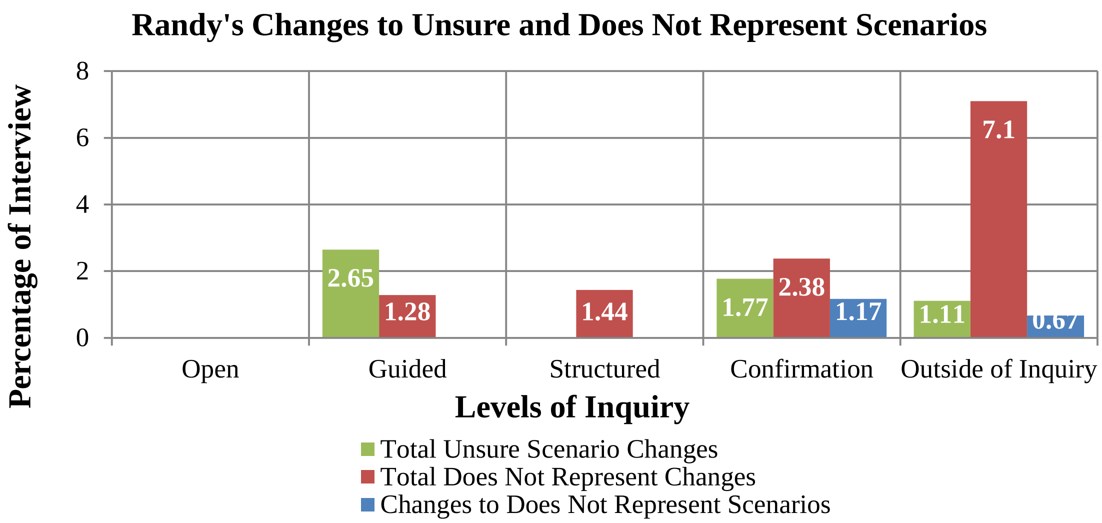

Figure 4.29: Histogram of Frequencies of Changes to Unsure and Does Not Represent

Randy's overall preferences to the changes to unsure and does not represent were outside of inquiry. He described an English Language Arts strategy of pre-teaching vocabulary instead of an inquiry strategy.

> But I find that the kids don't know phases of the moon. So I would want to teach them the phases of the moon first – give them the vocabulary that they would need, before they actually went and did their observations.

The changes he made to scenarios that he did not prefer actually moved them more towards the outside of inquiry end of the continuum.

> They just try to find background information - find out more. And then again, there's the hands-on piece - what about talking to somebody. That's

sort of hands-on too - if you talk to an expert. It's like if we were talking about rocks that are librarian has a degree in geology.

Campus Culture Expectations

The histogram below shows lesson cycle instructional preference, the only area coded for campus culture expectations.

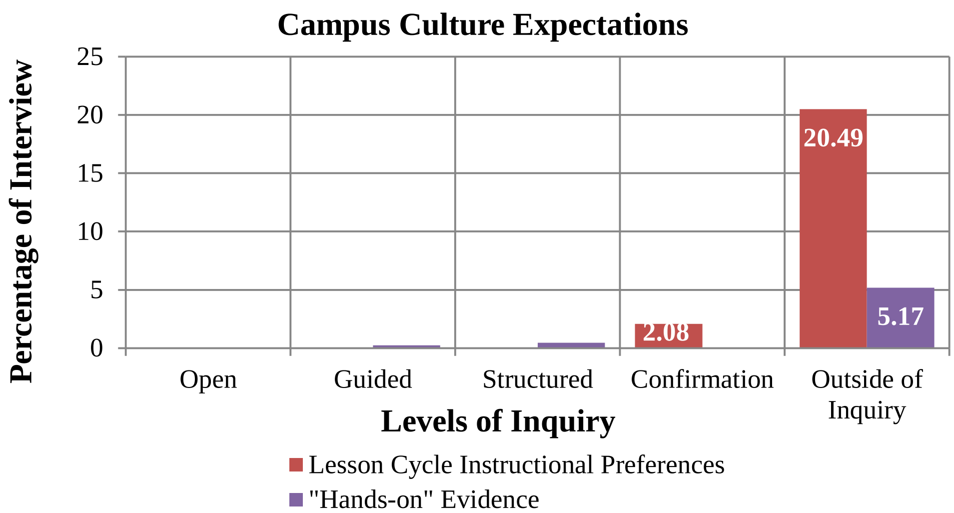

Figure 4.30: Histogram of Frequencies related to Campus Culture

Randy's definition of "hands-on" instruction was primarily manipulation of objects. "It means they can actually manipulate whatever they are working with. And talk about what they are experiencing. If it's that particular lesson it was objects." For him, students primarily read to gain information, and the purpose of hands-on instruction is for the sake of engagement and reinforcement.

> Sometimes when I teach science I just don't get that opportunity (to do hands-on) because you have to go through our vocabulary; we have to understand that vocabulary. We have to read about something which to me is not hands-on. They need to learn that material in a different way and then they were going to practice. At other times we utilize whatever came out of that - hopefully we get the hands-on. They touch and they do something and it helps reinforce whatever they read.

Randy's lesson cycle preferences were primarily outside of inquiry as he describes in his improvements to a moon phases lesson.

> But I find that the kids don't know phases of the moon. So I went want to teach them the phases of the moon first – give them the vocabulary that they would need, before they actually went and did their observations. It's the biggest problem I have with this. To me you need to teach that part first, then they go and do some hands-on, which is doing the observations. Then and then they card sort. That's the teaching part where they create the foldable, and then to me they have to explain whether foldable was all about. I would want them to do that - so they verbalize also what started from the beginning of this series of lessons. To me, that's the biggest flaw - you didn't give them anything up front.

Randy's description of lesson cycle preferences are teacher-centered, preferring lessons with an emphasis on vocabulary, isolated observations, and no student created explanations.

Role of Experiments and Research

Other areas include the role of investigation, research, and testable questions. See the figure below.

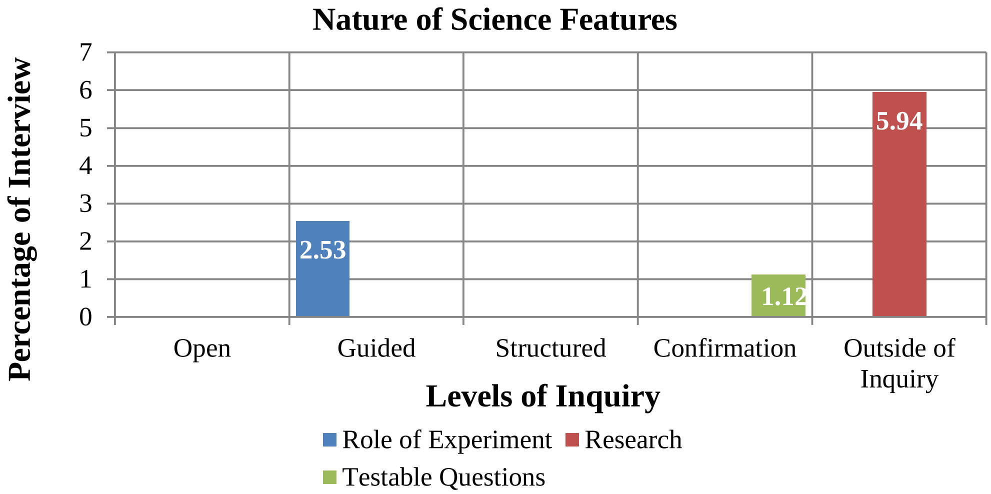

Figure 4.30: Histogram of Frequencies related to Nature of Science

Randy's description of the role of research was also outside of inquiry, an exercise in locating written references. "If we're doing something in science we go to the library together to look at some of the books in the library that are about that." But an experiment is guided,

> It's something I think I have to guide the kids to do. I want them to find out things on their own. But you teach them the method for doing that and then you want them to come up with their own questions. Then they all designed the experiments and they did them when they could. Sometimes they design experiments they really can't do, that don't make a lot of sense. So they wind up not doing them, or they do them and don't find out anything.

Finally, for him testable questions are more about finding something appropriate for his students.

> Well we have a discussion about why it's not testable or why it might be dangerous, because they'll come up with things that are dangerous. So I just tell them that it might be very interesting to find out, but in fifth grade

> we don't have a way to make it safe. We’re not going to blow something up to the classroom.

Randy’s holistic placement along the inquiry continuum would be for teacher-centered, outside of inquiry model of instruction. The justifications for this placement are that although his best represents scenarios show marked preference for guided, the changes he made to his does not represent and unsure were outside of inquiry as were his best represents lesson. It was an exercise in observation and writing records of the observation. Plus his discussions of research, lesson cycle preferences and hands-on instruction show a preference for an outside of inquiry model – reading and watching videos to obtain information, explanations provided to the students, and writing summaries as assessment.

SUMMARY OF VIGNETTES

In general, all of the teacher participants preferred open questions, but didn’t describe this inclination in their own practices. They criticized scenarios by suggesting that students should ask their own questions, but contradicted this in their own descriptions of lessons that best represent how they prefer to teach, and often when discussing testable questions. Their ratings of scenarios designated a preference for the guided level of evidence but, mostly due the desire to implement hands-on for the sake of engagement. Little analysis of the evidence was performed, and they did not specifically describe how they have students analyze data, just a mention of “discussing” their ideas.

One of the strongest patterns that emerged was their preference for providing explanations to the students. The very few references to students creating their own explanations emphasized them eventually coming to the “right” explanation, often the one that will be on the high-stakes test such as the Earth-Sun-Moon relationship that frequently appears in the Elementary Science STAAR test. Furthermore, there was no justifying their explanations. No mention was made in any interview of students allowed to justify or self-correct a misconception. Instead they are corrected by the teacher, often before the students can adopt them and do poorly on a standardized test.

There was a marked preference for reading to acquire knowledge instead of reading to compare student explanations to accepted scientific explanations. The emphasis was on the acquisition of vocabulary, usually by direct teach methods. Plus, research and investigation were seen as learning to locate written references or follow a mythical scientific method. For the areas not directly part of the scenarios, most of the teacher responses described a preference for instructional strategies that fall outside of the inquiry continuum.

Finally, member checking matches were performed by the researcher describing the teacher’s preferences based on interview responses. At the conclusion of each interview the researcher used notes and scenario ratings and asked each participant how close they came in their description of their preferences for science instructional strategies. All participants agreed with the researcher description of their preferences making no changes to the restatement of their responses or probing questions. Two teachers added to the description by including areas not pertinent to the scope of the research such as the role of music or bilingual education in science. The member checking question helped elicit a verification of teacher preferences for a primarily teacher-centered model of instruction.

Research Question 2 - *Is there a relationship between the levels of science anxiety/science teaching self-efficacy and the preference for a teacher-centered model of instruction as opposed to a learner-centered model? If so, what is the relationship?*

Based on the holistic classifications from Question 1, the teacher participants were placed along the levels of inquiry continuum. Each participant matched many aspects of teacher-centered instruction, such as a preference for mastery of an instructional objective to pass standardized test. Their descriptions of their own lessons were isolated activities without guiding questions. For the essential inquiry feature of explanation, no real examples of student created explanations were cited. Instead of communicating their findings to justify their explanations to their peers, communication was a summary for assessment purposes. There were few aspects of a learner-centered model of instruction, although many teachers voiced a strong preference for open questions and guided evidence, but mainly due to increasing student achievement, not analyzing and evidence. Holistic classification of teachers as primarily teacher- or learner-centered placed half of the teachers within the confirmation level, and the others outside of inquiry completely with all teacher participants closest to the teacher-centered end of the continuum.

Table 4.17

Holistic Ratings by Levels of Inquiry for Participants

Variations/Levels of Inquiry				
			Barbara – High Anxiety/Low SE	**Daniel** – Low Anxiety/High SE
			Jane – Med Anxiety/High SE	**Karen** – High Anxiety/Low SE
			Linda – High Anxiety/Low SE	**Mary** – High Anxiety/Low SE
			Nancy – High Anxiety/High SE	**Randy** – High Anxiety/High SE
OPEN *Students investigate topic-related questions that are student formulated through student designed/selected procedures.*	**GUIDED** *Students investigate a teacher-presented question using student designed or selected procedures.*	**STRUCTURED** *Students investigate a teacher-presented question through a prescribed procedure.*	**CONFIRMATION** *Students confirm a principle through an activity in which the results are known in advance.*	**OUTSIDE OF INQUIRY** *Students follow a teacher-directed, isolated activity/skills based lesson heavily dependent on text-based acquisition of knowledge.*
More-----------------------Amount of Learner Self-Direction-----------------------Less				
Less----------------Amount of Direction from Teacher or Material--------------More				

n = 8

The relationship between levels of anxiety and self-efficacy to preference for teacher or student-centered instruction indicated a strong inclination to favor a teacher-centered model of instruction regardless of the level of anxiety or self-efficacy. As shown in Table 4.17, the three groups of anxiety and self-efficacy were evenly divided among the confirmation and outside of inquiry levels. The low anxiety, high self-efficacy group was comprised of two teachers, both upper grade teachers. The other high anxiety group was high self-efficacy and had two members, also upper grade teachers. The largest group of teachers was high anxiety and low self-efficacy and comprised entirely of primary grade teachers. All teachers, regardless of anxiety and self-efficacy preferred a more teacher-centered model of instruction.

As described by Table 2.3, “Parallels between Authentic Scientific Inquiry, Inquiry-Based Instruction and Traditional Instructional Strategies/Methodologies,” one of the aspects of teacher-centered instruction is that it begins with an objective instead of a question (R. L. Bell et al., 2005; Hodgin, 2008; NRC, 1996, 2000). Even though teachers stated a preference for open questions, they did not implement them in their practice. Descriptions of their recently taught lessons were not driven by a question but an objective.

> A lot of your goals are driven by meeting the TEKS that we do. That’s a reality of where we are right now in education. You’ve got the meet the TEKS. (Jane)

The evidence feature was also outside of inquiry as all of the teachers described an isolated activity or data collected as a process skill. No analysis of the data was performed, an essential feature of inquiry missing from these lessons.

> Students engage in an isolated, activity based lesson on the topic. “You know, I think it would be fun to do a pre- and a post- insect. Give them just all kinds of random things that would be on any kind of a mammal, an insect, whatever and have them put together something that they think either is an insect or maybe is just your own animal. Maybe at the end let’s see how we would modify that and actually make it fit the true description of what an insect is. (Jane)

In addition, no data was collected but information was given by reading text or watching a video. Students summarize knowledge from reading; an explanation is provided to the students and the communication of that is an assessment. “We had them make their own cube. On the side of each cube was a like a different thing about each planet, and each child did a different planet, or each group of children did a different planet” (Barbara). In the lessons described by the teachers, no learner explanations were created. Instead, an explanation was provided to the learner. Students do not create their own explanations for the confirmation and outside of inquiry levels. “We had two graphic organizers already set up, so they just kind of filled in, like coloring, like they would color which options they used where” (Barbara). For the vast majority of all of the interviews, any reference to creating explanations was those provided by the teacher or resources.

> In this, I think that the kids have enough access to information that will help them to construct and reach the end goal. Even if it’s that they’re opening a book and doing it just the same way that they did it in the book, they’re still putting it together, they still have it right in front of them, they still can see that little light come on and so I’m very happy with that. (Mary)

The only mention of an explanation being created by the students (possibly with assistance from the teacher) implied by “we” discussed ideas. One emphasis was on vocabulary and reading to prepare for testing.

> Especially with our population, vocabulary is huge because they come in not equipped with a very wide vocabulary in terms of content area. So again, with the non-fiction reading and with me being very much at the helm, I’m sure that the vocabulary that’s related to the content is being delivered to the students and that the students are interacting and using it. That’s a very critical goal of the school, all right. (Mary)

Another teacher also stated that, “Sometimes when I teach science I just don't get that opportunity because you have to go through our vocabulary; we have to understand that vocabulary” (Randy). No alternative explanations were explored as part of the explanation level of inquiry. A marker of the outside of inquiry level is the confirmation of a principle where the explanation is already known. “I want to be able to guide them into finding out the answers or the parts that I want them to” (Jane). As part of the teacher-centered instructional model, teachers avoid alternative explanations to prevent misconceptions. Nancy stated that,

> And so seeing those terminology and all that stuff, and the test strategy part of it is also very important. But when I do that, I give them immediate feedback, like okay, who got it right and who got it wrong? Okay, those you who got it wrong, let’s talk about it. We’ll go through every single strategy they could have used to get to the right answer. And it’s an unfortunate reality that we have to do this - we have to take this time.

Alternative explanations are labeled as “wrong” if not in agreement with the explanations as part of the teacher-centered model of instruction. “I would want to use what little time I have to research it and read lists of common misconceptions or where things go wrong and don’t ever let the students do this, you know, because this will happen” (Jane). With the teacher-centered model communication is a summary of knowledge presented to the student or an assessment of mastery. The purpose for communication then becomes finding the “right” answer. “You know, there’s that little assessment piece: here’s the phases, put them in order and label them” (Jane). She also indicated her preferences for communication by stating that, “Of course some of the kids seem to just know, it’s like a textbook. They come up with the right answer, the right procedure all the time…" There were also no justification of explanations; in fact, students didn't create their own explanations, so there was no need to justify them! All the teachers mentioned dealing with misconceptions with class discussions and with providing another experience, a discussion, or the right answer.

For the teacher-centered model of instruction, mastery of an instructional objective is the main driver. It plays a big role in standardized testing, as test questions are written to assess objectives, not find out if students can answer questions or create their own explanations. There is also no time to use inquiry if teachers are trying to prepare students to take a high-stakes test. Jane stated that,

> Math and Reading aren't even at the end of the year so we have to teach all the Math and Reading TEKS… Yes, it used to be March and now it's early April because we have to give it again if they fail. That's where there's this constant little voice in my head going hurry up, hurry up, hurry up.

The pressure to teach lessons based on mastering an objective in tested grade levels is immense. Linda described some of these time pressures as,

> The only thing that sometimes about science is that, especially the elementary grades, it kinda gets pushed on the back burner because of other things that we have to do. I love to do these kinds of things, but sometimes they're weeks where I can't - I just got to do more of this kind of stuff because of time, and I've got a get them ready for this test, for this benchmark. That's kind of the only bummer thing - in a perfect world we wouldn't have standardized testing.

Another reason teachers may resort to teacher-centered strategies is the belief that inquiry doesn't prepare kids for a standardized test such as the Elementary State of Texas

Assessment of Academic Readiness (STAAR) test. Nancy described a teacher-centered strategy she used to prepare students.

> I pull in 1 to 4 STAAR questions - like actual, on the paper, have them answer the questions. Because the big thing is they can do all the hands-on all day, but if they can't take the 3-D thing to the 2-D version of it, they're not going to be very successful.

Mastering an instructional objective in order to pass a high-stakes test was frequently described by teachers, and may be one reason for adopting teacher-centered instruction.

One aspect of teacher-centered instruction is an external locus of control that some teachers alluded to, and others stated an outright preference for. A feature of this is expert knowledge memorized for testing, instead of student explanations driven by curiosity. Jane stated that,

> the reality now is that academic words are on the STAAR test so sometimes I feel like some of our vocabulary lessons are not as effective… well, they're just not very fun or they're not very thrilling, but sometimes it's just you know, like memorizing multiplication facts. Sorry, you've got to do it so it can help you to move on.

The lack of time also drove Linda to state that, "Sometimes I can get two or three really good collaboration projects going during the year - that's about it. Sometimes it's just hard - the time to try to pull it together." Although only one participant openly professed a teacher-centered philosophy, the other participants described very teacher-centered instruction driven by issues such as the importance of vocabulary, the demands of high-stakes testing, and a lack of time.

Some of the aspects of a learner-centered philosophy of instruction were a strongly stated preference for open questions, and a desire for students to actively collect their own data. Most of the teachers stated a strong preference for open questions, or students creating their own questions to investigate. This type of questioning was stated as a preference by teachers in order to engage their students. Barbara stated, “Letting the kids have input cause I think that gives them a greater feeling of ownership. We’re not just in answering the book’s questions – we’re answering their questions. I think that's important.” But teachers did not communicate this in their best represents lessons. Instead, participants described activity based lessons that were not driven by questions, but were either isolated activities, a process skill, or direct teach of an objective. During the rating of scenarios participants also voiced a preference for guided evidence where students collect data. But this was more for the sake engagement – a “hands-on” activity that didn’t give priority to evidence students gathered or an analysis they created. Students also did not create an explanation, and communication was for the sake of assessment, not justifying explanations. Cross-checks also revealed numerous inconsistencies in their professed desire to use student created questions or guided evidence. Their stated preferences for a student-centered philosophy were not realized in descriptions of their own teaching, only in their criticism of scenarios in the card sort. Their changes to “does not represent and unsure” scenarios actually moved them closer to teacher-centered instruction. Other factors such as lesson cycle preferences that were coded as primarily outside of inquiry. The role of writing and vocabulary instruction was described as essential to test preparation and to “pre-teach” vocabulary instead of an inquiry strategy that permits students to create working definitions as vocabulary words emerge during a lesson. Another aspect is the role of "hands-on" instruction for student engagement instead of gathering data for analysis. Finally, high-stakes testing and its relationship to teacher-centered instructional model may be the most accepted method to promote test-taking strategies.

In summary, the teacher participants all subscribed to a primarily teacher-centered philosophy of instruction, regardless of their levels of science teaching anxiety or self-efficacy. Teachers were holistically placed along the inquiry continuum based on how their preferences matched numerous aspects of teacher-centered instruction such how as their description of their own lessons begin with an objective instead of a question. They described isolated, activity-based lessons where no learner explanations were created, and communication was a summary or assessment. In addition, there were few matches to learner-centered instruction. Although teachers stated preferences for open questions, this preference may not be genuine since few indicated this in their practice. One of the most common preferences was for guided evidence, yet it was more a desire to include hands-on activities for the sake of engagement. So even with many scenarios classified within the learner-centered continuum, the holistic classification placed all the teachers with preferences for a teacher-centered philosophy, regardless of their degree of anxiety and self-efficacy.

Research Question 3 - *How do teachers with low science anxiety and high science teaching self-efficacy compare with high anxiety, low self-efficacy and high anxiety, high* *self-efficacy teachers in their implementation of a traditional or inquiry-based model of instruction?*

The implementation of an inquiry-based or traditional model of instruction may be related to a teacher's level of anxiety and self-efficacy. The three comparison groups, low anxiety and high self-efficacy, high anxiety and low self-efficacy, and both high anxiety and high self-efficacy demographics displayed patterns based on grades taught and self-reported areas of specialization. One pattern was that all of the low self-efficacy participants taught in the primary grades (pre-K – 3rd) and listed areas outside of science as their specializations. The high self-efficacy teachers were all upper grade teachers (4th – 5th) and each listed science as at least one of their areas of specialization.

Table 4.18

Comparisons of Anxiety and Self-Efficacy Groups

Anxiety/Self-Efficacy Groups	**n**	**Grade Taught**	**Specialization(s)**
Low Anxiety/High Self-Efficacy	2	4th and 5th	Science and Math, Science
High Anxiety/Low Self-Efficacy	4	Pre-K – 3rd	Math, Reading, Language Arts
High Anxiety/High Self-Efficacy	2	5th	Science and ELA, Science

Yet little differences exist between the three groups when classified holistically. They all preferred traditional models of instruction when all aspects of their interviews were analyzed. All of the teachers were placed closest to the confirmation and outside of inquiry level on the continuum based on not only their best represents scenarios, but how they changed their “unsure and does not represent” scenarios. However, their descriptions of their best represents lessons were all consistent. They described traditional, outside of inquiry lessons directed at mastery of an objective with an isolated activity or process skill lesson. They preferred that evidence be collected by student, but for the sake of engagement. No student explanations were created and communication was for the purpose of summarizing or assessment.

High Anxiety, Low Self-efficacy Group

The high anxiety, low self-efficacy group was the most represented among the participants. It is comprised of four teachers, all teaching the primary grades. There is no real emphasis on teaching science in the primary grades, especially in Pre-K through 1^{st} since the elementary science test is not until 5^{th} grade. The focus for these grades is preparing students to be independent readers and for the 3^{rd} grade tests in Reading and Math. None of the participants listed science as an area of specialization, only reading and math, so these teachers may have been assigned to teach these grades because they do possess low science teaching self-efficacy.

One of the levels of inquiry – question preferences – was predominantly open and confirmation. See Table 4.19 below.

Table 4.19

Essential Features of Inquiry - Question Preferences for High Anxiety/Low Self-Efficacy

Essential Feature	Sample Quotes	Freq.	%
Open	"I like that they're sharing their findings and that they're presenting their experiments, their hypothesis, and you know, talking about that." Karen	9	6.76
Guided	"Again, because I provided the list of questions and so in doing that I am fairly certain that I'm asking the students to select something that they will be able to answer." Mary	5	3.07
Structured	"So then the triads would probably put together the lab report forms and make a science board or something, an end product to show that they did, what they found, and the conclusion." Mary	1	0.74
Confirmation	"But again, my comfort zone, I already have it (question) and that's what they're going to work with." MB	5	6.34
Outside of Inquiry	"For science I start off my direct teaching usually at the very beginning, when I'm talking and explaining what we're gonna be studying, and I asked them a question to kind of start their brains spinning on the subject." KR	3	2.5

n = 4

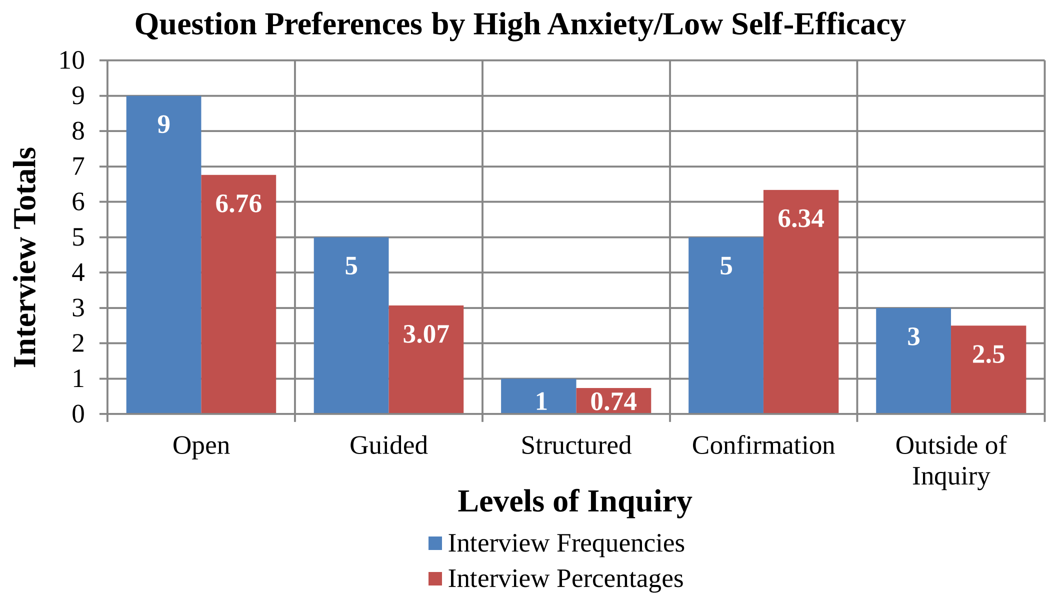

Figure 4.31: Question Preferences for High Anxiety and Low Self-Efficacy

The group of high anxiety, low self-efficacy participants preferred primarily an open and confirmation level of questions. They stated preferences for students asking the questions that drive the lesson. Although they may have tried to answer student questions during the course of a lesson, they did not write lessons based on a student(s) question. Their open preferences may have been based on desire for student engagement, yet is not seen in their instructional practices. “We did a solids activity where we discussed the definition of a solid, which was very hard to do at the first grade level” (Mary). Evidence preferences for the groups were primarily guided, confirmation, and outside of inquiry.

Table 4.20

Essential Features of Inquiry - Evidence Preferences for High Anxiety/Low Self-Efficacy

Essential Feature	Sample Quotes	Freq.	%
Open	"But the only thing that I don't like about this one is that I provide the questions. I would like them to come up with the questions." Karen	3	1.84
Guided	"I guess it depends on age group; like with my kids, third-graders, they may need a list of questions to choose from. " Linda	7	7.76
Structured	"I like the first part because you're kind of designing the unit around what the kids want to know, so the kids a little bit more engaged about that because it's more student centered…the class refines the question" Linda	3	2.67
Confirmation	"I gave them the materials; they have access to non-fiction resources so they can find in books, Internet how it's been done previously by others so that they have a way to recreate something that was done before if that's what they need." Mary	8	10.66
Outside of Inquiry	"Okay. In science I prefer to teach a little bit of a hands-on - visual - a small one, and then maybe go into a little independent activity with the students." Karen	20	34.55

n = 4

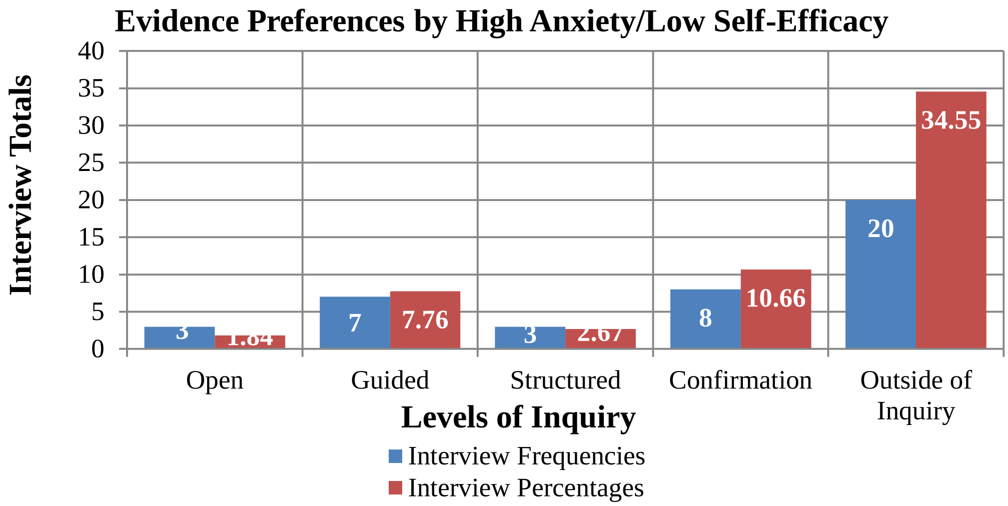

Figure 4.32: Evidence Preferences for High Anxiety and Low Self-Efficacy

Teachers in this group preferred primarily guided evidence for the sake of engagement. “There would be movement, there would be group involvement, maybe some collaboration going on hopefully some really good discussions about why this belongs they are and that belongs there.” (Barbara) Participants stated preferences for evidence gathered to practice process skills instead of to analyze data. “So they are taking data; each of them had a role, each of them had a job - materials manager, data collector, things like that” (Linda).

Their explanation preferences were overwhelmingly outside of inquiry, with some preferences for confirmation and structured. See Table 4.21 below.

Table 4.21

Essential Features of Inquiry - Explanation Preferences for High Anxiety/Low Self-Efficacy

Essential Feature	Sample Quotes	Freq.	%
Open	"Even though it says write a summary - that has some of their explanations and answers and all that." Karen	1	0.34
Guided	"So I think that the kids would be able to do some of this research on their own. Okay, I could certainly do some preliminaries to maybe guide them to some Internet websites that are approved places to look and our library would be a great place to go." Mary	3	1.67
Structured	"So we can find out who's was strongest and whose was the better designed, and we would analyze. Why was that a good choice?" Barbara	6	4.82
Confirmation	"I understand why you would read several nonfiction books to build background." Linda	6	9.52
Outside of Inquiry	"They're breaking them down, they're putting them on a graphic organizer. So they're using you know also vocabulary - I'm sure in this graphic organizer there's vocabulary. It's just something that really lends itself, so I like this." Karen	15	26.37

n = 4

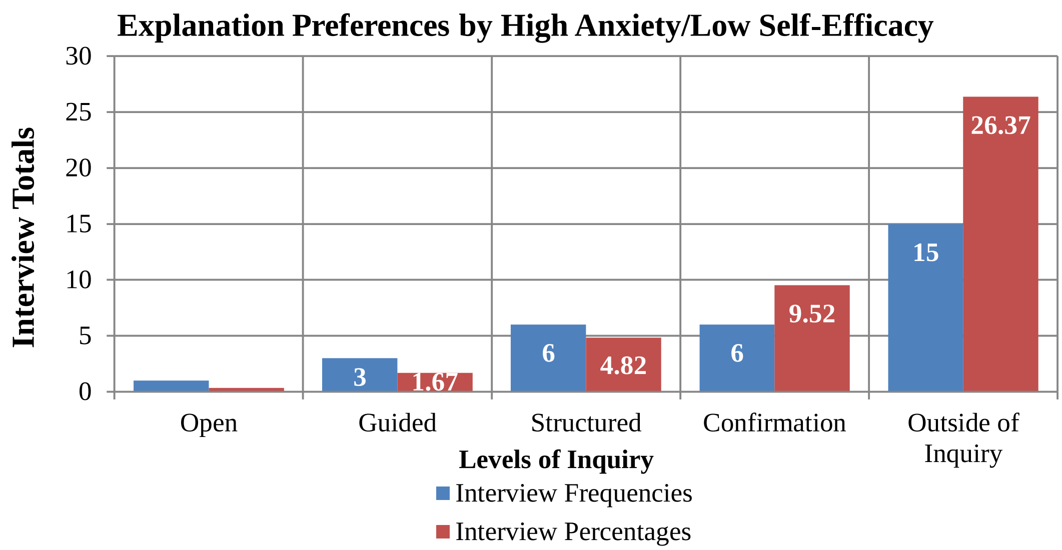

Figure 4.33: Explanation Preferences for High Anxiety and Low Self-Efficacy

Like all the other groups of participants, these teachers were primarily outside of inquiry for the explanation level. In the outside of inquiry and confirmation levels, the explanations are provided by the teacher or no explanation is created. “I would have them all look at the observations they've made, and how are they the same, and her they different. Hopefully then they would see the commonalities” (Linda). Another participant stated that, “When I’m presenting information to the students and then they tell me what they’ve learned, they make an erroneous statement and so that gives me an opportunity to screen for that” (Mary).

This group’s communication preferences are also primarily outside of inquiry with some structured preferences. See Table 4.22.

Table 4.22

Essential Features of Inquiry - Communication Preferences for High Anxiety/Low Self-Efficacy

Essential Feature	Sample Quotes	Freq.	%
Open	"I like that they're sharing their findings and that they're presenting their experiments, their hypothesis, and you know, talking about that." Karen	1	0.69
Guided		0	0
Structured	"I like the idea of the written part - I like to have a lot of writing in my classroom even with the little guys, cause we're doing science manuals and they're having a great time was science." Barbara	3	5.73
Confirmation	"I like the writing component, and explaining about their observations, having another observation from there." Barbara	6	2.73
Outside of Inquiry	"The graphic organizer I like; and I like the fact that they're working groups to do this other project then that's also a part of it which is creating a poster." Barbara	12	11.64

n = 4

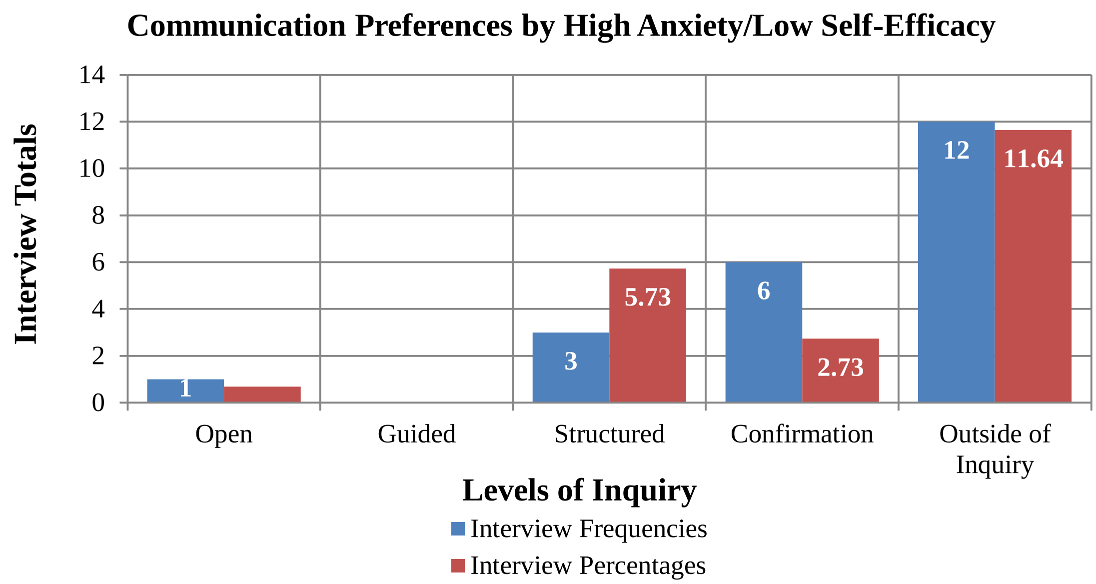

Figure 4.34: Communication Preferences for High Anxiety and Low Self-Efficacy

The high anxiety, low self-efficacy group described primarily a structured and outside of inquiry preference for science instruction. A structured communication level describes students receiving explicit instructions for communicating and justifying their findings. “It would be interesting for them to write a report documenting what they found in their experiment or what happened in their experiment and how that connected to what they found in their Internet or non-fiction research” (Mary). For an outside of inquiry level there is no justification of an explanation, so teachers described a strategy for summarizing information. “They’re sharing it on the bulletin board, so they can still do a gallery walk and look at each other's insects” (Mary).

Overall, the high anxiety, low self-efficacy group holistically preferred a traditional of instruction. They stated preference for open and confirmation questions, but did not follow those preferences in their descriptions of their own lessons. Their descriptions of their own lessons were all outside of inquiry – isolated activities driven by objectives, not questions. Although they described preferences for outside of inquiry with some confirmation and guided evidence, this was mostly due to a desire to provide engaging hands-on activities. The group preferred a traditional explanation, provided by teacher or materials instead of being created by the students. Communication was primarily outside of inquiry as an exercise in summarizing information or assessing mastery of an objective. Therefore the holistic classification of the high anxiety, low self-efficacy group fits within a traditional model of instruction.

Low Anxiety, High Self-efficacy Group

This group is represented by two teachers, both teaching in the upper grades (4^{th} and 5^{th}). Because science is tested in 5^{th} and writing in 4^{th} (in addition to Reading and Math for both) this group is under pressure to prepare students for several high-stakes tests, including science. Both of these teachers also listed Science and Mathematics as areas of specialization.

Their question preferences were primarily outside of inquiry with a smaller percentage of preferences at the guided level. See Table 4.23 below.

Table 4.23

Essential Features of Inquiry - Question Preferences for Low Anxiety/High Self-Efficacy

Essential Feature	Sample Quotes	Freq.	%
Open		0	0
Guided	"so I guess again if I were going to give them questions, I'd have to give them some probing questions." Jane	3	1.99
Structured	"what is my goal? Is it to teach them just about an earthworm? Are they learning how earthworms interact with their environment? Are we looking to make an earthworm turn a certain way or draw back when you touch it? What am I doing?" Jane	1	0.43
Confirmation	"I think that starting out with the big idea question is important – "what makes an animal an insect?"- gets the students involved in that. And I think starting a lesson by presenting question that you want to be answered in the course of lesson kind of like prompts students the things to look out for." Daniel	2	1.18
Outside of Inquiry	"we do study electricity. We do study parallel circuits, series circuits, all those different types of things." Jane	10	6.03

n = 2

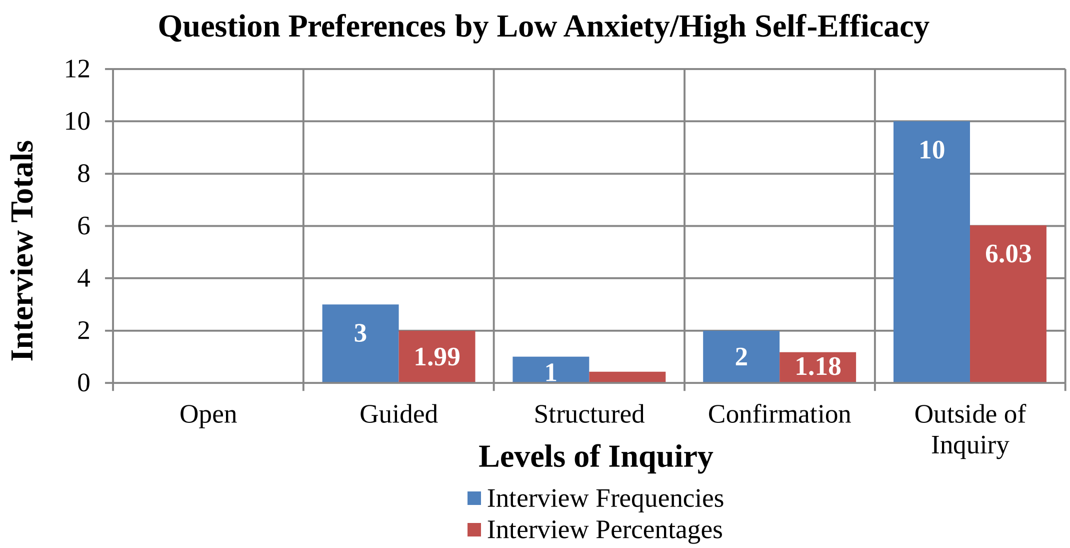

Figure 4.35: Question Preferences for Low Anxiety and High Self-Efficacy

The group's preferences are primarily outside of inquiry with some guided and structured levels. Outside of inquiry preferences are driven by the need to master an objective, not to explore a question. "Well, obviously I have TEKS or TEKS or whatever you want to call them and want them learning about the world and the different disciplines in Science" (Jane). Guided and structured preferences were also expressed. Even when teachers chose a guided approach, they sometimes qualified it by stating that students might not be able to choose an appropriate guided question.

> You like the idea of students driving some of the questions, but you realize that sometimes they come up with questions that are just not testable and you have to politely explain that to them and get them to move on in a direction that you can explore. (Barbara)

The teachers in the group described a preference for guided and outside of inquiry evidence. See Table 4.24 below.

Table 4.24

Essential Features of Inquiry - Evidence Preferences for Low Anxiety/High Self-Efficacy

Essential Feature	Sample Quotes	Freq.	%
Open	"So I do like the fact that this investigation that they are observing and actually recording their data on their own." Daniel	3	2.93
Guided	"I'm absolutely going to have to guide them… am I going to be able to successfully monitor thirty fifth graders or twenty kindergarteners in what they're doing with these earthworms? I think they'd need at least some kind of parameters." Jane	10	7.78
Structured	"I think that data includes that it is collected over time. So we can measure how much paper that we're recycling here. Or we can put plastic, and aluminum cans - recycled materials." Daniel	1	0.72
Confirmation	"I would like to do some, you know, even if we record daily, weekly weather on a chart - humidity, barometric pressure, weather systems, high pressure fronts, low pressure fronts and we do talk about if there's a low pressure front here in this city on a US map." Jane	3	2.87
Outside of Inquiry	"Web resources are good. They love that. I think they love non-fiction Science books, especially with photographs. Photographs of weather events are good too." Jane	18	21.47

n = 2

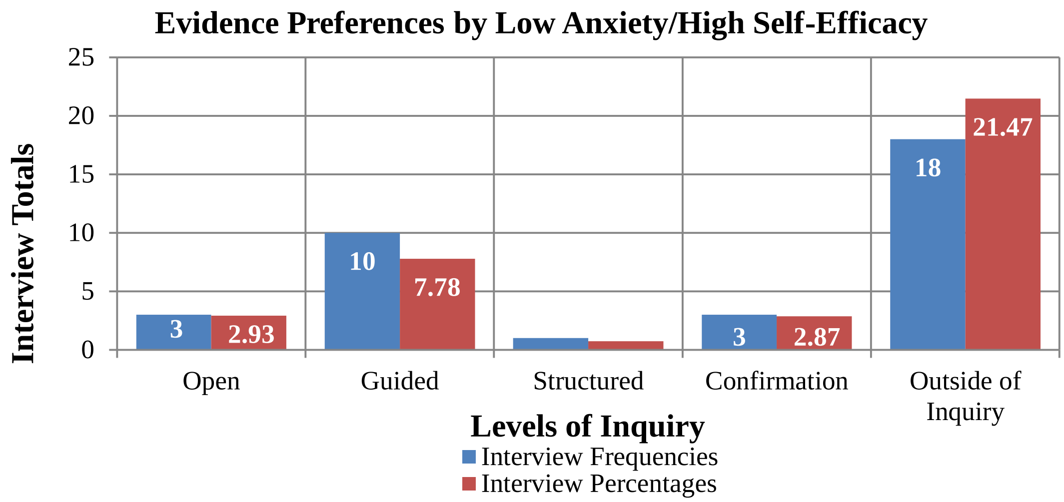

Figure 4.36: Evidence Preferences for Low Anxiety and High Self-Efficacy

This group's preferences for evidence are very similar to the high anxiety, low self-efficacy group. They stated a primarily outside of inquiry level, with some guided and confirmation levels. Evidence classified as outside of inquiry is an exercise in reading or watching video to acquire information. "We look at a video; we're incorporating reading more as a part and parcel of science instruction. We start the lesson with reading about it, highlighting questions, underlining things that need to be underlined" (Jane). There is a preference stated for guided evidence, but for the purpose of developing process skills, not authentic data collection and analysis.

> I do not think that little kids should be left to their own devices to come up with this sort of investigation. But at the same time it is important that the students develop observation skills and learning about how their five senses are so very, very relevant in what they learn in school. (Daniel)

The group's explanation preferences are almost the same as high anxiety, low self-efficacy group. They described a preference overwhelmingly outside of inquiry, where explanations are provided to the student and alternatives are ignored. "We have to share in class what we found, what we saw, what we drew. I would put it up on a class chart to see and make sure everybody saw the same thing" (Jane). Other stated preferences at a smaller percentage of the interview are structured and confirmation. With confirmation, the students perform a set of instructions to find a predetermined outcome. Daniel describes this as, "They do the observations, they had cards and photos to match up, and all the sort of things, and correctly labeled." Communication preferences include an outside of inquiry level for the purpose of summarizing knowledge gained through reading, not justifying student explanations. "I like the letter sent home to parents, definitely pulling in that home-school connection" (Jane). The group also described some confirmation preferences for reporting their results. "Writing a summary comparing their explanation…they've written an explanation of why they think it does this or whatever and then they research it and maybe find out they were wrong or they were right" (Jane)?

Overall, the low anxiety, high self-efficacy group was holistically classified as preferring a traditional philosophy of instruction. They stated preference for outside of inquiry with some guided and structured questions, but did not follow those preferences in their descriptions of their own lessons. These lessons were all outside of inquiry – isolated activities driven by objectives, not questions. In addition, their stated preferences for outside of inquiry and guided evidence were mostly for a desire to provide engaging hands-on activities to their students. As with all of the groups, they preferred a traditional approach to explanations, provided by the teacher or materials instead of being created by the student. Finally, communication was primarily outside of inquiry as an exercise in summarizing information or assessing mastery of an objective. Therefore the holistic classification of the low anxiety, high self-efficacy group fits within a traditional model of instruction.

High Anxiety, High Self-efficacy Group

Two teachers, both in 5th grade, a science tested grade, are members of the high anxiety, high self-efficacy group. Both teachers described Science and English Language Arts (ELA) as their areas of specialization.

Question preferences for the group were primarily structured and open. See Table 4.25.

Table 4.25

Essential Features of Inquiry - Question Preferences for High Anxiety/High Self-Efficacy

Essential Feature	Sample Quotes	Freq.	%
Open	"I like that this is something they were interested in the first place, something they already had interest in - it wasn't just handed to them - here do this. The students are doing a lot of the work here - they're coming up with their own questions." Nancy	7	3.22
Guided	"Okay what kind of questions do you have, and help generate them - then generate the questions and let them pick the question they want to answer." Nancy	2	0.95
Structured	"So what are some of the things you see here? I see earthworms, if see dirt, - whatever other things. Okay so what is something we could change, and kind of elicit it that way." Nancy	2	3.36
Confirmation	"So things I've done in the past is "say, what if I use more than one battery?" What if I use the buzzer?" Nancy	3	1.01
Outside of Inquiry		0	0

n = 2

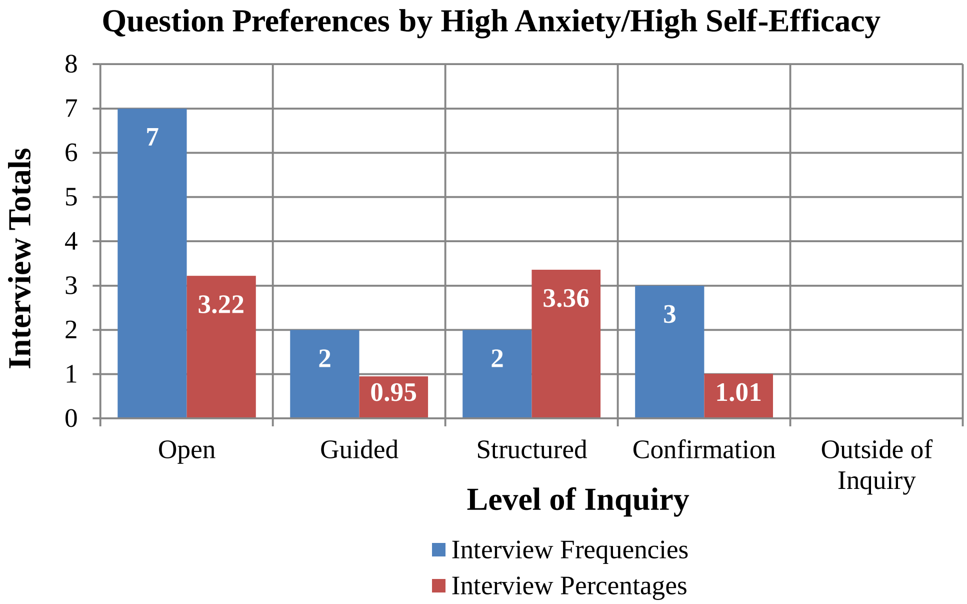

Figure 4.37: Question Preferences for High Anxiety and High Self-Efficacy

This group described primarily an open level of question as teachers stated a preference for student created questions when criticizing the scenarios. “The only thing I would change is the students would come up with the questions” (Nancy). She also described some structured changes to scenarios as she states how she deals with kids who come up with questions that are not testable.

> I could pull them into a small group and say “hey let's work on this.” Maybe one kid discovered that question’s not testable, and then another one that has one non-testable can help teach that kid with what was not clicking in their investigation. (Nancy)

Evidence preferences for the high anxiety, high self-efficacy group were primarily guided and outside of inquiry. See Table 4.26 below.

Table 4.26

Essential Features of Inquiry - Evidence Preferences for High Anxiety/High Self-Efficacy

Essential Feature	Sample Quotes	Freq.	%
Open	" All of this this is great because they made the bridges to begin with, and now they're going to make them move in different ways, so they get to apply engineering principles to what they built." Randy	4	2.09
Guided	"We can go test water in the creek, and go outside of the classroom and test things in different places. But the kids could collect them from different places and we can test that because our drinking water is ultimately what comes up out of the ground. What's in our streams?" Randy	15	12.58
Structured	"I prefer that they had some hands-on idea of recycling. By that I mean, we're recycling - what is it? I mean we can go to a field trip where things get recycled." Randy	0	0
Confirmation	"They can look in the newspaper or they can look online for the daily weather - to see what it is every day. To relate what they're reading to what is happening outside" Randy	3	1.58
Outside of Inquiry	"I want the literacy piece in there, so I would have every single kid with a copy of whatever I was reading, and mandatory that they're following along. For kids on who can read fluently, reading with me too." Nancy	6	9.03

n = 2

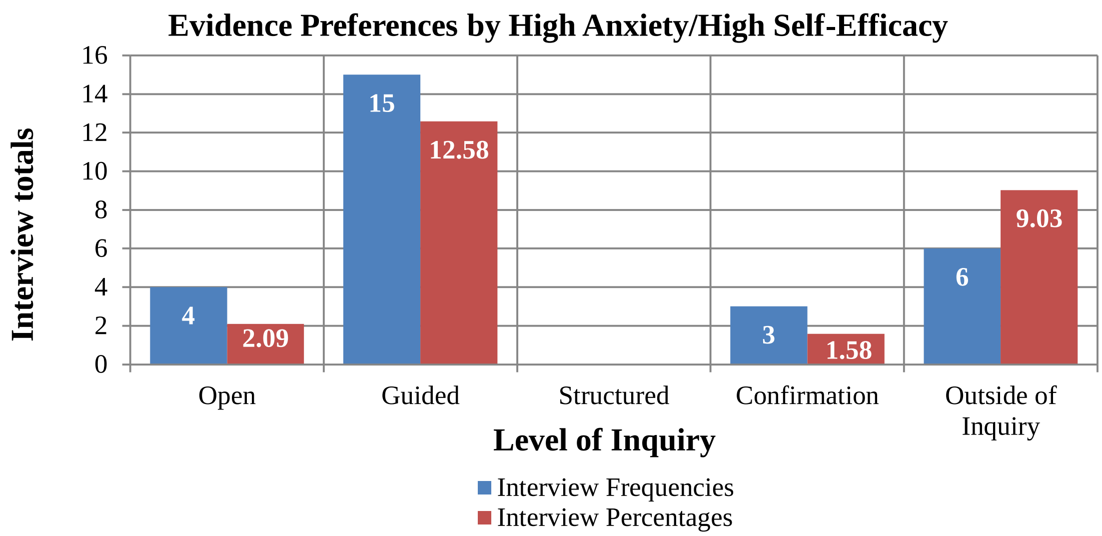

Figure 4.38: Evidence Preferences for High Anxiety and High Self-Efficacy

The group's preference was for a primarily guided level of inquiry to provide a process skills lesson in observation and comparisons.

> I like assembling the body parts, but if they haven't actually physically like observed, taken a hand lenses and observed different insects. If they were little, I would also like them like to look at what different insects have a common - like these have six legs or whatever. (Nancy)

Their choices also included some outside of inquiry preferences for isolated activities such as reading text or online references. "I mean I would want them to actually like go to weather.com and record the weather, notice trends in the weather. Have them do that for like the week before we teach weather" (Nancy).

The high anxiety, high self-efficacy group's explanation preferences were very similar to the high anxiety, low self-efficacy group. Their descriptions were overwhelmingly outside of inquiry in order to master an objective, particularly one tested on the Elementary Science test. One of the participants stated that, “I wanted them to apply it - knowing whether something uses or produces energy - for instance the projector uses electrical because you played it, and mechanical because you press a button, and it produces light, heat, and sound” (Nancy).

Finally the communication preferences for the group were primarily guided for preference with students creating a rubric to guide an assessment. See Table 4.26 below.

Table 4.26

Essential Features of Inquiry - Communication Preferences for High Anxiety/High Self-Efficacy

Essential Feature	Sample Quotes	Freq.	%
Open		0	0
Guided	"The science essay, I don't have a problem with either – it's fine. I don't have them do essays, I mean I have them do writing pieces, like an essay is a very formal thing." Nancy	4	5.79
Structured	"I do like that they have help writing the lab reports because they do need help with that, no matter the grade level." Nancy	2	0.57
Confirmation	"I would have them do that same activity, just draw the pictures with the names labeled in their notebook. I wouldn't waste my time with cutting and folding." Nancy	2	1.41
Outside of Inquiry	"I had them put little facts on notecards and tie to strings at the bottom of their planet, and we hung their planets up in order." Nancy	1	0.37

n = 2

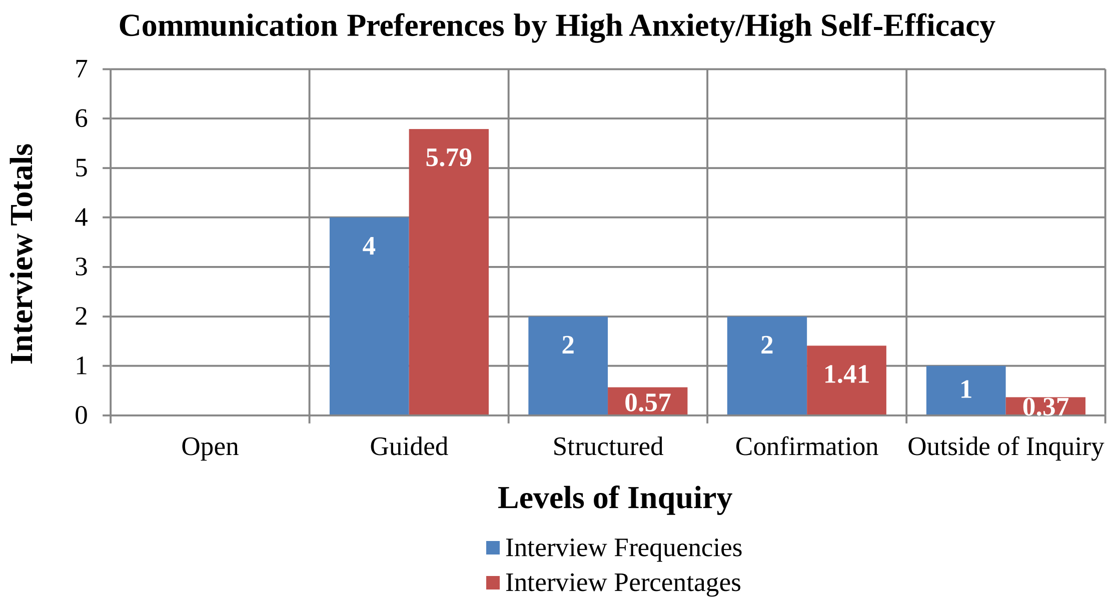

Figure 4.39: Communication Preferences for High Anxiety and High Self-Efficacy

This preference constituted a large part of the interview because the teacher talked extensively about the practice of helping students create their own rubrics. “I like that they’re presenting it. The only thing I would change is I would have them help me create a rubric” (Nancy). The preference for the confirmation level of inquiry was also described by the teacher as the practice of having students summarize information for mastery of an objective. “I would have them do that same activity, just draw the pictures with the names labeled in their notebook” (Nancy).

In summary, the holistic placement of the high anxiety, high self-efficacy teachers were for a traditional instructional philosophy. They stated preference for open and structured questions, but did not follow those preferences in their descriptions of their own lessons. All of their descriptions of best represents lessons were all outside of inquiry – isolated activities driven by objectives, not questions. Plus, their stated preferences for guided and outside of inquiry evidence were driven mostly for a desire to provide engaging hands-on activities. They also chose a traditional approach to explanations. As with all the groups, explanations were not created by the students, provided by the teacher or materials. Communication was primarily at the guided and confirmation level, mostly based on one teacher's lengthy discussion of students working with her to create rubrics. The purpose of communication, as with the other groups, was to summarize knowledge and assess mastery of an objective, with no justification of explanations. The overall classification of the high anxiety, high self-efficacy group is within the traditional approach at the confirmation and outside of inquiry end of the continuum.

Holistically, there were few differences between any teachers regardless of anxiety or self-efficacy. Even though most of the participants found it easy to criticize the scenarios, there were inconsistencies throughout their interviews in their preferences. There were also few but significant references to anxiety.

> I would need to find out the what if's so I'm not in the class just giving them random materials and going oh gosh, or saying something oh, my gosh, I didn't think that would happen. I don't feel… I like to feel comfortable and feel knowledgeable. I don't want to feel like an idiot teaching something. (Jane)

The role that campus culture and the nature of science plays in instruction included areas described in the interviews such as each teacher's individual interpretations and application of is part of traditional instructional methods, an objective-driven approach that treats scientific inquiry as a set of formulaic steps to follow. It is sometimes called a "transmission" model, and follows the sequence of inform, verify, and practice (Jadrich & Bruxvoort, 2011). All of these areas moved teachers much closer to the traditional model of instruction.

Finally, a self-reporting bias may have teachers stating preferences for scenarios that are more inquiry-based than their actual practice. Teachers may profess a preference for student-centered instruction, but may actually prefer strategies that when taken together provide a more teacher-center lesson cycle.

SUMMARY

The overall analysis of the data is that the theoretical framework was not supported by the evidence. Teachers with high anxiety did not necessarily possess low self-efficacy, and all teachers, regardless of their degree of anxiety or self-efficacy preferred a teacher-centered, traditional model of instruction. Although teachers stated a preference for student-centered instruction when evaluating the researcher-created scenarios, their selection of strategies and descriptions of instructional practices did not match a student-centered approach. Other factors significantly influencing a teacher or student-centered model include the pressures of testing and the resultant barriers such as the time needed to utilize inquiry competing with traditional methods intended to produce acceptable test scores. Testing skills such as reading and vocabulary are viewed by teachers as an essential part of preparing students to be successful on a high-stakes test. The next chapter will discuss the possible reasons that the entire framework was not supported by data, and includes a discussion of the findings along with areas for future research.

Chapter 5: Discussion and Conclusions

Introduction

This chapter presents a summary of the results, and a discussion of the research questions within the theoretical framework. It includes an examination of implications, limitations of the study, and areas for further research.

Research Questions

The results of this study focused on the following questions:

1. Do teacher beliefs direct their personal philosophy of science instruction, and if so, how?
2. Is there a relationship between the levels of science anxiety/science teaching self-efficacy and the preference for a teacher-centered model of instruction as opposed to a learner-centered model? If so, what is the relationship?
3. How do teachers with low science anxiety and high science teaching self-efficacy compare with high anxiety, low self-efficacy and high anxiety, high self-efficacy teachers in their implementation of a traditional or inquiry-based model of instruction?

SUMMARY OF THE STUDY

This descriptive, mixed-methods study explored teacher beliefs through the lens of science teaching anxiety and self-efficacy. The quantitative portion of the study sought to examine a possible relationship between anxiety, self-efficacy and how teacher beliefs may influence their philosophy of education. A survey consisting of questions from two instruments was used to identify levels of anxiety and self-efficacy. The online survey was sent to all the elementary teachers within a large urban school district, and completed by 86 elementary science teachers. Scores for both anxiety and self-efficacy were ranked, and participants classified by percentiles with the top 25% of both instruments rated as high, bottom 25% as low, and the middle 50% as medium. Three groups were identified – low anxiety and high self-efficacy; high anxiety and low self-efficacy; and high anxiety, high self-efficacy. There were no low anxiety, low self-efficacy participants – nor would it be a group likely to be worth investigating.

Participants from each of the three groups were contacted and asked to participate in an interview to examine the two other research questions. The semi-structured interview was designed to explore a possible relationship between levels of anxiety and self-efficacy, and a preference for a teacher or learner-centered model of instruction. Each of the participants was holistically classified along the essential features of inquiry with either a preference for a traditional or inquiry-based model of instruction. A card sort methodology of twelve science teaching scenarios was the basis for the structured part of the interview protocol, along with other probing questions based on participant responses to questions such as “what does hands-on instruction look like in your class?”

Participants rated scenarios as best represents, unsure, or does not represent their preferences for science instruction. The researcher coded the scenario responses along the NRC's five essential features of inquiry to place teacher preferences along a continuum of traditional or inquiry-based instructional strategies that also range from the most to least teacher and student-centered approaches (NRC, 2000). There were no differences between the group's final holistic classifications, as all the teachers preferred a traditional model of instruction. The teachers with the lowest level of anxiety described the most overtly traditional approach, and high anxiety teachers of both high and low self-efficacy described a preference for a more open and guided approach than the low anxiety teachers. None of the teachers had students create their own explanations, as well as contradicting many of their preferences when describing a lesson they recently taught that best represents how they prefer to teach. Although most of the teachers preferred an open level of inquiry with student questions driving the lessons and a guided level of evidence gathering with students collecting data, they did not begin any of their own lessons with a question and the desire for collecting data was primarily to address the myth of hands-on science for the sake of engagement. Many teachers described a preferred traditional lesson cycle entirely outside of inquiry with students being presented with explanations up front, participating in an isolated activity, and no student explanations or justifications created or communicated. Therefore, the theoretical framework of this study was not completely supported by the data, although the results for high anxiety teachers did support the assertions made within the theoretical framework. Finally, although the model for the low anxiety teachers within the framework was not supported, the framework does exist within the background of high-stakes testing, and this may be a contributing factor.

DISCUSSION

Numerous factors may have affected the results of this study, namely that all of the teacher participants preferred a more teacher-centered, traditional model of instruction. Teachers were classified along the inquiry continuum based on teacher interviews coded for correspondence to the essential features of inquiry, including their levels from most open to outside of inquiry and from most learner-centered (matches most open) to most teacher-centered (matches confirmation and outside of inquiry). A teacher-centered model of instruction holistically placed all individuals and groups of teachers. This teacher-centered model is the opposite of inquiry, and the most traditional instructional focus. It falls outside of inquiry, as the students follow a teacher-directed, isolated activity/skills based lesson heavily dependent on text-based acquisition of knowledge (R. L. Bell et al., 2005; Hodgin, 2011; NRC, 2000). This is also known as a "transmission model of instruction" that follows the sequence "inform, verify, practice" (Jadrich & Bruxvoort, 2011, p. 164). An example described by both high anxiety and high self-efficacy teachers is illustrated by their description of changes they would make to the moon phases scenario. Both teachers described how they would pre-teach the phases of the moon, have the students observe, then create a foldable or journal entry.

> So I would pre-teach the phases of the moon. I think I do moon phases and tides in the same week – what's the moon's effect on earth in one week -

> so three or four of those days are the moon phases. So I would do that first, and then Monday I would assign the moon homework, which I do. And then take a little bit of time every week and go back and look over it and just make sure everything is done as you want them. (Nancy)

The teachers described traditional lessons with predetermined outcomes that students must reach in order to show mastery of an objective. All of the 5th grade teachers stated that they would pre-teach the names of the moon phase, and show the students a video or PowerPoint of a moon cycle before they did their observations.

Also described by many of the teachers was their belief that they needed to pre-teach concepts and vocabulary. "But I like to do the pre-teach and the brainstorming and model. These kids definitely need clear steps, need modeling, need an example to refer to." (Jane) She also described the role of vocabulary instruction in science.

> So I've introduced and pre-taught those, giving them little examples, solvents, solute, you know. The solid is the solute and the solvent is what's doing the dissolving, whether it's a liquid, whether it's another solid dissolving. So we give them examples trying to relate it to something that they understand like we talked about dissolving lemonade powder in water. I even mentioned if you're trying to get tarnish off of jewelry or something like that. Give them examples, real world examples, they write it down. Sometimes they draw a picture. So we do kind of the pre-teach and then as we're going through the lesson every day, every week, as much as it comes up, today mixture, solution, heterogeneous solution, homogenous came up. Talk about it, refer to it, we've got the definitions; here's another example of this. So we're just constantly bringing it up, bringing it up, and then that way that more academic vocabulary becomes second nature to them. (Jane)

This desire to "inform" first is a traditional, outside of inquiry model that presents students with information, gives them isolated activities to verify the information and engage their interests (Jadrich & Bruxvoort, 2011). Teachers adopt this model out of a genuine concern for students and the belief that they will not be able to understand science discussions or activities without first knowing the vocabulary. Barbara justified this practice by stating that, "we would do the vocabulary first so they knew what they were dealing with." Another teacher represented the concerns of many other participants that they had a responsibility to teach vocabulary to English Language Learners (ELLs). "Especially with our population, vocabulary is huge because they come in not equipped with a very wide vocabulary in terms of content area" (Mary). Finally, a bilingual science teacher described how he preferred to introduce vocabulary into his science instruction. "Present the vocabulary and associate it with pictures of the moon before they do the observations rather than only at the end. I think sort of pre-teaching would be better and then they would sort of observe after" (Randy).

Teachers also frequently expressed a preference for open questions and guided evidence that they frequently contradicted within the course of the interview. They stated preferences for using the student's questions, but did not include these questions as the focus of instruction in descriptions of their own lessons. Teachers talked about the importance of student engagement and hands-on activities, yet did not write lessons that included these elements. One example was the kindergarten teacher who talked about how important hands-on activities were, yet in her own lesson she described how the district sent her 12 magnets for 19 students, so instead of working in pairs or small groups she did a whole class demonstration where she called one student at a time to the front of the room to test a few objects. Another teacher talked about the importance of taking students outdoors to observe the weather, yet in the description of that lesson he had them collect data from online sources only. During her rating of some scenarios, Mary stated a preference for guided evidence and open questions, even though the majority of her ratings were outside of inquiry. But later in the interview she contradicted herself and stated that, “My preferred way of teaching is I guess you’d call it… lazy. I would prefer to call it controlling. I actually prefer to show the students rather than have them do it themselves. That’s my preference.”

The teachers in this study also conveyed a preference for “hands-on” activities, but for the sake of engagement without the analysis of data and explanation of patterns and trends that are an essential feature of inquiry-based instruction. In a study of teacher attitudes about high-stakes testing in elementary science, Pringle and Martin found that many teachers equated inquiry with hands-on (R. Pringle & S. Martin, 2005). Contradictory answers during interviews were also found by Milner in a study of teacher beliefs of how No Child Left Behind (NCLB federal legislation) has affected their practices (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012). Although two-thirds of teachers reported using inquiry in their classroom practices, an even larger percentage reported a lack of time to teach science due to meeting reading and math testing demands (Milner et al., 2012). Of the teachers in the Milner study, 36% reported using science topics in reading and language arts to satisfy science requirements (Milner et al., 2012).

Several possible explanations for why teachers contradicted their preferences within the interview may be an emphasis on student engagement and the difficulty of implementing inquiry-based lessons, especially if science is not a teacher’s area of specialization. It may be easy to criticize the scenarios as not having enough hands-on activities, yet more difficult to create these lessons or interpret the district's lessons. The teachers in this study emphasized the importance of student engagement through open questions and hands-on activities, yet did not describe this when writing their own lessons. The myth that hands-on activities insure inquiry learning is described by the teachers in this and other studies, and although engagement is important, hands-on for the sake of engagement does not address other essential features such as the ability to create and justify explanations (NRC, 2000; Zembal-Saul, Haefner, & Avraamidou, 2002). Because these isolated activities do not analyze data or have students create explanations, they do not qualify as inquiry-based instruction (R. Bell et al., 2010; NRC, 2000). Like the preservice teachers in a study by Cady and Rearden, even though the participating teachers stated that hands-on was important, they wrote few lessons incorporating these activities (Cady & Rearden, 2007). More than one teacher interviewee reported difficulty with implementing district-created lessons that included an experimental component. Karen stated that she has difficulty implementing the hands-on activities and materials provided by the district and wanted more explicit directions.

> It would really be nice if (the district) was to provide us with, like whenever there's an experiment, like show us in a little video clip - this is what you're gonna do. I remember when I taught second grade once they were showing us how to do like inclined planes and cars and in my mind it doesn't work that way. It took me a while to learn it. Just reading it – I couldn't really understand what I was doing.

So although teachers may find it easy to criticize lessons for not being inquiry-based, the descriptions of their own practices indicate that they may lack the skills to create or implement the more rigorous demands of inquiry.

Another factor that may have affected teacher preferences for a traditional model of instruction is their campus culture and the pressure to produce acceptable scores on the Elementary Science STAAR test. A traditional approach may be viewed as more effective in producing acceptable test scores. Jane described preparing for a standardized test as an unpleasant chore that students had to do to be successful.

> But the reality now is that academic words are on the STAAR test so sometimes I feel like some of our vocabulary lessons are not as effective… well, they're just not very fun or they're not very thrilling, but sometimes it's just you know, like memorizing multiplication facts. Sorry, you've got to do it so it can help you to move on. But yet, on the STAAR test they are going to use those words and even though that's not the end all be all, we want them to be successful and show their knowledge.

Tsai and Chang described a traditional approach as a direct teach model with some added demonstrations, and with explanations provided to the students (Tsai & Chang, 2005). In a study comparing a traditional and inquiry-based model of instruction, participating teachers reported that this traditional model, with no student created explanation, and text-driven instruction is the best way to produce acceptable test scores (Carrier et al., 2013). When participants in this study were asked to describe the lesson cycle that they prefer, Karen described a traditional lesson that began with an explanation, followed by an activity, then practice.

> It's usually a direct teach, then if there's time for an experiment or video or a whole group activity - then they can go off and do it independently or as a group or with a partner. And then they can go to the center and explore maybe with the magnets if we have magnets, or if we're studying bugs maybe they can go and explore the bugs.

Randy's description of a lesson that best represents him is an isolated activity to practice the process skill of observation. He stated that the lesson best represented him because they were working on "the properties of matter" and this was a hands-on lesson.

> First I modeled that in front of the class with a big bag; then I gave them small bags in small groups. What they had to do was to reach inside the bag, but they couldn't look, so they couldn't use that sense. They had to feel the things and describe what they were feeling and break that down. Then they got to pull stuff out of the bag and describe what they now had in their hands. They were focused on one sense at a time.

Finally, Mary stated that, "I'm not going to use discovery learning. It says encourage students to find ways to light the bulb. Not going to do that before they have a chance to look at books or the Internet or a movie that showed how the materials were assembled in one way."

In a study comparing student outcomes from a traditional lesson and an inquiry lesson, Tsai and Chang described traditional lessons as instruction with "clear and detailed lectures and explanations" (Tsai & Chang, 2005, p. 1098). Unfortunately, even though the teacher participants in this study preferred to provide explanations up front instead of having students create their own, they were seldom clear or detailed. In one example Mary states,

> Maybe I should talk about the lesson on liquids, because that actually worked. Because the liquid was easier to define in terms of taking the shape of the container and something that you could actually put your hand into and have you know, surrounded by liquid. I did not do a demo, all right, and I should have. That's what I figured out afterward and then we brainstormed different liquids and the children made a web, a graphic organizer web of liquids. So they drew and labeled, all right. Now that's the one that we actually completed.

In an explanation that could in no way be considered clear or detailed, Daniel declared that,

> I know for a fact by observing birds that not all birds like the same types of seeds. For example some are very specific about it. Maybe you'll understand why. You could come into adaptations - expound on the lesson as Darwin discovered with the finches in the Galapagos that their beaks had adapted due to their diet.

The participants in this study may be very similar to the teachers and students in Carrier's study who accepted the traditional method of instruction as most likely to help students pass standardized tests (Carrier et al., 2013).

Another factor that may influence teacher preferences for science instructional strategies is their campus culture, especially the push to prepare students for the rigorous reading demands of a high-stakes test. Instructional strategies driven by testing include a focus on reading and writing to prepare for other tests and to insure success on the Elementary Science STAAR test. In research comparing the use of traditional instruction and inquiry within an outdoor education set of lessons, the traditional approach was predominantly the one teachers chose to use because they felt it was the most efficient way to meet standards and prepare students for testing (Carrier et al., 2013). Daniel describes how reading and writing are emphasized in science instruction at his campus and within the district. "We're incorporating reading more as a part and parcel of science instruction. We start the lesson with reading about it, highlighting questions, underlining things that need to be underlined." Other teachers described how they had students read science content books as part of their science instructional model. "Well, one thing is using the non-fiction books and having the students do writing about what they're learning as they're learning it," is one of Mary's preferred strategies. Widespread adoption of a teacher-centered instructional model featuring an emphasis on reading and vocabulary because teacher and students believed it to be most efficient was justified by teachers in this study and other recent research. "We must address the perception that science is best and most efficiently learned only inside the classroom through traditional text-driven instruction" (Carrier et al., 2013, p. 2079).

The demands of testing in other subjects (such as reading and mathematics) may drive teachers to adopt traditional models of science instruction to include more reading and writing in their class time. Even though teachers in this study stated that they wanted to include more hands-on activities, they found that a lack of time pushed them to spend the majority of their time on reading and writing.

> However, every year I vow that we are going to spend more time doing Science activities, Science instruction. It is critical, but again, if they can't read, nothing else matters. None of it matters. So as a first grade teacher of this population it's unfortunate, but they have to know how to read and it comes at the expense of other subjects (Mary).

Although students in the Carrier study complained about the excessive amount of time spent on lectures and note-taking, they accepted it as part of the process to "get through material for the test" (Carrier et al., 2013, p. 2074). This traditional approach may be viewed by teachers as the most effective for producing acceptable test scores. Carrier mentioned that despite the success of an outdoor education program, traditional strategies were still the norm. The participants in this study were part of an urban school district facing the same challenges, and perhaps the same rewards for implementing traditional instructional methods. One of the most powerful explanations of why school districts and campuses may promote a traditional model of instruction in science was asserted by Carrier. “Through students’ test score gains, the teachers’ traditional teaching strategies in this study were reinforced, earning administrative encouragement at the school, district, and state levels” (Carrier et al., 2013, p. 2076). In order to produce acceptable test scores, urban schools may employ a “pedagogy of poverty” that utilizes traditional teaching methodologies such as direct instruction, individual assignments, teacher explanations, and testing (Haberman, 2010).

The demands of high-stakes testing and the campus cultural response may also leave teachers with the perception that they have no time to implement inquiry. High-stakes testing demands include more time devoted to reading and math instead of science (Milner et al., 2012). Karen described this by stating how hard it is for her to not only plan the lessons, and locate the resources, but the considerable time it takes just to figure out how to set up an investigation when she has never done it herself.

> You know it takes a while to come up with it, so the time - is not as efficient either. We have five other subjects to teach and science is really a very, very small chunk - 30 to 45 minutes of teaching. You have to prepare, and you have to have it ready, that you can use your time efficiently, and when you're stuck trying to decipher what they mean in the lesson plan it is frustrating.

Pringle and Martin reported that teachers would not have time for hands-on activities and would have to replace them with test-prep materials (R. Pringle & S. Martin, 2005).

Linda and other participants in the study commented that they would have no time to teach science, so would instead read about a science topic.

> Even if that week I've got to do more reading to get them ready for this, that, and the other (test), their small group may be a nonfiction book on a science topic or something we talking about in class. So I try to cross the curriculum when I can, and it helps a little bit.

Teachers may perceive inquiry as too demanding for them to implement and cover the material necessary to prepare students for the STAAR tests. Pringle suggested that "the time it takes to engage students with hands-on, minds-on activities might be seen as a time-consuming luxury given the perceived needs to cover the content for these high-stakes tests" (R. Pringle & S. Martin, 2005, p. 358). In a study of the comparison of traditional and inquiry-based strategies, teacher may have wanted to use inquiry, but reverted to a traditional model of instruction as the most efficient use of time in order to meet "heavy content demands," especially through lectures and taking notes (Carrier et al., 2013, p. 2079). The pressure of teaching all the objectives tested on a high-stakes test may be driving teachers to utilize traditional strategies.

If teacher's have no autonomy in the choice of their instructional strategies, this reduces the role of teacher beliefs in instructional practices and may result in a universal move to adopt a traditional model of instruction. Teachers in this study reported that they had no time to teach anything but tested TEKS.

> I love to do these kinds of things, but sometimes they're weeks where I can't - I just got to do more of this kind of stuff because of time, and I've got to get them ready for this test, for this benchmark. That's kind of the only bummer thing - in a perfect world we wouldn't have standardized testing. (Linda)

Milner reported that 82% of the teachers in her study had no time to teach anything that interested the students because of testing demands (Milner et al., 2012). A teacher in this study commented that although she would love to have students do more projects, she has to spend her time preparing them to take the Elementary Science STAAR test.

> I would do this type of thing, but in fifth grade especially, when what I teach is so focused on specific skills, you have such limited time. I guess I'm torn because I don't have the time to do this entire process (Nancy).

Of all the factors that may impact this study, high-stakes testing permeates every decision teachers make and their core practices in science instruction, perhaps being the strongest driver towards implementing a traditional instead of an inquiry-based model of instruction.

IMPLICATIONS

The implications of this study suggest that teacher preparation and professional development programs may require a stronger and more concrete emphasis on inquiry-based instruction and increased science teaching self-efficacy. Pre-service teacher preparation programs may need to make more explicit use of the essential features of inquiry such as directly addressing the use of questions to drive inquiry and data collection as more than just hands-on engagement. Although teachers seem to value student-created questions as the basis for instruction, this was not practiced by the participant teachers in this study. This needs to be an unequivocal part of pre-service teacher education, providing the students of elementary science instruction with opportunities to experience inquiry as a student and also create inquiry-based lessons. Inquiry-based instruction, a model of instruction that must be planned to scaffold student's abilities over time (Jadrich & Bruxvoort, 2011), must be accepted by preservice teachers as the most authentic and efficient way to teach science if they are going to overcome barriers such as anxiety and self-efficacy to achieve full implementation.

Student-created explanations also need to be modeled since no teachers in this study described a process of student's doing inquiry, but one of transmission of knowledge. Induction teachers will face pressure from administration and even their students to adopt a traditional model of instruction. This pedagogy of poverty is often an accepted practice in urban schools and will reward the teacher for a class that appears busy and compliant, yet makes no rigorous intellectual requirements (Haberman, 2010). The demands of inquiry, especially promoting student created explanations, can be daunting for a new teacher, so they need both preservice experiences to lay the foundation, and professional development to improve their practice.

Even if an inquiry foundation is laid during preservice instruction, it must still be sustained through ongoing professional development. As with pre-service teachers, explicit training on inquiry and aspects of the nature of science must be modeled and supported by professional development activities such as workshops, conferences, and professional learning communities. It is essential that elementary teachers experience inquiry-based science instruction during professional development in order to better understand not just the content, but to experience an authentic science investigation. Many teachers in this study commented on how easy it would be for their students to light a light bulb, but may have never tried this as learners. Too often teachers see a lesson without being able to experience it as a learner, and never actually perform the inquiry before presenting it to their students. During professional development, teachers need to actually work though all five essential features of inquiry at the most open end of the continuum in order to experience the power of inquiry in helping even adult learners to make sense of the natural world and create explanations that become a part of their understanding instead of simply memorizing the explanations of others. Teachers also need to work as part of a professional learning community to adapt a traditional lesson into a more inquiry-based lesson. If practicing science teachers hope to overcome high anxiety or low self-efficacy, the teacher preparation programs need to impact teacher beliefs about their ability to teach science and explicitly address issues of self-efficacy (Yürük, 2011). Working as part of a community of learners may also greatly help to alleviate any anxiety or self-efficacy issues. Ramey-Gassert and Shroyer (1992) suggest that there are several components which can enhance the science teaching self-efficacy of preservice teachers. Science teaching environments which foster an essential feeling of success and a positive "let's find out" atmosphere, provide a contrast to traditional views of science and science teaching (Ramey-Gassert & Shroyer, 1992). "An introduction to the nature of science and other orientation information is important for students who are uncomfortable with science" (Ramey-Gassert et al., 1996, p. 310). Professional development based on these tenets may be one of the best ways to address the prevalence of traditional instruction found in this study.

Finally, the role of high-stakes testing may have a large impact on teacher beliefs and their choice of instructional models. Teachers must prepare students to take a standardized test by making sure they teach all of the objectives on the Elementary Science STAAR test. Nancy described some of the demands of testing as "we have to teach the TEKS - we have to do that accountability piece, we have to get those kids ready for the test." When Jane was asked how much the pressure of preparing students for the STAAR test drives her instruction, she replied, "Way too much. Way too much." And she also stated, "A lot of your goals are driven by meeting the TEKS that we do. That's a reality of where we are right now in education. You've got the meet the TEKS." Daniel described the pressure to teach all the TEKS to prepare students for the STAAR test "I get the impression some of the things are investigations just to investigate and tied up with a nice little ribbon and you've got someone who will pass the fifth-grade science STAAR test. You covered all the angles." The influence of high-stakes testing may be one of the biggest implications highlighted in this study, and significant barrier to full implementation of inquiry-based instruction.

LIMITATIONS

Several limitations to this study were the instruments used, the interview protocol, participant biases, and a reliance on self-reporting. The anxiety and self-efficacy instruments used in this study were not created or normed before high-stakes testing was fully implemented. Therefore, the STAI may not accurately reflect teacher anxiety, especially since there are pressures at the campus and district level to produce acceptable scores on a standardized test.. Teacher levels of science anxiety as measured by the STAI mean were lower than the normalized score for working adults. Perhaps the STAI is not sensitive enough to measure anxiety within the background of high-stakes accountability. In fact, the pilot study for this research measuring anxiety with the STAI found very low anxiety results in pre-K teachers. Recent research studies examining science teaching anxiety have not been using STAI, but researcher-created instruments. An investigation of both science anxiety and self-efficacy in pre-service teachers used a scale created by the researcher (Science Teaching Anxiety Scale) to measure anxiety and to prevent overlap with the STEBI (Yürük, 2011). The Science Anxiety Survey (SANX), an instrument created by Bursal for use with pre-service teachers to measure anxiety, was also used in combination with the STEBI to examine science teaching anxiety (Bursal, 2008, 2012). Although the STEBI is still being used in recent research, the move from the STAI to researcher-created measures may indicate that the STAI is no longer considered an appropriate measure for science teaching anxiety. If teachers are achieving acceptable results on STAAR with traditional methods, they may not feel anxious or doubt their ability to teach science (especially teachers who have risen through the ranks to be assigned as science teachers by their principals).

Self-selection bias may also be a limitation, especially if teachers with high anxiety and/or low self-efficacy chose not to take the survey. With a tiny percentage of teachers responding to the survey, this is a likely but unavoidable outcome. Only about 2.6% of teachers contacted by email participated in the survey. The small number of participants interviewed was also a limitation, with two groups comprised of only two participants. Because the interview format required in-person instead of phone interviews and time constraints already making demands on teacher's time, a small number of survey participants agreed to be interviewed.

Although the card-sorting methodology used in the interview produced many interesting descriptions, it also had the limitation of eliciting many contradictory statements. Teachers are familiar with questioning as part of their instructional practice, so they spoke extensively about question preferences, perhaps skewing the percentages of data preferences for inquiry-based questioning strategies. Teachers also discussed at great length their preferences for hands-on instruction, possibly weighting the results for guided evidence. Yet neither practice was communicated in descriptions of recently taught lessons. The wording of the card sort methodology was intentional to elicit candid responses, yet without terms such as "explanation," teachers may not have discussed them fully. The scenarios were varying descriptions without any author accredited, so it may have made them very easy to criticize. Finally, the qualitative data was entirely dependent on self-reporting, so the data is limited by participant desires to represent themselves and their campuses in the best possible light. Because no cross-check observations of their practices occurred, teachers may have reported an idealized rather than accurate description of their practices.

AREAS FOR FURTHER RESEARCH

Areas to explore for further research include the use of other quantitative instruments, alterations to the card-sorting scenarios, and more in-depth research of individual teacher practices. One of the first areas to explore would be creating another quantitative measurement of anxiety, such as has been accomplished by recent research studies on science teaching anxiety and self-efficacy (Bursal, 2012; Yürük, 2011). An interesting next step would be to develop an anxiety instrument based on interview data for areas teachers expressed as their "does not represent" strategies, such as asking students to make observations about a natural phenomenon such as moon phases without any pre-teaching. Other themes to address in an anxiety instrument would be to explicitly focus on preferences for traditional and inquiry-based lessons, such as questions that address teacher concerns about their ability to implement activities when given the materials and written instructions, but no accompanying professional development.

Alterations to card-sorting scenarios might be created to revise some outside of inquiry lessons to more closely match the "transmission" model. An example would be to alter the insect lesson using a "pre-teach" or explanation of the characteristics of an insect presented first through text and video, and then have students observe an actual insect to verify, practice classifying invertebrates to rehearse the skill, and ending with an assessment of the objective. Another change to the interview protocol worth exploring is to remove the communication feature of inquiry. Teachers spent more time discussing how they did, or did not like methods of communication such as writing reports, creating PowerPoint, rubrics, or foldables than they did discussing how students would either show mastery of concepts (traditional model) or justify their explanations (inquiry-based model). The card-sort methodology could possibly make essential features more explicit such as stating that “students create their own explanations and justify them for the class during a discussion,” or “students collect the data the teacher instructs them to collect, and then analyze the data in order to create an explanation with some assistance from the teacher.”

One of the most interesting possibilities for further research is a more in-depth study of teacher practices, possibly through a combination of case studies and action research. Gathering data on observations that align with actual practice of self-reported preferences for groups or high and low anxiety teachers could increase the strength of researcher classifications and provide additional triangulations. Teachers could be studied through several informal class observations of an actual instructional model used to teach a scenario described as one of their “best represents.” Lessons would be audio and video taped to code for holistic classification along the continuum to categorize the lesson as primarily traditional or inquiry-based. Action research with teachers could prove very informative, especially using one of their best represents scenarios, altered to most closely match their preferences for science instruction, then recorded and coded for percentages and frequencies of matches to the inquiry continuum. The teacher and researcher would then examine the data as part of a collaborative research team to compare teacher beliefs to their actual practice. The process could then be repeated with a lesson that the teacher described as not representing their preferred instructional model. These are but a few of the possible extensions to this study that may provide even more information on teacher beliefs and preferences for a traditional, or an inquiry-based model of instruction.

Appendix A

Science Teaching Attitude Survey

Thank you for volunteering to participate by taking the following survey. Please read the statements below that detail your rights as a participant in a research study.

Risks/Benefits/Confidentiality of Data
There is minimal risk that you will feel uncomfortable or anxious. There will be no costs for participating, and you might not benefit from participating. If provided, your name, email address, and telephone number will be kept during the data collection phase for tracking and contact purposes only. A limited number of research team members will have access to the data during data collection. All information will be secured in locked filing cabinets within locked offices. Identifying information will be stripped from the final dataset.

Participation or Withdrawal
Your participation in this study is voluntary. You may decline to answer any question and you have the right to withdraw from participation at any time. Withdrawal will not affect your relationship with The University of Texas at Austin in any way. If you do not want to participate simply close the browser window during the survey.

Contacts
If you have any questions about the study or need to update your email address contact the researcher Claire Hodgin at 512-466-0702 or send an email to chodgin@austin.utexas.edu. This study has been reviewed by The University of Texas at Austin Institutional Review Board and the study number is [STUDY NUMBER].

Questions about your rights as a research participant.
If you have questions about your rights or are dissatisfied at any time with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

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As an Elementary school teacher, your principal has asked you to teach a science lesson for your class that reflects best practices in science instruction. Please read the directions, and answer the following survey questions based on how you feel about teaching this science lesson.

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then select the qualifier that most closely matches how you feel at this moment. There are no right or wrong answers. Do not spend too much time on any statement but give the answer which seems to describe your present feelings best.

1) I feel calm

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

2) I feel secure

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

3) I am tense

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

4) I feel strained

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

5) I feel at ease

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

6) I feel upset

- ☐ Not at all

□ Somewhat
□ Moderately So
□ Very Much So

7) I am presently worrying over possible misfortunes

□ Not at all
□ Somewhat
□ Moderately So
□ Very Much So

8) I feel satisfied

□ Not at all
□ Somewhat
□ Moderately So
□ Very Much So

9) I feel frightened

□ Not at all
□ Somewhat
□ Moderately So
□ Very Much So

10) I feel comfortable

□ Not at all
□ Somewhat
□ Moderately So
□ Very Much So

11) I feel self-confident

□ Not at all
□ Somewhat
□ Moderately So
□ Very Much So

12) I feel nervous

□ Not at all

- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

13) I am jittery

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

14) I feel indecisive

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

15) I am relaxed

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

16) I feel content

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

17) I am worried

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately So
- ☐ Very Much So

18) I feel confused

- ☐ Not at all

□ Somewhat
□ Moderately So
□ Very Much So

19) I feel steady

□ Not at all
□ Somewhat
□ Moderately So
□ Very Much So

20) I feel pleasant

□ Not at all
□ Somewhat
□ Moderately So
□ Very Much So

For the next statements please indicate the degree to which you agree or disagree with each statement below by clicking on the appropriate choice for each statement.

21) I continually find better ways to teach science.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

22) Even if I try very hard, I do not teach science as well as I do most subjects.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

23) I know the steps necessary to teach science concepts effectively.

□ Strongly Agree
□ Agree

□ Uncertain
□ Disagree
□ Strongly Disagree

24) I am not very effective in monitoring science experiments.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

25) I generally teach science ineffectively.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

26) I understand science concepts well enough to be effective in teaching elementary science.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

27) I find it difficult to explain to students why science experiments work.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

28) I am typically able to answer students' science questions.

□ Strongly Agree
□ Agree

□ Uncertain
□ Disagree
□ Strongly Disagree

29) I wonder if I have the necessary skills to teach science.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

30) Given a choice, I would not invite the principal to evaluate my science teaching.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

31) When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

32) When teaching science, I usually welcome student questions.

□ Strongly Agree
□ Agree
□ Uncertain
□ Disagree
□ Strongly Disagree

33) I do not know what to do to turn students on to science.

□ Strongly Agree
□ Agree

☐ Uncertain
☐ Disagree
☐ Strongly Disagree

34) What is your gender?

☐ Female
☐ Male

35) How many years of teaching experience do you have?

☐ 0 – 2 years
☐ 3 – 5 years
☐ 6 – 8 years
☐ 9 – 11 years
☐ 12+ years

36) Describe your current teaching assignment. (Ex: 1st grade self-contained; K-5 Special Ed Inclusion; 5th grade science and mathematics)

____

37) What do you consider your subject area of specialization? (Ex: Reading, Mathematics, Art, or Spanish)

____

38) Please describe your degrees and major areas of study. (Ex: BA in Psychology, MS is Special Education)

____

39) OPTIONAL: If you provide contact information (name, email address and telephone number) then your name will be entered in a drawing for one of FOUR gift certificates for $25 at Teacher Heaven. By providing your contact information, you are agreeing to be contacted by the researcher for possible additional participation in this study. Providing this information is optional and you are in no way obligated to participate in any other portion of the study.

Name:____

Email Address:____

Telephone
number:____

If you have any questions, contact **Claire Hodgin**
chodgin@austin.utexas.edu

THANK YOU FOR YOUR HELP AND PARTICIPATION IN THIS RESEARCH PROJECT!

Appendix B

Elementary: Science Teaching Scenarios Card-Sorting Task

1	You are teaching a unit on space. Each day during the unit you read to the class from a non-fiction book about the solar system. After reading about a particular planet, you ask students to make a statement about what they have learned. You record these statements on a chart for inclusion in a letter sent home to parents at the end of the unit.
2	You ask students "What makes an animal an insect?" You decide the best way to do this is to have children cut out pattern body parts and assemble these into an insect that is placed on the bulletin board. You read several non-fiction books on insects to students, having them complete a teacher-created graphic organizer of the characteristics of insects. Students work in groups to fill in sections of a poster comparing insects to other animals and present it to the class.
3	Your students have just completed a bridge-building project. For the next unit on simple machines, you ask the students to make their bridges move using a combination of two or more simple machines. The students create plans they think will allow their bridges to move. Then they research simple machines using resources you supply and compare their designs to other student's bridges. Finally, they present their finished bridges to the class, along with a poster presentation from a rubric you supply.
4	You begin a new unit by asking students what they already know about weather. You use a KWL chart to record the students' prior knowledge and find non-fiction books and web resources to teach TEKS related to weather. Students use graphic organizers to write summaries of the information from these sources.
5	You have students observe earthworms and generate questions about earthworm behavior. Each group designs and carries out their own experiment to test a hypothesis related to the group's questions and an explanation of how their data links to other resources. The groups communicate their findings in a presentation to other groups.
6	You place bird feeders outside your classroom window and ask students to carefully and accurately record their observations in an electronic journal. Based on the observations in their journals, you ask each student to select a question from a list you provide, then guide the students in researching birds. From their research and further observations, students write a science essay, answering their questions and explaining

	how their observations prove these answers.
7	Your students are intrigued with a toy water rocket that you brought to school. As a group, the students identify questions and ways to explore how the rocket works. You help the students organize into investigation teams and you investigate along with the students. The students work as a team to research scientific answers to their questions and write a summary comparing their explanation to the answers they researched. At the end of the project, the students create presentations of their investigation.
8	Your students are asking questions about recycling, so you create a unit to study important information about recycling. Your class refines the question and you find data to give the students on recycling. After the class draws conclusions from the data, they use information from your unit and with your guidance formulate explanations that agree with the resources you have provided. Given a rubric and some guidelines, your students present their explanations during your campus Science Festival.
9	You encourage students to explore the natural world by asking them to select a question from a list. Some of your students want to investigate bread molds. Many of their experiments are failures, with either mold covering everything or no mold growing. You research molds on the internet and provide students with picture cards, reading selections, and other references. Students work collaboratively to come up with explanations that answer their questions. With help from you, the students write lab reports explaining what they have learned about molds.
10	You design a science unit around the question, “What’s in our drinking water?” Your district provides a science kit to teach this unit that includes all materials, instructions, data tables, ancillary materials, and lab report forms.
11	During an electricity unit, you furnish students with batteries, bulbs and wires. A group of students select the question “How can you use these materials to light a bulb?” from a list of questions you have provided. You encourage the students to find all the possible ways to light the bulb. The students create diagrams with explanations during group discussions, guided by teacher questions and non-fiction resources. The group creates a PowerPoint with some teacher assistance that is presented to the class.
12	You want students to name and describe the phases of the moon. You ask your students to observe and make sketches of the moon each night for a period of one month. At the end of a month, students are given cards with photos of moon phases and then asked to place the cards in order and label with the correct names of the phases. Each student creates a foldable with the names and pictures of the moon phases.

Appendix C

STSCS – Classification of Scenarios by Research Team

Number	Scenario	
	Pertinent Feature of Inquiry	**Inquiry Continuum** (NRC, 2000, p. 29)
1	**Question:** No Question asked **Evidence:** None **Explanation:** None **Connect:** None **Communicate:** Student statements recorded	**Outside of Inquiry Continuum:** ELA-Based Lesson Entirely Teacher-directed
2	**Question:** Question provided by teacher **Evidence:** Given data & told how to analyze **Explanation:** Provided with evidence and told how to formulate explanation **Connect:** None **Communicate:** Given steps and procedures for communication	**Confirmation for all 5 features** Teacher-directed activity
3	**Question:** Learner clarifies question provided by teacher **Evidence:** Learner determines what constitutes evidence and collects it. **Explanation:** Learner formulates after summarizing evidence **Connect:** Learner directed to sources of scientific knowledge **Communicate:** Learner coached in development of communication	**Open**: Evidence and Explanation **Guided:** Connection and Communication **Structured:** Question
4	**Question:** No Question asked **Evidence:** None **Explanation:** None **Connect:** None **Communicate:** Student statements recorded	**Outside of Inquiry Continuum:** ELA-Based Lesson Entirely Teacher-directed

5	**Question:** Learner poses a question **Evidence:** Learner determines evidence and collects it **Explanation:** Learner formulates explanation **Connect:** Examines other resources & forms links to explanations **Communicate:** Learner forms explanation independently and communicates to others	**Open**: For all 5 Essential Features Most Learner-Directed Scenario
6	**Question:** Learner selects question provided by teacher **Evidence:** Learner determines what constitutes evidence and collects it **Explanation:** Learner guided in process **Connect:** Learner directed to sources **Communicate:** Learner coached in development	**Guided:** for Question, Explanation, Connection, and Communication **Open:** for Evidence
7	**Question:** Learner poses a question **Evidence:** Learner determines evidence and collects it **Explanation:** Learner formulates explanation after summarizing evidence **Connect:** Learners examine other resources and compare their results to other research **Communicate:** Learners create presentations	**Open**: for all 5 Essential features Learner-Directed Scenario Teacher as Learner
8	**Question:** Students clarify question provided by teacher **Evidence:** Given data and asked to analyze **Explanation:** Given possible ways to form explanations **Connect:** Given possible connections **Communicate:** Provided guidelines to sharpen communications	**Structured**: for all 5 Essential features Mostly Teacher-directed
9	**Question:** Learner selects from a list provided by the Teacher **Evidence:** Learner given data and asked to analyze **Explanation:** Learner guided in process of forming explanations	**Guided:** Question and Explanation **Structured:** Evidence, Connections, and Communication

	Connect: Given possible connections **Communicate:** Provided with broad guidelines	
10	**Question:** Provided by teacher **Evidence:** Directed to collect certain data **Explanation:** Provided with evidence and how to use evidence to formulate explanations **Connect:** Given possible connections **Communicate:** Given steps and procedures for communication	**Confirmation:** for Question, Explanation and Communication **Guided**: for Evidence **Structured**: for Connections Mostly teacher-directed Myth 3: Inquiry occurs easily through use of kits (NRC, 2000, p.35 - 37)
11	**Question:** Ss select among questions **Evidence:** Directed to collect certain data **Explanation:** Guided in process formulating evidence **Connect:** Directed to sources of scientific knowledge **Communicate:** Coached in development of communication	**Guided for all 5 features** Mostly student-directed activity
12	**Question:** Teacher provides question **Evidence:** Learner directed to collect certain data **Explanation:** Learner told how to formulate explanation **Connect:** None **Communicate:** Learner given steps & procedures	**Confirmation**: for Question, Explanation and Communication **Guided:** for Evidence

Appendix D

STSCS Interview Protocol Script

Say: The purpose of this interview is to elicit teacher ideas about science instructional strategies. I will record this with a digital recorder in order to keep a close record of what is discussed.

Perform a short test of the recorder

Q#	Activity of the Card-Sorting Task
13	BEFORE THE CARD SORT (Question 13) *Say: Please describe a science lesson that you recently taught that best represents how you prefer to teach science.*
1 - 12	*Say: I am going to ask you to read a set of 12 cards that describe various elementary science teaching scenarios. Each scenario has a number to help me identify it; the number has no meaning other than that of an identifier. For this activity, I ask you to make some assumptions:* ***1)*** *You are an elementary teacher of any grade level K – 5. If a card describes a scenario that you think would be appropriate for a particular grade level, pretend you teach that grade level.* ***2)*** *When a card-sort describes a unit, assume that it is a multi-day series of lessons that will take as much time as you deem necessary. You may choose to increase or reduce the number of days that you think it will take to teach a particular scenario.* ***3)*** *Please feel free to comment on any scenario to approve, criticize, or alter a strategy to more closely match your preferences for science instruction.* Say: *Read the set of scenario cards aloud and sort the cards into the following stacks*: (a) "This scenario <u>Best Represents</u> how I would teach," (b) "This scenario <u>Does Not Represent</u> how I would teach," and (c) "You are <u>Unsure</u> about this scenario." *You are encouraged to "think aloud" during the initial card-*sorting process. *Look at the scenario as a whole – classify it based on not just one aspect that*

	you may like or dislike, but on the entire description. For instance, you may really like that the scenario uses a rubric, but may not like the rest of the scenario so you would add it to the Does Not Represent group. *Please begin, and be sure to read aloud both the description of the scenario and the number.*
Q 14 14aQ	*Say: "Please reexamine the cards in the "Best Represents" stack and select the 4-5 cards that best represent your preferred science teaching strategies. For instance, if I were to visit your classroom, which cards would be most like what I would observe?"* After selecting the top 4-5, ask the teacher to articulate the decision-making process used in selecting the cards. *Say: "Look at the cards you just selected. What do these (4-5) cards have in common?" and* *"In what ways do these scenarios support your purposes and goals for teaching science?"*
Q15	Selects a scenario from the third stack (<u>does not represent</u>) that evoked a strong negative reaction, and ask the individual to explain why they rejected the card. *Say: "What aspects of the scenario would need to be changed before you could place the card in the first stack of preferred scenarios?"* Repeat this process with two more scenario cards that evoked strong negative reactions.
Q16	Identify a small subset of scenarios that you feel will be productive to explore. *Say: "In what ways are these scenarios alike?* *"In what ways are these scenarios different?"*
Open *	Based on data from Steps 1–5, share your perceptions of the teacher's purposes and goals for teaching science. Give the teacher an opportunity to respond and negotiate, if necessary.

Probing questions

"When you say (_______________) exactly what does that look like in your classroom?"
"How do you conduct discussions in your class?"
"When you mention reading non-fiction, what type of reading selections do you typically use in your class?"

Recording Chart for Card Sort

	Best Represents	Unsure (Neutral)	Does Not Represent
Strongly Positive (Top 4-5)			
Weakly Positive			
Neutral			
Weakly Negative			
Strongly Negative			

NOTES:

Appendix E

Email Recruitment and Consent Form

Subject: Request for Participation in a Research Study – DRAWING FOR 1 OF 4 GIFT CERTIFICATES

My name is Claire Hodgin, and I am a doctoral candidate in The University of Texas at Austin, Science, Technology, Engineering, and Mathematics Education program. I write to you today to ask for your help as a participant in my research on attitudes about science teaching in elementary school. This study is for my dissertation, which I hope will lead to additional research and programs to improve both professional development and teacher preparation.

If you would like to participate in my study you will be entered in a random drawing to ***win one of four $25 gift certificates if you provide contact information*** (name, email address, and telephone number) in order for me to do follow up interviews with approximately 10 participants. Please read the information below, and click on the link to the survey if you would like to take part in the research study.

Identification of Investigator and Purpose of Study

You are invited to participate in a research study, entitled "Science Teaching Beliefs: Impact on Teacher Preferences of Instructional Strategies." The study is being conducted by Claire Hodgin, Doctoral Candidate in the Science & Mathematics Education Program, College of Education of The University of Texas at Austin, Department of Curriculum and Instruction, College of Education, 1 University Station D5700 Austin, TX 78712; Cell 512-466-0702; and Email: chodgin@austin.utexas.edu

The purpose of this research study is to examine how a teacher's beliefs and attitudes may affect their instructional strategies. Your participation in the study will contribute to a better understanding of how elementary teachers are prepared to teach by university faculty, and how professional development may help meet the needs of elementary teachers concerned about teaching science. You are free to contact the investigator at the above address and phone number to discuss the study. You must be at least 18 years old to participate.

If you agree to participate:

- The **online survey** will take approximately **20 minutes** of your time.
- If you agree to an optional interview, you will complete an activity in about **1 ½ hours.**
- You **will not** be compensated**.** However, if you DO provide contact information you will be entered in a drawing for one of four $25 gift certificates.

- You **will** be compensated with a gift certificate for completion of an interview.

If you agree to participate, click on the following link:

Link to Survey Monkey – Science Attitudes Survey

in Survey Monkey, an online survey provider. **All survey information is SSL secured.**
Please print a copy of this document for your records
IRB APPROVED: O5/22/2013 EXPIRES ON: 05/21/2014 IRB# 2013-05-0014

Thank you,
Claire Hodgin
Doctoral Candidate
University of Texas - STEM Education
512-466-0702(cell)
chodgin@austin.utexas.edu

Appendix F

Interview Recruitment: Telephone Script

Screening Interview Script: <Name of Teacher> <Name of Campus) <Contact Number>

Hello, my name is Claire Hodgin and I am calling for *<Name of Teacher>*

Last May you participated in an online survey as part of my research study examining science attitudes in elementary teachers.

First of all, I want to thank you so much for providing your contact information. I am calling today to ask if you would agree to be interviewed as part of a study examining a teacher's instructional preferences for teaching science.

In the survey, I also indicated that participants will receive a gift to support classroom instruction if they complete the interview.

Interviews will take about 1 hour and can be conducted on or off of your campus depending on your scheduling needs. At this time, would you be willing to participate in an interview?

If not, thank you very much for your time.

If so, I need to ask a few follow-up questions. Are you currently teaching, or plan to teach one of the elementary grade levels EC-5th? Is you teaching assignment primarily science teaching?

Can we set up a time to meet?

Thank you very much for your help,

References

AAAS. (1989). Science for All Americans. A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology: AAAS Books, Dept. 2061, P.O. Box 753, Waldorf, MD 20604 (for price, contact AAAS offices; quantity prices available).

AAAS. (1993). *Benchmarks for Science Literacy*: Oxford University Press, 198 Madison Avenue, New York, NY 10016-4314.

Abd-El-Khalick, F. (2001). Embedding nature of science instruction in preservice elementary science courses: abandoning scientism, but. *Journal of Science Teacher Education*, *12*(3), 215-233.

Abd-El-Khalick, F., & Akerson, V. L. (2004). Learning as conceptual change: Factors mediating the development of preservice elementary teachers' views of nature of science. *Science Education, 88*(5), 785-810.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: making the unnatural natural. *Science Education, 82*(4), 417-436.

Abd-El-Khalick, F., & BouJaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching, 34*(7), 673-699.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education, 22*(7), 665-701.

Abd-El-Khalick, F., Lederman, N. G., Bell, R. L., & Schwartz, R. S. (2001). Views of Nature of Science Questionnaire (VNOS): Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science.

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a Reflective Explicit Activity-Based Approach on Elementary Teachers' Conceptions of Nature of Science. *Journal of Research in Science Teaching, 37*(4), 295-317.

Akerson, V. L., & Hanuscin, D. L. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching*, *44*(5), 653-680.

Alake-Tuenter, E., Biemans, H. J. A., Tobi, H., Wals, A. E. J., Oosterheert, I., & Mulder, M. (2012). Inquiry-Based Science Education Competencies of Primary School Teachers: A literature study and critical review of the American National Science Education Standards. [Article]. *International Journal of Science Education, 34*(17), 2609-2640. doi: 10.1080/09500693.2012.669076

Amaral, O. M., Garrison, L., & Klentschy, M. (2002). Helping English learners increase achievement through inquiry-based science instruction. *Bilingual Research Journal, 26*(2), 213.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215.

Bandura, A. (1981). Self-referent thought: a developmental analysis of self-efficacy. In J. H. Flavell & L. Ross (Eds.), *Social cognitive development: frontiers and possible*

futures B2 - Social cognitive development: frontiers and possible futures (pp. 200-239). Cambridge: Cambridge University Press.
Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 37*(2), 122-147.
Barufaldi, J. (1982). Science anxiety. *Discovery, 7*(1), 20-22.
Barufaldi, J. (Ed.). (1989). *Improving Preservice/Inservice Science Teacher Education: Future Perspectives*: Eric Clearinghouse for Science, Mathematics and Environmental Education Columbus O. H.
Bell, R., Maeng, J., & Peters, E. E. (2010). Teaching About Scientific Inquiry and the Nature of Science: Executive Summary *Scientific Inquiry and the Nature of Science Task Force Report*: Virginia Mathematics and Science Coalition.
Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (1998). Implicit versus explicit nature of science instruction: An explicit response to Palmquist and Finley. *Journal of Research in Science Teaching, 35*(9), 1057-1061.
Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of Research in Science Teaching, 37*(6), 563-581.
Bell, R. L., Smetana, L., & Binns, I. (2005). Simplifying Inquiry Instruction. [Article]. *Science Teacher, 72*(7), 30-33.
Bencze, L., Di Giuseppe, M., Hodson, D., Pedretti, E., Serebrin, L., & Decoito, I. (2003). Paradigmatic road blocks in elementary school science reform: Reconsidering nature-of-science teaching within a rational-realist milieu. *Systemic Practice and Action Research, 16*(5), 285-308.
Bleicher, R. E. (2004). Revisiting the STEBI-B: Measuring Self-Efficacy in Preservice Elementary Teachers. *School Science and Mathematics, 104*(8), 383-391.
Bransford, J. D., Ed.; Brown, Ann L., Ed.; Cocking, Rodney R., Ed. (2000). *How People Learn: Brain, Mind, Experience, and School: Expanded Edition*. U.S.; District of Columbia National Academy of Sciences - National Research Council, Washington, DC. Commission on Behavioral and Social Sciences and Education. (BBB21833).
Brownlow, S., & Jacobi, T. (2000). Science Anxiety as a Function of Gender and Experience. *Sex Roles, 42*(1/2), 119-131.
Bursal, M. (2008). Changes in Turkish Pre-Service Elementary Teachers' Personal Science Teaching Efficacy Beliefs and Science Anxieties during a Science Methods Course. *Journal of Turkish Science Education, 5*(1).
Bursal, M. (2012). Changes in American preservice elementary teachers' efficacy beliefs and anxieties during a science methods course. *Science Education International, 23*(1), 40-55.
Bursal, M., & Paznokas, L. (2006). Mathematics Anxiety and Preservice Elementary Teachers' Confidence to Teach Mathematics and Science. *School Science and Mathematics, 106*(4), 173-180.
Bybee, R. W. (2011). Inquiry Is Essential. [Article]. *Science and Children, 48*(7), 8-9.

Cady, J. A., & Rearden, K. (2007). Pre-service Teachers' Beliefs about Knowledge, Mathematics, and Science. *School Science and Mathematics, 107*(6), 237-245.

Carrier, S., Tugurian, L., & Thomson, M. (2013). Elementary Science Indoors and Out: Teachers, Time, and Testing. [Article]. *Research in Science Education, 43*(5), 2059-2083. doi: 10.1007/s11165-012-9347-5

Clough, M. (2011). The Story Behind the Science: Bringing Science and Scientists to Life in Post-Secondary Science Education. *Science & Education, 20*(7), 701-717. doi: 10.1007/s11191-010-9310-7

Cobern, W. W., & Loving, C. C. (2002). Investigation of preservice elementary teachers' thinking about science. *Journal of Research in Science Teaching, 39*(10), 1016-1031.

Council, G. s. B. (2006). Excellence in the classroom. Austin, TX.

Czerniak, C., & Chiarelott, L. (1984, April 23 -27, 1984). *Science Anxiety: An Investigation of Science Achievement, Sex and Grade Level Factors.* Paper presented at the American Educational Research Association, New Orleans, LA.

Czerniak, C. M. (1989). *An investigation of the relationships among science teaching anxiety, self-efficacy, teacher education variables, and instructional strategies.* Ph.D. Dissertation, The Ohio State University, United States -- Ohio.

Czerniak, C. M., & Schriver, M. (1994). An Examination of Preservice Science Teachers' Beliefs and Behaviors as Related to Self-Efficacy. *Journal of Science Teacher Education, 5*(3), 77-86.

Daley, B. J. (2003). A case for learner-centered teaching and learning. *New Directions for Adult & Continuing Education*(98), 23.

Dembo, M. H., & Gibson, S. (1985). Teachers' sense of efficacy: An important factor in school improvement *The Elementary School Journal* (Vol. 86, pp. 173-184).

Eisenhart, M., Finkel, E., & Marion, S. F. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal, 33*(2), 261-295.

Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teacher efficiency belief instrument: a preservice elementary scale. *School Science and Mathematics, v90*(n8), p694(613).

Fletcher, C., & McClellan, P. (2008). *Professional development, implementation fidelity, and student achievement*. Paper presented at the Association for Science Teacher Education, 2008 International Conference, St. Louis, MO.

Frels, R. K., & Onwuegbuzie, A. J. (2013). Administering Quantitative Instruments With Qualitative Interviews: A Mixed Research Approach. [Article]. *Journal of Counseling & Development, 91*(2), 184-194. doi: 10.1002/j.1556-6676.2013.00085.x

Friedrichsen, P. M., & Dana, T. M. (2003). Using a Card-Sorting Task to Elicit and Clarify Science-Teaching Orientations. [Article]. *Journal of Science Teacher Education, 14*(4), 291-309. doi: 10.1023/B:JSTE.0000009551.37237.b3

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What Makes Professional Development Effective? Results From a National Sample of

Teachers. *American Educational Research Journal, 38*(4), 915-945. doi: 10.3102/00028312038004915

Gibson, S., & Dembo, M. (1984). Teacher efficacy: A construct validation *Journal of Educational Psychology* (Vol. 76, pp. 569-582).

Gibson, S., & Dembo, M. H. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology, 76*(4), 569-582.

Haberman, M. (2010). The Pedagogy of Poverty Versus Good Teaching. [Article]. *Phi Delta Kappan, 92*(2), 81-87.

Haefner, L. A., & Zembal-Saul, C. (2004). Learning by doing? Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning. *International Journal of Science Education, 26*(13), 1653-1674.

Haury, D. L. (1993). Teaching Science through Inquiry. ERIC/CSMEE Digest (pp. 3): ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1929 Kenny Road, Columbus, OH 43210-1080 (first copy free, additional copies, $0.25).

Henson, K. T. (2003). Foundations for learner-centered education: A knowledge base. *Education, 124*(1), 5-16.

Herron, M. D. (1971). The Nature of Scientific Enquiry. *The School Review, 79*(2), 171-212.

Hodgin, C. (2008). *Science teaching anxiety in the elementary classroom: A preliminary ethnographic and qualitative research study*. Unpublished ethnographic research report. The University of Texas at Austin.

Hodgin, C. (2011). *Meeting the TEKS Requirements: What Comprises a Laboratory or Field Investigation?* Literature review.

Howe, A. C. (1998, Winter). Turning activities into inquiry lessons, *Science Activities,* p. 3.

Jadrich, J., & Bruxvoort, C. (2011). *Learning and Teaching Scientific Inquiry: Research and Applications*: NSTA press.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher, 33*(7), 14-26.

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a Definition of Mixed Methods Research. *Journal of Mixed Methods Research, 1*(2), 112-133. doi: 10.1177/1558689806298224

Jorgenson, O., & Vanosdall, R. (2002). The death of science? *Phi Delta Kappan, 83*(8), 601.

Kelly, M. P., & Staver, J. R. (2005). A case study of one school system's adoption and implementation of an elementary science program. *Journal of Research in Science Teaching, 42*(1), 25-52. doi: 10.1002/tea.20043

King, F. J., Heinrich, D. L., Stephenson, R. S., & Spielberger, C. D. (1976). An investigation of the causal influence of trait and state anxiety on academic achievement. *Journal of Educational Psychology, 68*(3), 330-334.

Kraft, N. P. (2002). Teacher research as a way to engage in critical reflection: A case study. *Reflective Practice, 3*(2), 175-189.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Lindgren, J. (2003). Why We Have Seasons and Other Common Misconceptions. *Science Scope, 26*(4), 50-51.

Lindgren, J., & Bleicher, R. E. (2005). Learning the learning cycle: The differential effect on elementary preservice teachers. *School Science and Mathematics, 105*(2), 61-72.

Lowery, N. V. (2002). Construction of teacher knowledge in context: preparing elementary teachers to teach mathematics and science. *School Science and Mathematics, 102*(2), 68-83.

Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (2000). Assessing teachers' beliefs about their science teaching context *Journal of Research in Science Teaching* (Vol. 37, pp. 275-292).

Mallow, J., & Greenburg, S. (1983). Science anxiety and science learning. *The Physics Teacher, 21*(2), 95-99.

Mallow, J. V. (1978). A science anxiety program. *American Journal of Physics, 46*(8), 862-862.

Mallow, J. V. (1981). *Science anxiety : Fear of science and how to overcome it*. New York: Van Nostrand Reinhold.

Mallow, J. V. (2006). Science Anxiety: Research and Action (pp. 3-14).

Merriam, S. B. (1998). *Qualitative research and case study applications in education: Revised and expanded from case study research in education*. San Francisco: Jossey-Bass.

Meyers, J., & Martin, R. (1974). Relationships of state and trait anxiety to concept-learning performance. *Journal of Educational Psychology, 66*(1), 33-39.

Milner, A., Sondergeld, T., Demir, A., Johnson, C., & Czerniak, C. (2012). Elementary Teachers' Beliefs About Teaching Science and Classroom Practice: An Examination of Pre/Post NCLB Testing in Science. [Article]. *Journal of Science Teacher Education, 23*(2), 111-132. doi: 10.1007/s10972-011-9230-7

NRC. (1996). National science education standards. Washington, DC: National Academies Press.

NRC. (2000). Inquiry and the national science education standards: A guide for teaching and learning. Washington, DC: National Academies Press.

Parker, J., & Spink, E. (1997). Becoming science teachers: An evaluation of the initial stages of primary teacher training. *Assessment & Evaluation in Higher Education, 22*(1), 17.

Pell, A., & Jarvis, T. (2003). Developing attitude to science education scales for use with primary teachers. [Article]. *International Journal of Science Education, 25*(10), 1273-1295. doi: 10.1080/0950069022000017289

Peterson, F., Carpenter, and Loef. (1989). Teacher’s Pedagogical Content Beliefs in Mathematics. *Cognition and Instruction, 6*(1), 1-40.

Phillips, D. J. (2004). *Voices long silent were invited to speak: A study of science anxiety in female biology students at a two-year branch campus.* Ed.D. dissertation, University of Cincinnati, Cincinnati, Ohio.

Pine, J., Aschbacher, P., & Roth, E. (2006). Fifth Graders' Science Inquiry Abilities: A Comparative Study of Students in Hands-On and Textbook Curricula. [Article]. *Journal of Research in Science Teaching, 43*(5), 467-484. doi: 10.1002/tea.20140

Plowright, D. (2011). *Using Mixed Methods: Framework for an Integrated Methodology*. Thousand Oaks, CA: SAGE Publications, Inc.

Pringle, R., & Martin, S. (2005). The Potential Impacts of Upcoming High-Stakes Testing on the Teaching of Science in Elementary Classrooms. *Research in Science Education, 35*(2-3), 347-361. doi: 10.1007/s11165-004-5599-z

Pringle, R. M., & Martin, S. C. (2005). The Potential Impacts of Upcoming High-Stakes Testing on the Teaching of Science in Elementary Classrooms. [Article]. *Research in Science Education, 35*(2/3), 347-361. doi: 10.1007/s11165-004-5599-z

Ramey-Gassert, L., & Shroyer, M. G. (1992). Enhancing Science Teaching Self-Efficacy in Preservice Elementary Teachers. *Journal of Elementary Science Education, 4*(1), 26-34.

Ramey-Gassert, L., Shroyer, M. G., & Staver, J. R. (1996). A qualitative study of factors influencing science teaching self-efficacy of elementary level teachers. *Science Education, 80*(3), 283-315.

Riggs, I. M., & Enochs, L. H. (1990). Toward the development of an elementary science teachers' science teaching efficacy belief instrument *Science Education* (Vol. 74, pp. 625-637).

Sanger, M. J. (2007). Is inquiry-based instruction good for elementary teaching majors? The effects on chemistry content knowledge and views about teaching and learning science. *AIP Conference Proceedings, 883*(1), 7-10.

Schneider, R. M., Krajcik, J., Marx, R. W., & Soloway, E. (2002). Performance of students in project-based science classrooms on a national measure of science achievement. *Journal of Research in Science Teaching, 39*(5), 410-422.

Scholz, R., & Tietje, O. (2002). *Embedded Case Study Methods: Integrating Quantitative and Qualitative Knowledge*. Thousand Oaks, CA: Sage Publications, Inc.

Schoon, K. J., & Boone, W. J. (1998). Self-efficacy and alternative conceptions of science of preservice elementary teachers. *Science Education, 82*(5), 553-568.

Schwab, J. (1960). What Do Scientists Do? *Behavioral Sciences, 5*(3).

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing Views of Nature of Science in an Authentic Context: An Explicit Approach to Bridging the Gap Between Nature of Science and Scientific Inquiry. [Feature ABI: Y]. *Science Education, 88*(4), 610-645. doi: 10.1002/sce.10128

Settlage, J., Southerland, S. A., Smith, L. K., & Ceglie, R. (2009). Constructing a doubt-free teaching self: Self-efficacy, teacher identity, and science instruction within diverse settings. *Journal of Research in Science Teaching, 46*(1), 102-125.

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *STAI Manual: For the state-trait anxiety inventory*. Palo Alto, CA: Consulting Psychologists Press, Inc.

Spielberger, C. D., Gorsuch, R. L., Lushene, R. E., Vagg, P. R., & Jacobs, G. A. (1983). *State-Trait Anxiety Inventory for Adults: Manual Instrument and Scoring Guide*. Palo Alto, CA: Consulting Psychologists Press, Inc.

Stake, R. E. (1995). *The Art of Case Study Research*. Thousand Oaks, CA: Sage Publications, Inc.

Stofflett, R. T. (1994). The accommodation of science pedagogical knowledge: the application of conceptual change constructs to teacher education. [Article]. *Journal of Research in Science Teaching, 31*, 787-810. doi: 10.1002/tea.3660310804

Swars, S. L., Daane, C. J., & Giesen, J. (2006). Mathematics Anxiety and Mathematics Teacher Efficacy: What is the Relationship in Elementary Preservice Teachers? *School Science and Mathematics, 106*(7), 306-315.

Taraban, R., Box, C., Myers, R., Pollard, R., & Bowen, C. W. (2007). Effects of active-learning experiences on achievement, attitudes, and behaviors in high school biology. *Journal of Research in Science Teaching, 9999*(9999), n/a.

TEA. (2010). *Texas Essential Knowledge and Skills: Science*. Texas Education Agency Retrieved from http://www.tea.state.tx.us/rules/tac/chapter112/index.html.

Tosun, T. (2000). The Beliefs of Preservice Elementary Teachers toward Science and Science Teaching. *School Science and Mathematics, 100*(7), 374-379.

Trujillo, K. M., & Hadfield, O. D. (1999). Tracing the roots of mathematics anxiety through in-depth interviews with preservice elementary teachers. *College Student Journal, 33*(2), 219-232.

Tsai, C.-C., & Chang, C.-Y. (2005). Lasting effects of instruction guided by the conflict map: Experimental study of learning about the causes of the seasons. *Journal of Research in Science Teaching, 42*(10), 1089-1111.

Udo, M., Ramsey, G., & Mallow, J. (2004). Science Anxiety and Gender in Students Taking General Education Science Courses. *Journal of Science Education & Technology, 13*(4), 435-446.

Udo, M. K., Ramsey, G. P., Reynolds-Alpert, S., & Mallow, J. V. (2001). Does Physics Teaching Affect Gender-Based Science Anxiety? *Journal of Science Education and Technology, 10*(3), 237-247.

Van Zee, E. H., & Roberts, D. (2001). Using pedagogical inquiries as a basis for learning to teach: Prospective teachers' reflections upon positive science learning experiences. *Science Education, 85*(6), 733-757.

Webeck, M. L., Field, S., & Salinas, C. (2004). Tell me more: Boundaries, expectations, challenges, and possibilities for preservice methods of teaching courses. In G. E. Hamot, J. J. Patrick & R. S. Leming (Eds.), *Civic Learning in Teacher Education: International Perspectives on Education for Democracy in the Preparation of Teachers* (Vol. 3, pp. 147-167). Bloomington, IN: ERIC Clearinghouse for Social Studies/Social Science Education.

Weiss, I. R. (1994). *Learning From Strangers: The Art and Method of Qualitative Interview Studies*. New York, NY: The Free Press.
West, S. (2010). An Analysis of the Descriptive, Comparative and Experimental Scientific Research Designs in the 2009 Texas Essential Knowledge and Skills (TEKS). *The Texas Science Teacher, 39*(1), 20-29.
Westerback, M. E. (1981). The Use of the State-Trait Anxiety Inventory in Science Education.
Westerback, M. E. (1982). Studies on Attitude Toward Teaching Science and Anxiety About Teaching Science in Preservice Elementary Teachers. *Journal of Research in Science Teaching, 19*(7), 603-616.
Westerback, M. E. (1984). Studies on anxiety about teaching science in preservice elementary teachers. *Journal of Research in Science Teaching, 21*(9), 937-950.
Westerback, M. E., & Gonzalez, C. (1982). Anxiety Reduction in Preservice Elementary Teachers and the Fulfillment of Expectations for Identification of Minerals and Rocks.
Westerback, M. E., & Long, M. J. (1990). Science knowledge and the reduction of anxiety about teaching earth science in exemplary teachers as measured by the science teaching state-trait anxiety inventory. *School Science and Mathematics, 90*(5), 361-374.
Westerback, M. E., & Primavera, L. H. (1992). *A Science Educator's and a Psychologists' Perspective on Research about Science Anxiety*.
Westerback, M. E., & Roll, D. (1982). Basic Studies on Anxiety about Teaching Science in Preservice Elementary Teachers.
Yürük, N. (2011). The Predictors of Pre-Service Elementary Teachers' Anxiety About Teaching Science. [Article]. *Nejla Yürük., 10*(1), 17-26.
Zembal-Saul, C., Haefner, L. A., & Avraamidou, L. (2002). Web-Based Portfolios: A Vehicle for Examining Prospective Elementary Teachers' Developing Understandings of Teaching Science. [Article]. *Journal of Science Teacher Education, 13*(4), 283-302.
Zion, M., Michalsky, T., & Mevarech, Z. (2005). The effects of metacognitive instruction embedded within an asynchronous learning network on scientific inquiry skills. *International Journal of Science Education, 27*(8), 957-983.

Vita

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