USING INQUIRY TO TEACH AND LEARN SCIENCE:

A NARRATIVE INQUIRY

A Doctoral Thesis Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Education
in Professional Leadership

by

Perri F. Segura

May, 2011

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ABSTRACT

The focus of this inquiry was to further the understanding of what happens to science teachers' beliefs about inquiry-based science instruction, as well as their ability to conduct inquiry-based lessons, as they are systematically immersed in professional development designed to model teaching science as inquiry. Additionally, barriers that prevent science teachers' abilities to teach science as inquiry were explored. Study participants were rural school science teachers who were part of a Texas Teacher Quality Grant and who completed a 45-hour graduate course and 60 hours of professional development over 8 months. As part of the grant activities, the teachers participated as learners in authentic, inquiry-based science activities which focused on physics principles; explored inquiry as a pedagogical approach to teaching science; and developed inquiry-based lesson plans to teach in their classrooms.

The narrative inquiry research method, a collaborative approach involving mutual storytelling and restorying as the research proceeds (Connelly & Clandinin, 1990) was utilized. Two teacher participants' stories were expressed through journaling, interviews, conversations, and the researcher's observations. The research stories generated from the experiences of the three teachers will inform how science instruction in the *teach*HOUSTON program will unfold in the future as well as the knowledge base

concerning how and what teachers learn through inquiry-based teacher professional development.

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Chapter One: Setting the Scene

Introduction

As a former public school science teacher and a current science teacher educator, I have experienced the satisfaction of watching students, from early elementary school through in-service educators, enthusiastically engaged in scientific endeavors. As students confront intriguing challenges and puzzle their way through problems, I have experienced an incredible source of professional enjoyment. Observing students immersed in scientific phenomenon where curiosities are engaged and questions materialize is an exhilarating experience. Watching students formulate pathways to answer their questions through experimentation and data collection and finally drawing conclusions and communicating those conclusions effectively leaves no doubt in my mind that these students truly are doing science. My experiences have led me to the discovery that when students are engaged in scientific inquiry, where they are working to construct their own understandings and have opportunities to use their learning in new and novel ways in real life situations, they experience tremendous satisfaction and pride in learning science.

Yet during my educational career, I have not always known how to orchestrate successful scientific inquiry with students in my classrooms. I did my undergraduate teacher preparation program at a small university in the late 1980's. As I was immersed in my traditional teacher preparation program, I believed I was receiving excellent instruction and preparation to teach. My teacher preparation courses included a teaching methods course where my most poignant memories are of learning how to operate a ditto machine for copies and utilizing audio visual equipment which consisted of a Ducane film-strip projector and a slide projector for pictures. Upon completion of my university course work, but prior to graduation, I completed a full semester of student teaching. Part of the semester I practiced teaching science in a high school biology classroom. My student teaching mentor teacher taught me how to lecture from the text book and encouraged me to write copious notes on the chalk board for discussion purposes. I never questioned this approach to instruction as it was in direct alignment with my own public school experience; I felt I was being prepared exceptionally well although I was fully aware that many students in my class clearly did not comprehend the material being taught. It was at this point that the idea came to me that in order to make science accessible to all students more would be required beyond simple lecturing and note taking.

Upon graduation from college I took my first teaching job in a middle school in an average-size suburban school district in south Texas. It was here that I first heard the word inquiry as it related to science instruction. My science department chair informed me, within the first few weeks of school, that inquiry was the most effective way to teach science and that I should use this approach when writing my lessons and delivering instruction. As a new and novice teacher, I was extremely anxious to do an exemplary job. I believed I could, and deeply desired to, make a significant impact on the students in my charge. I must say I was perplexed to learn that there was a best way to teach science and that it was through a strategy of which I had never heard. I wondered how it was possible that I had just completed my undergraduate training, including student teaching, and had never been engaged in learning science or teaching science as inquiry.

As I tried to reconcile this within, I concluded that teaching science as inquiry must be the approach Texas educators used and because I was not native to the state this explained why I had not encountered this particular instructional approach. However, having been told by my esteemed mentor and department chair, that teaching science as inquiry was the most effective way to teach science, I found myself deeply intrigued and interested to learn how to teach utilizing this highly effective instructional strategy. My quest for understanding inquiry as an instructional approach to teaching science had begun, and it was here that I started to grapple with intensive educational issues including how teachers science content knowledge, pedagogical knowledge, and knowledge about students impacts student achievement.

I spent the next several years working to understand science as inquiry and to implement my early understandings of teaching through this approach. I experienced many issues frequently associated with novice teachers including problematic classroom management, pressure to cover endless essential objectives and continued confusion in my understanding of inquiry-based science. My early conception of teaching science as inquiry equated to the belief that students were immersed in inquiry if they were conducting cookbook laboratory activities utilizing the tools of science. The science activities I used were very structured telling the students what questions to answer, what materials to use, and how to go about solving the question or problem. Many of these activities included the charts or tables for students to record their observations, measurements or data. These activities followed a very linear approach, and well they should, as I was entrenched in my belief that I must teach my students to utilize the scientific method; the same method that I was taught in my own college science courses.

Joseph Schwab (1962) referred to this approach to teaching science as a "rhetoric of conclusions" or as a finished product. As time passed and I continued to teach utilizing this hands-on approach, I became exceptionally confused and frustrated because my students, although seemingly enjoying science, were not mastering the content as evidenced by their inability to apply their freshly acquired knowledge in new ways. So, my quest continued to become the exceptional science teacher that I truly desired to be.

Surprisingly, as I sought to become instructionally more effective, my supervisors began to promote me to leadership positions within the school. After two years of teaching I was asked to become a team-leader of my interdisciplinary team, and as a result I began to mentor new teachers in the science department. I accepted these positions with determination to make a positive impact on student achievement. In an effort to continue my own growth I sought out and attended professional development as frequently as I could, including attending after school and weekend classes and summer workshops. I found the term inquiry to be very much in vogue in science education circles. Surely this was a result of inquiry being placed as the central tenet in science education by the National Science Education Standards in 1996. Many professional development sessions I attended touted the word inquiry in its description. At this same time, I had ever more opportunities to interact with more seasoned science educators and found a seed of doubt planted in my brain by some of them. These teachers were quick to share that inquiry was simply the latest "fad" in science education. This left me deeply concerned and I was almost convinced that perhaps it was true. In my brief tenure as an educator I had seen several initiatives come and go quickly. I did not want to spend time seeking how to be more effective with students only to have this approach thrown to the side as some new approach became popular.

In an effort to make a decision to continue to develop my understanding of science as inquiry or abandon my efforts looking for a new instructional approach, I sought advice from several mentors that I respected. One mentor, a former teacher of mine, suggested I read some of John Dewey's work. Having learned precious little of John Dewey in my undergraduate preparation, I sought out his work at the university library. My passion was renewed as I learned that John Dewey was an educational reformer of the early 1900's who stressed to American educators the importance of discovery learning and inquiry. Dewey (1938) proposed that learning does not start and intelligence is not engaged until the learner is confronted with a problematic situation. I immediately embraced this approach and knew that if teaching science as inquiry had been a topic of educational discussion in the late 1800's this indeed was not just the latest fad in science education.

For the next six years, I enthusiastically continued to teach my students science. I branched out from the course assigned text book and looked for resource books and lab manuals to support the activities in my classroom. In reflecting over Dewey's work I knew I needed to provide my students with real-life, problem-based experiences. With renewed vigor, I increased the amount of lab activities I provided to my students. If students learned through encountering problems then I was going to provide them with many problems to puzzle through. What I had no recollection of at this time was the fact that the structure of these developed labs were counter-productive to getting my students engaged as problem solvers.

In my ninth year of teaching I was promoted to the position of science specialist in a large suburban school district in which I had transferred only three years earlier. My campus principal had been in my classroom on numerous occasions in the years prior to my promotion, and I had received many positive comments and accolades about the work I was doing with my students. I had become a frequent presenter of professional development for my campus, the district and the regional area. I was proud of the work I was doing; indeed I was working hard. But at the same time I felt a significant source of despair. The continually lingering and deeply rooted belief, which was instilled at my core, learned, in part, through reading Richard Feynman's (1997) work which expressed that the operational definition for learning was the ability of students to utilize the knowledge gained from their experiences in new and novel ways, was blatantly missing. When I forced myself to look with a critical lens at what my students were able to do, I knew that many were not effectively able to utilize their knowledge in new ways. The wrestling of this conflict was a form of anguish that kept me up at night. It nagged at me, taunted me, and perplexed me! It almost prevented me from accepting the promotion to science specialist. Although I was thrilled most of my students seemingly enjoyed what we were doing in science, I wanted, indeed needed, more for and from them.

After much personal conflict, but with sincere desire to work toward improving science opportunities for all children, I moved into the role of science specialist. It became my responsibility to work with all of the secondary science teachers (over 150 middle and high school teachers) in the district; coaching them to become better teachers so they could positively impact student achievement. What a charge! I quickly found myself very busy working with many science educators in their classrooms with their students. I was simply overwhelmed by the massive amounts of teachers' utilizing direct instruction, power point notes and textbook generated lectures as their primary instructional strategies. As research informs us, too often science teaching emphasizes recall of factual content with little focus on knowledge generation (McComas, Clough, & Almazroa, 1998).

During my first several years of working as the secondary science specialist, I focused my attention on those teachers who were most willing to embrace trying something new in their classroom. Through my years of teaching I had acquired many instructional resources and was quick to share laboratory exercises with my colleagues. This approach to teaching was embraced by many and I took pride in knowing that I was helping teachers provide science experiences for their students. Still, I was committed to improving my knowledge and skills as a science educator, determined to improve my craft, never wavering from the belief that I could, just as all good teachers could, help improve students' scientific literacy.

Through all the years up to this point in my career it is important to note that I continued to attend many in-services and professional development sessions. I was a diligent attendee of our state annual science conference, the Conference for the Advancement of Science Teaching (CAST). Additionally I attended professional development sessions which emphasized utilizing technology in the science classroom, workshops where I was exposed to lesson plan ideas as well as short courses that emphasized working with diverse learners. I recall becoming slightly disillusioned when attending professional development because, over time, it seemed that much was the same. Many times professional developers were sharing activities that they did in their classrooms or displaying student projects, and while I was grateful to learn from others, I also realized that there was frequently nothing new and innovative in their instructional approaches. Finally, I stumbled into a professional development experience that transformed my understanding of teaching science as inquiry. For the first time ever, my understanding of *how* to teach science as inquiry was engaged. Through attendance at a professional development facilitated by the Exploratorium in San Francisco called the Inquiry Institute, I truly learned what scientific inquiry was and how to orchestrate it in a classroom. Over the course of a week, I engaged in carefully planned investigations that were specifically designed to address the particular needs and developmental levels of teachers. Here I experienced learning where I was left with a deeper understanding of science content and learned how teaching science as inquiry was facilitated. It was through this experience that I came face to face with my understanding that adults, like children, learn best in constructivist environments where learning and understanding are developed from within. Human beings are natural inquirers and inquiry is at the heart of all learning. Teachers need opportunities to explore, question, and debate, in order to integrate new ideas into their repertoires and their classroom practices. My learning was most effective as I experienced high levels of cognitive dissonance between my existing beliefs and those I confronted through innovative teaching and learning opportunities. Through well-structured opportunities to work toward resolving dissonance, revision of thinking and beliefs was obtained.

After attending the Exploratorium's professional development, I returned to the district with a renewed sense of excitement – anxious to get to work with teachers raising their awareness of how to teach science as inquiry. As I visited teachers in their classrooms, I started to engage teachers in conversations sharing with them my recent learning experience. Some teachers showed excitement as I shared with them some of the strategies I had learned, but most, I perceived, were not impacted by my story. Quickly it became very evident that I needed to provide these teachers the same opportunity I had been given – an experience to learn for themselves the powerful features of teaching and learning science as inquiry.

For the next couple of years I worked through the school district providing professional development to teachers. Over time I noticed a few teachers I observed utilizing very constructivist, student-centered approaches. These teachers were using an inquiry-based approach and consequently I observed students taking active control of their learning. In these environments students were enthusiastically generating questions, developing procedures, collecting data and drawing evidence-based conclusions. These teachers were teaching students in ways that allowed students to make sense of complex science concepts and to apply their understandings to new situations. This should not be surprising as research informs us that teachers are critical to enhancing learning in schools. Good teaching is critical to students' understanding and mastery of ideas (Michaels, Shouse & Schweingruber, 2008).

Further into my career, I became involved in the preparation and development of preservice science and mathematics teachers in the *teach*HOUSTON program at a large urban university's teacher education program. At this time, I experienced a new challenge of teaching inquiry-based science to preservice teachers. As I worked with preservice science teachers, attempting to implement their understanding of inquiry-based science, I struggled to find ways to change their belief structures about the characteristics of effective science education and help them to overcome their pre-existing beliefs. My interactions with preservice science teachers and the development of their conceptions of inquiry encouraged me to pursue inquiry as a focus for my own research.

As my knowledge and understanding of teaching science as inquiry evolved I found myself once again confronted with the question of the effectiveness of teaching science as inquiry. This conflict arose as I was preparing to undertake an educational visit to three cities in China: Beijing, Xi'an and Shanghai. From years of studying educational data, I knew that many countries were experiencing educational achievements in math and science that far surpassed the children in the US. I was immensely excited at the opportunity to get an international perspective on science education. As I pondered and prepared for the wonderful opportunity provided in making this trip to China I found myself keenly curious about China's educational system. For many years I had heard and seen reference to the exceptional quality of the Chinese educational system. My personal experiences with my own students of Chinese heritage had taught me that education is valued in their society and that children, from a very young age, are often times exceptional students. I've often wondered why. I wondered if their system of education was replicable. As my trip approached, I wondered what I would learn about the way China educates their children. My personal philosophy of science education was very centered in constructivism. An ideal learning environment, I had come to believe, was one in which students were personally involved with their learning, having the freedom and encouragement to take risks in their quest for understanding. Would Chinese educators also value this philosophy? I wondered if I would see it in practice and thus have even more evidence of the effectiveness of a constructivist approach to teaching and learning. I firmly believed that students, when exposed to problem finding and solving activities, become passionate in their learning experiences and gain deep understanding. Through active engagement students learn to make connections with information and are able to apply it in productive means. As I pondered my trip to China I wondered if I would see learning happening in classrooms that exemplified this philosophy. If not, what then was I to make of my learning philosophy? Was it not accurate or complete? Did it only work in certain conditions? Would I find myself confronted with a philosophy that did not hold up? If Chinese students are exemplary and these are not common practices in their classrooms, what then? I was most fearful of this – fearful to confront a reality that may unravel a career of working toward developing teachers and preservice teachers understandings of inquiry-based science education. I wondered what the famous constructivists, John Dewey, Jean Piaget, and Joseph Schwab would say about education if they had studied the current Chinese educational system. Again, drawing on my experiences, my Chinese-American students have typically been the most resistant to learn independently. They have been the students that crave structure, order, direction. They are the students who will spend hours in silent study, reading, and practicing rote formulas and recitation of vocabulary. They are masterful at assessment which requires extensive memorization and recollection of vocabulary. However, when asked to be innovative, to construct their own pathway through solving a problem, I have often been met with dogged exasperation, pleas for guidelines, and occasionally tears of frustration. Yet, it must be said that these children often times excel in many school activities and competitions. They are often the high place winners in science and mathematics fairs, spelling bees, robotics competitions and the like. I found myself questioning whether exceptional students must first have a very strong foundation in the basics (perhaps learned through vocabulary development and memorization of formulas) before they can be “let loose” to be independent learners engaged in activities that require application of knowledge.

I firmly believe that education reform efforts in the United States cannot succeed without work toward assisting educators to become more effective in their approaches to teaching children. Serving in my roles as a teacher, science specialist, and later as a science supervisor, I observed that many teachers lacked familiarity with and were unable to effectively deliver inquiry-based instruction in their classrooms. “Inquiry-based teaching is simply an abstract idea to teachers who never encountered this type of teaching during their own K-16 education and did not learn to teach in this fashion in their education training” (Kazempour, 2009).

Purpose of the Study

To assist the building of a research literature that may begin to help bridge the theory-practice gap in inquiry-based science education reform, Keys and Bryan (2001) suggest a research agenda that places "teacher knowledge, actions, and meanings for inquiry-based science at the center of the reform process" (p. 632). In an effort to further understand how teachers come to understand and implement inquiry based science instruction, I decided to undertake research that would allow me to begin to understand what could happen to science teachers' understandings of inquiry when systematically exposed to learning science content through an inquiry approach followed by reflection on their planning and teaching of inquiry-based lessons within their classrooms.

My goal is to inquire into and make meaning of science teachers' attitudes and abilities regarding teaching science as inquiry and to document how attitudes and abilities change when teachers are taught science content through an inquiry-based approach. As a narrative inquirer, I will bring to light the changes in attitudes and abilities teachers' experience when exposed to professional development which aims to situate teachers as learners of both science content and pedagogy. Further, I hope to illuminate barriers which potentially prevent teachers from implementing the particular pedagogical approach in study in their classrooms with their students.

Chapter Two: A Review of the Literature

This inquiry uses the principles and structures of narrative inquiry in order to further the understanding of what happens to science teachers' beliefs about, as well as their ability to conduct, inquiry-based science instruction as they are systematically immersed in professional development designed to model teaching science as inquiry. Furthermore, what science teachers identify as influencing their perspectives and abilities to teach science as inquiry will be explored. In theory, as teachers examine their initial beliefs and abilities about teaching science as inquiry and then reconcile them through professional learning, practice, and reflection, a change in beliefs and abilities will be effected. In an attempt to explore these issues, this review of literature will overview research that reflects the current state of education in the United States developing the need for exploring the potential impact of teaching science as inquiry. Educational barriers including poverty, resources and teachers' knowledge will be explored as they are relevant variables that have the potential to influence teachers' instructional abilities. Additionally, the definition and historical development of inquiry will be studied in order to understand the theoretical foundation of this instructional approach. Finally, teacher professional development will be reviewed including research regarding the teacher as curriculum maker.

Introduction

A large body of compelling evidence indicates that educational endeavors in the United States are moderately behind that of some Western European and Asian nations in teaching students the knowledge and skills necessary to compete in the 21st century. The shortcomings of education have been documented in the National Science Academies, *Rising above the Gathering Storm* (2007), which warned of an approaching shortage of scientists, engineers, and technical employees at least partly caused by inadequate K-12 science education; *A Nation at Risk*, a report by the National Commission on Excellence in education (1983), and in *An Imperiled Generation: Saving Urban Schools* (Carnegie Foundation, 1988). With American prosperity dependent on innovation, these reports point out that the United States long-standing scientific leadership, as well as the nation's economic future, is at risk. Additionally, in February 1998, the United States Department of Education issued the discouraging results of American high school seniors in the Third International Mathematics and Science Study (TIMSS), a worldwide competition among all nations. U.S. twelfth graders performed well below the international average and among the lowest of the 21 TIMSS countries on the assessment of science and mathematics knowledge. These reports reveal that U.S. students are not achieving at the international standards demanded by current labor markets. Poor performance in science is particularly disappointing for a country that aims to continue to be a world economic leader (TIMSS, 1998).

The Nation's report card, the National Assessment of Educational Progress (NAEP) gives the best estimate of schoolchildren's learning skills. Assessments conducted by the NAEP in reading, math, science, history and geography provide scores that offer perspectives into what is happening in American schoolrooms. The NAEP (2005) test in the science domain claimed that "high school students displayed frightening ignorance in a nation whose future, in peace and war, depends heavily on science and technology" (p 18).

Many results of international assessments, as outlined earlier, depict the United States as standing still while more focused nations move rapidly ahead. In 2006, on the most recent international assessment conducted by the Program in International Student Assessment (PISA), the United States ranked 21st of 30 countries in science and 25th of 30 in mathematics – showing a drop in both raw scores and rankings from three years earlier (Darling-Hammond, 2010). The PISA assessments results are particularly discouraging because the assessments require more advanced analysis than most U.S. tests, going beyond testing specific facts and asking students to apply what they know to new problems. Unfortunately, U.S. students fall furthest behind on PISA tasks that require complex problem solving (Darling-Hammond, 2010).

Need for the Study

Because traditional education is failing to prepare many of our students for work and higher education, educational leaders must address the myriad of issues that affect our large urban districts who are responsible for the education of so many students, many from poverty. Major educational hurdles must be overcome if we are ever to be successful in building a system of high-achieving and equitable schools that provides every child the opportunity to learn. Comparative research around education and instruction is urgent as other nations, including China, are transforming their school systems to meet these new demands.

The New Commission on the Skills of the American Workforce (2007) summarizes the reasons why it is absolutely crucial for the United States to address educational improvement for all our youth:

> The best employers the world over will be looking for the most competent, most creative, and most innovative people on the face of the earth and will be willing to pay them top dollar for their services… Beyond [strong skills in English, mathematics, technology and science], candidates will have to be comfortable with ideas and abstractions, good at both analysis and synthesis, creative and innovative, self-disciplined and well organized, able to learn very quickly and work well as a member of a team and have the flexibility to adapt quickly to frequent changes in the labor market as the shifts in the economy become ever faster and more dramatic. If we continue on our current course, and the number of nations outpacing us in the education race continues to grow at its current rate, the American standard of living will steadily fall relative to those nations, rich and poor, that are doing a better job. The core problem is that our education and training systems were built for another era, an era in which most workers needed only a rudimentary education. (p. 1)

In this report, important rationale can be found which illuminate the reasons why the U.S. needs to be internationally competitive, particularly where communication (English) and the STEM (science, technology, engineering, and mathematics) are concerned.

As can be seen, science education plays a critical role in U.S. competitiveness and America's future economic prosperity. The most recent employment projections by the

U.S. Department of Labor (2006) show that of the 20 fastest growing occupations projected for 2014, 15 of them require significant science or mathematics preparation. America's global competitiveness will increasingly depend on its ability to better educate young people in the sciences.

Education reform efforts in the U.S. cannot succeed without assisting educators in becoming more effective in their approaches to teaching children. We must continue to develop ways to better instruct our children, particularly in science and mathematics, because our students need a significantly different preparation for work in a global economy and life in modern society. Reform efforts must aim to nurture students to develop critical thinking and problem solving skills so that our students are capable of meeting the challenges of the 21st century.

The solution to the problem of ensuring academic success for all students will determine the prosperity or demise of our nation. People have been trying to understand learning for over 2000 years. Learning theorists have conducted debates on how people learn that began at least as far back as the Greek philosophers, Socrates, Plato and Aristotle. The debates that have occurred through the ages are still engaged in today. The purposes of education and how to encourage learning are frequently discussed in educational arenas. Research on teaching is a significant resource to teachers; it helps both validate good practice and suggests directions for improvement.

International comparisons may help us understand effective instructional practices. Many nations around the world are transforming their school systems to support the more complex knowledge and skills needed today. The Chinese educational system is in a state of instructional reformation. In 2001, the Chinese Ministry of Education proposed a new instructional focus designed to change the overemphasis from rote memorization and mechanical drill to promoting instead students' active participation in analyzing and solving problems. As disclosed in a lecture (June, 2010) given by the Ministry of Education representative at Beijing University, China found their instructional model lacking in developing students' creativity and analytical abilities, and are currently implementing reforms designed to make their education systems more child-centered and thus constructivist in nature. In a summer 2010 visit to three cities in China, many references were made by Chinese educators depicting a call for more child-centered pedagogy, which hunkers back to America's John Dewey, his philosophy of education, and his groundbreaking trips to China.

Finland is another example of a nation who has implemented educational reform initiatives into their schools. Darling-Hammond (2010) states:

> Finland dismantled the rigid tracking system that had allocated differential access to knowledge to its young people and eliminated the state-mandated testing system that was used for this purpose, replacing them with highly trained teachers and curriculum and assessments focused on problem solving, creativity, independent learning, and student reflection. The changes implemented have propelled student achievement to the top of the international rankings and closed what was once a large, intractable achievement gap. (p. 5)

As Darling Hammond has suggested, Finland's strong example appears to be a productive plotline that the US should consider following.

Singapore, China and Finland have all undertaken educational reform initiatives which provide insights into effective practice. Global comparisons of educational reform efforts offer perspectives that might be utilized in the United States, particularly as related to science education. Today, science teaching emphasizes recall of factual content with little focus on knowledge generation (McComas, Clough, & Almazroa, 1998). In many K-12 science classrooms, science is treated as a large body of knowledge that students must possess in order to pass a standardized test. While the tests vary from state to state, much classroom time is often devoted to test preparation, and the rote memorization of science facts.

Educational Barriers

Poverty

Linda Darling-Hammond in her book, *The Flat World and Education, How America's Commitment to Equity will Determine Our Future*, shines a spot light on equity issues in education. She poignantly details staggering statistics that depict the extent to which the United States faces a national crisis because students in other nations, including China, are outperforming our students in mathematics and science achievement. Her statistics point to the fact that the U.S. will be unable to meet the scientific and technical needs of our country unless a national commitment to improve schools, teachers, educational leaders and teacher preparation programs is undertaken. Darling-Hammond (2010) carefully reveals the extent of the achievement gap in this country and posits that the country's educational destiny will become more tightly connected to the academic status and achievement of students of color. Nationwide only 71 percent of students graduate from high school and worse, only about half of black and Latino students graduate.

Poverty is a social crisis that is dividing the United States in two. The ever-growing achievement gap between the “haves” and the “have-nots” is the major driving force behind much educational legislation, with the latest being the No Child Left Behind Act (NCLB). Allington (2002) notes that American schools have never found it as easy or inexpensive to effectively educate children from impoverished homes when compared to children from more affluent means. Interestingly enough, he further posits the relative ease and convenience of politicians and lobbyists to place the blame and responsibility squarely upon the shoulders of the public school system as the culprit (Allington, 2002). Haycock (2001) states another angle of blame, which seems to center firmly on the children themselves and their families. From concerns of their families being too poor with the lack of basic necessities such as food and shelter to little or no parental involvement and the lack of educational emphasis in the homes, the responsibility, again, seems to rest solely on one source – the child (Goldberg, 2001; Haycock, 2001). Poverty is the responsibility of all and educators may hold the keys to freedom from illiteracy and continued impoverishment. The “avoidable injustice” of not providing all children, regardless of race or socioeconomic status, with a proper education must be eradicated (Goldberg, 2001).

Researchers (Coleman et. al. 1966) have long sought to understand and explain the vast racial and ethnic disparities in achievement that have always existed in the United States. Although numerous investigations have been undertaken, no consensus exists concerning the primary cause of these disparities. Blaming and finger-pointing alone is not the answer. Haycock (2001) states “raising the achievement of low-income children requires ameliorating the social and economic conditions of their lives, not just reforming schools" (p. 43).

In addition to being taught by less expert teachers than their white counterparts, students of color face stark differences in course and curricular programs (Darling-Hammond, 2010). Many times it will only be through education that those from poverty will have an opportunity to move out of the intergenerational cycles of poverty (Lewis, 1996). However, Haycock (2001) and Coutinho, Oswald, and Best (2003) posit that often poor and minority students face underestimation of their potential within the system and are placed in lower-level courses, with a curriculum and a set of expectations so low-level that they literally bore the students and do not foster the level of expectation that is needed to succeed.

The types of skills that students need to be successful in the 21st century include: critical thinking and problem solving; agility and adaptability; initiative and entrepreneurialism; effective oral and written communication; accessing and analyzing information; curiosity and imagination. The type of curriculum that supports these qualities has typically been rationed to the most advantaged students in the United States (Darling-Hammond, 2010).

Resource allocation

A study conducted by Ferguson (1991), found a strong relationship between students' economic status and the level of resources provided for their classroom experiences. Darling-Hammond (2010) states that 80 percent of the teachers in schools with a middle or upper socioeconomic status (SES) received all or most of the materials or resources they requested whereas only 41 percent of teachers at schools with the largest concentrations of low SES students received all or most of the instructional materials they requested.

Darling-Hammond (2010) references Singapore as a shining example of an urban city that has focused attention on allocating resources for their students of poverty. 80 percent of families from Singapore live in public housing; however its 4th and 8th grade students scored first in the world in both math and science on the 2003 TIMSS assessment. Children in Singapore attend schools throughout the city where students work (including papers, projects, awards and art) is displayed; libraries and classrooms are well stocked; instructional technology is plentiful; and teachers are well trained and supported. This scenario stands in stark contrast to many dilapidated schools in the U.S, some of which can be found in the vicinity of Greater Houston.

Teacher quality

In the United States, teachers are the most inequitably distributed school resource (Darling-Hammond, 2010). Allington (2002); Halford (1996); Haycock (2001); Jerald (2002); and Haycock & Chenoweth (2005) posit that high-poverty schools are more likely to have critical, core knowledge taught by teachers who are without even a minor in the subjects they teach, and the students who most depend on their teachers for subject matter learning are assigned teachers with the weakest academic foundations. Many times it comes down to a funding issue where the "highest-poverty schools typically employ the least experienced, least credentialed, and therefore the least expensive and least expert teachers" (Darling-Hammond, 2010).

Importance of Teachers

Subject Matter Knowledge

Around the world, there is a growing recognition that expert teachers and leaders are the key resource for improving student learning. Many Asian teachers come closer to practicing the principles of “informed teaching” than their American counterparts; Asian teachers are largely well-informed, well-prepared and are able to guide their students through material; structure and purpose are built into lessons deliberately (Dimmock & Walker, 2005). This literature supports the supposition that Asian teachers have command of their subject matter and have sound pedagogical approaches to teaching.

Many researchers of student achievement take teachers subject matter competence into consideration. Subject matter knowledge is a variable that needs to be considered as student achievement is explored. Research on the links between teacher inputs and student outputs began in the U.S. nearly 35 years ago with the publication of the Equality of Educational Opportunity Study of 1966, also known as the Coleman Report (Coleman et al., 1966). This study related teacher inputs to student outputs and found the link between the two was weak. In response to the Coleman Report, many studies have been conducted relating teacher inputs to student outputs.

There are studies that confirm a positive significant relationship between student achievement and teachers’ measured ability. A major study conducted by Wenglinsky (2000) examined nearly 15,000 NAEP (National Assessment of Educational Progress) 1996 scores of grade eight students’ performance on math and science. He found that students whose teachers majored or minored in the subject they were teaching outperformed their peers by about 40 percent of a grade level in both math and science.

Without knowledge of the structures of a discipline, teachers may misrepresent both the content and the nature of the discipline itself. Teachers' knowledge of the content to be taught influences how and what they teach. This lack of content knowledge by teachers may affect the level of classroom discourse and student achievement (Carlsen, 1988).

A large-scale study done by Goldhaber (1999) tried to assess the effect of teachers' subject matter knowledge on student achievement by examining differences in students for teachers with different academic majors. In general, this study found that in classes where teachers have an academic major in the subject area in which students are being tested, the tested students have higher adjusted achievement gains.

Another study (Strauss & Sawyer, 1986) found that North Carolina's teachers' average scores on the National Teacher Examinations (a licensing test which measures subject matter and teaching knowledge) had a strong influence on average school district test performance. Taking into account per-capital income, student race, district capital assets, student plans to attend college, and pupil/student ratios, teachers' test scores had a strikingly large effect on students' failure rates on the state competency examinations: a one percent increase in teacher quality (as measured by NTE scores) was associated with a three to five percent decline in percentage of students failing the exam (Darling-Hammond, 2010).

Pedagogical Knowledge

Pedagogical knowledge means understanding the methods and strategies of teaching. Specific methods or strategies that have been proven to work in a content area such as science are referred to as pedagogical content knowledge. Good pedagogical knowledge is the ability to teach well.

Asian teachers generally spend more time working together and helping each other design lessons than their American counterparts. In contrast U.S. teachers often lack the time and incentive to engage in collaborative practice (Dimmock & Walker, 2005). This lack of collaborative practice leaves U.S teachers in isolation while Chinese teachers have time to work together to plan lessons more carefully, to discuss appropriate, high-quality teaching techniques and develop plans to address common student misconceptions. Inquiry about practice is pervasive in Asian nations, made possible by the extensive time that teachers have to work with colleagues on developing lessons, participating in research and study groups, observing one another's classrooms, and engaging in seminars and visits to other schools (Darling-Hammond, 2010).

Knowledge about science teaching rests on an understanding of the misconceptions students typically hold about natural phenomenon as well as a scaffolding of ideas and guidance of student inquiry (Ingersoll, 1999). These understandings are then joined to knowledge about teaching materials and resources that enable theoretical knowledge to come alive in purposeful, content-rich, teaching and learning (Darling-Hammond, 1999). According to Darling-Hammond (1999), an effective teacher is one who molds and adjusts his or her teaching to fit the demands of each student, topic, instructional method and teaching goal. Given the multidisciplinary, simultaneity and immediacy of classroom events, it is not surprising that teachers, like those in China, who have the opportunity to plan collaboratively, are able to adapt instruction to students' needs and infuse more creative approaches into their lessons thus producing positive student learning outcomes.

A study conducted by Perkes (1967-68) found that teachers' coursework credits in science were not significantly related to student learning, but coursework in science education was significantly related to students' achievement on tasks requiring problem solving and applications of science knowledge. Teachers with greater training in science teaching were more likely to use laboratory techniques and discussions and to emphasize conceptual applications of ideas, while those with less education training placed more emphasis on memorization. Globally, many nations require graduate-level preparation for teaching, often times at government expense, which includes at least a full year of training in a school connected to a university. These programs often include extensive coursework in content-specific pedagogy and a thesis researching an educational problem in the schools (Darling-Hammond, 2010).

Another study that positively linked pedagogical knowledge with student achievement was done by Ferguson and Womack (1993). They conducted a study of more than 200 graduates of a single teacher education program. They examined the influences on 13 dimensions of teaching performance of education and subject matter coursework, NTE subject matter test scores, and GPA in the student's major. They found that the amount of education coursework completed by teachers explained more than 16.5 percent of the variance in teacher performance than did measures of content knowledge (NTE scores and GPA in the major), which explained less than four percent.

A similar study was completed by Guton and Farokhi (1987). They compared influences of different kinds of knowledge on teacher performance for more than 270 teachers. They found consistent strong, positive relationships between teacher education coursework performance and teacher performance in the classroom as measured through a standardized observation instrument, while relationships between classroom performance and subject matter test scores were positive but insignificant and relationships between classroom performance and basic skill scores were almost nonexistent.

Teaching Science as Inquiry

Definition of Inquiry

Inquiry as the central strategy for teaching science is the cornerstone of current science education reform (American Association for the Advancement of Science [AAAS], 1989; Crawford, 2007; National Research Council [NRC], 1996, 2000). However, there is still disagreement between educational professionals about what the enactment of inquiry should look like and accomplish in instructional settings (Anderson, 2002, Crawford, 2007, Windschitl, 2003).

Inquiry is truly different from traditional science teaching practices. In *Inquiry and the National Science Education Standards* (NRC 2000), inquiry is defined by the following five essential features: engaging scientific questions, priority to evidence, explanations from evidence, evaluation of explanations, and communicate and justify explanations. The focus in an inquiry classroom is on what learners are doing, not on what the teacher is doing. Learners should be doing the intellectual work of making sense of the data and creating scientific explanations. Through inquiry, students learn to think (Luft, 2010). This view of learning is part of the movement in science education known as constructivism. When learning is recognized as a constructivist activity, it provides a rationale for allowing students to construct their knowledge.

Historical Support of Teaching Science as Inquiry

John Dewey is considered one of the 20th century's most influential educational theorists and philosophers and a robust advocate for student-centered, inquiry-based education. Dewey articulates that the problems to be studied in schools were created from the everyday needs, interests, and most importantly, experiences of the students (Dewey, 1902). Dewey's ideas about education were closely tied to the natural world and he firmly felt that learning was an active process, including solving problems that interested students. He believed that problems posed to pupils too often involve the interest of the teacher rather than the students. From Dewey we understand that learning must have personal meaning for the student because his world is a world with personal interests, rather than a realm of facts and laws (Dewey, 1902). Dewey believed that thinking arises when a person confronts a given problem and that each learner needs to make use of knowledge for it to be meaningful and retained. Furthermore, Dewey posited that learning occurs when the mind actively engages in a struggle to find appropriate solutions to problems by drawing on prior knowledge and experiences, formulating a strategy to solve the problem, and finally, weighing the consequences of action.

Joseph Schwab also had deeply rooted convictions about teaching science in a constructivist manner. Schwab (1961) observed that until about 1900, science was regarded as a “matter only of seeking the facts of nature and reporting what one saw” (p. 7). In the early 1920’s scientific discoveries in physics led to a revolution of the goals, structures, and processes of science. Scientists were faced with the fact that some of the oldest and least questioned ideas of the physical world could no longer be viewed as absolute truths. This was a critical junction in science where scientists began to treat scientific ideas as “principles of enquiry – conceptual structures – which could be revised when necessary.” In Schwab’s view, science was no longer a process for revealing stable truths about the world, but instead it reflected a flexible process of inquiry.

Joseph Schwab (1961) firmly believed that teachers and educators are “being asked to fulfill an urgent national need, to act as executors of public policy” (p. 3). Schwab powerfully protested the teaching of science as a presentation of already known facts, which he called a ‘‘rhetoric of conclusions” in which the current, temporary scientific knowledge is taught as exact and irrevocable truths. Schwab believed that a school curriculum should more accurately represent the scientific endeavor as engaged in by practicing scientists, including active questioning and investigation.

Teaching science as inquiry places the emphasis upon the student doing the learning and constructing their understandings. It encourages what John Dewey and Joseph Schwab stressed – learning occurs through doing and becoming actively involved in an experience. The student becomes the inquirer and is no longer required to be a passive observer but rather an active participant in the quest for knowledge (Sund &Towbridge, 1967). Dewey (1902), in discussing the importance of seeking to uncover the student’s perceptions and interests wrote: "Selected, utilized, emphasized, [activities of interest to students] may mark a turning point for good in the child's whole career; neglected, an opportunity goes, never to be recalled" (p. 14).

Joseph Schwab (1961) characterized inquiry as either "stable" or "fluid." Stable inquiry involved using current understandings to "fill a … blank space in a growing body of knowledge" (p. 15). He considered stable enquiry as the case when one constructs a structure of scientific knowledge, rather than questioning its plan. In contrast, the task of fluid enquiry is to study the failure of stable enquiries in order to discover what was lacking in the principles that guided them. Fluid enquiry involves the creation of new concepts and ideas that revolutionize science.

Dewey posited that the needs of the child and the demands of the curriculum are mediated by teachers (Dewey, 1902). The teacher's role is one of organizing and creating situations which will set the stage requiring a student to act out the role of a scientist. It is for this reason that curriculum development must assign a considerable amount of time to laboratory and field experiences. In teaching by inquiry the teacher's role is not to act as a reservoir of stored knowledge rather he/she facilitates the learning process by developing powerful experiential situations that engage students in the learning process. In an inquiry classroom a teacher seldom gives answers to questions but asks a series of questions which help the students to discover for themselves (Sund &Towbridge, 1967).

Dewey recognized that schools, particularly elementary and secondary schools often were repressive institutions that did not promote exploration and growth. Dewey believed that schools should teach students how to be problem-solvers by helping students learn how to think rather than simply learning rote lessons about miscellaneous pieces of information. Dewey emphasizes that science is a way of thinking. He believed that too much emphasis was given to the accumulation of information and not enough to science as a method of thinking and an attitude of the mind.

Today, science teaching emphasizes what Dewey denounced: recall of factual content with little focus on knowledge generation (McComas, Clough, & Almazroa, 1998). In most K-12 science classrooms, science is treated as a large body of knowledge that students must possess in order to pass a standardized test. In many classrooms today time is often devoted to test preparation, and rote memorization of science facts.

Schwab articulated the means necessary to bring about an enquiring curriculum in schools. The following list identifies his characteristics of an enquiring curriculum:

1. To help education model the modern practice of science more accurately, place students in the science laboratory immediately. In this way, students could ask questions and begin the process of collecting evidence and constructing explanations.
2. An enquiring classroom is developed where teachers model an enquiry approach and students are instructed on how to learn for themselves.
3. In an enquiring curriculum the teacher utilizes scientific papers as part of the curriculum materials. This allows for students to understand scientific processes as well as view rich and significant problems.
4. Scientific papers should be translated so reading comprehension is not impeded and students are able to convey the nature of the enquiries and the content of their conclusions.

5. Use of narrative enquiry allowing students to adopt a position of a scientist.
6. Invitations to students to conduct enquires must be provided.

Although the vast majority of K-12 students will be in science classrooms that do not embrace Schwab's characteristics of an enquiry curriculum and stress fact over action, process, or critical thinking, there has been a movement away from regurgitation of facts. Organizations such as American Association for the Advancement of Science (AAAS), the National Research Council (NRC), and the National Science Teachers Association (NSTA) have put forth statements and documents emphasizing the importance of scientific literacy. Inquiry-based science is a central component to the National Science Education Standards and is the cornerstone of current science education reform (American Association for the Advancement of Science [AAAS], 1989; Crawford, 2007; National Research Council [NRC], 1996). Additionally the National Research Council reinforces Dewey's position that science education must reflect the work that scientist do as they state that:

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to 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. (p. 23)

Despite the influential work of John Dewey and Joseph Schwab, few science teachers invite their students to conduct inquiry explorations in the classroom. Welch et al. (1981) determined several reasons for the lack of utilization of teaching science through inquiry.

Among the reasons teachers did not conduct scientific inquiry were (a) confusion about the meaning of inquiry, (b) an allegiance to teaching facts, (c) teachers' feeling inadequately prepared for inquiry-based instruction, (d) inquiry being viewed as difficult to manage, (e) the belief that inquiry instruction only works well with high ability students, and (f) the belief that the purpose of a course is preparing students for the next level of study.

Matson and Parsons (1998) discussed the issue of students' experiences in undergraduate science courses. They pointed out that in their experience many teachers are not prepared to teach science through inquiry methods because they learned science in classrooms that were dominated by teacher-centered activities rather than student-centered activities. Most undergraduate preservice science teachers are exposed to confirmatory lab experiences that are similar to those found in high schools instead of open inquiry (Windschitl, 2002). Thus, an important aspect of training science teachers is to provide them with a strong science content background in conjunction with developing a deep understanding of scientific inquiry through opportunities to conduct scientific inquiries in the classroom. By developing both content and inquiry-based pedagogy, preservice teachers will be more prepared to teach science in a way that promotes science literacy by using teaching methods that encourage conceptually oriented, hands-on/minds-on, problem solving, and critical thinking activities (Matson & Parsons, 1998).

In applying Dewey's philosophy to today's science classrooms, DeBoer (1991) says:

> Dewey believed all instruction should be organized in such a way that it takes account of what the student knows. Prior student experience is restructured in the mind through a process of interacting with the teacher and other students.

> Learning always involves present understanding as a starting point. Insistence on relevance of subject matter to enhance meaningful learning has been part of science education discussions since the late nineteenth century and continues to be a large part of good science teaching today. (p. 223)

Currently, inquiry-based science is a central component to the National Science Education Standards and is the cornerstone of current science education reform (American Association for the Advancement of Science [AAAS], 1989; Crawford, 2007; National Research Council [NRC], 1996, 2000). The standards and reform movement reflects Schwab's and Dewey's contribution to science education as they convey that scientific inquiry places students' questions at the center of experimental design. Schwab would concur that in this learning environment, students are invited to get personally involved in constructing their scientific understandings.

Teacher's Professional Development

Around the world, there is growing recognition that expert teachers and leaders are the key resource for improving student learning and the highest achieving nations make substantial investments in teacher quality (Darling-Hammond, 2010). Research indicates that there is a strong relationship between high-quality professional development (PD) and the kinds of teaching practices that are advocated by instructional reform in science education (Supovitz & Turner, 2000). However, Lowery (1998) discovered that many educators do not see the need to change from a sit-and-get type of instruction to practices that help students comprehend science by constructing meaning for themselves through investigation, collaboration and the use of prior knowledge. Research conducted by

Levitt (2002) supports the fact that many teachers believe that teaching science is primarily accomplished through the dissemination of factual information.

Reform focused only on adding new teaching resources or materials and randomly over viewing the latest instructional fad can result in little or no transfer to effective improvement in practice (Cohen & Hill, 1998). According to Thompson and Zeuli (1999), effective professional development for teacher learning and understanding is to engage teachers in strategies that produce transformative learning – learning that promotes "changes in deeply held beliefs, knowledge, and habits of practice" (p. 342). Research on changing teachers beliefs indicate that change often comes only after teachers use a new practice and see the benefit to their students (Ball & Cohen, 1999).

Inquiry-based PD programs influence in-service teachers as they are immersed in authentic inquiry-based experiences (Loucks-Horsley, Hewson, Love, & Stiles, 1998). The National Science Education Standards *(*NRC, 1996) describe standards for effective PD programs for science teachers. These standards are:

> Professional Development Standard A: Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry. (p. 59)

> Professional Development Standard B: Professional development for teachers of science requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching. (p. 62)

> Professional Development Standard C: Professional development for teachers of science requires building understanding and ability for lifelong learning. (p. 64)
>
> Professional Development Standard D: Professional development programs for teachers of science must be coherent and integrated. (p. 67)

Educators have a professional responsibility to seek these opportunities throughout their careers.

Teachers are critical to enhancing learning in schools. Good teaching is critical to students' understanding and mastery of ideas and practice (Michaels, Shouse, & Schweingruber, 2008). Education reform efforts in the United States cannot succeed without work toward assisting educators to become more effective in their approaches to teaching children. Schwab (1961) states that scientific enquiry "has never before been so urgently required, so visible to the naked, public eye, and understood by so few" (p. 4). Research today continues to bring to light that teachers are not certain how to implement an inquiry approach to teaching. "It is necessary for teachers to be familiar with and utilize inquiry-based practices in their classrooms; however this is not the case in many classrooms around the country" (Weiss, Pasley, Smith, Banilower & Heck, 2003). Many teachers lack familiarity with and are unable to effectively deliver inquiry-based instruction in their classrooms. "Inquiry-based teaching is simply an abstract idea to teachers who never encountered this type of teaching during their own K-16 education and did not learn to teach in this fashion in their education training" (Kazempour, 2009).

For effective curricular efforts to occur and for any curriculum situation to be understood, Schwab (1960/1978a) maintained that there must be interaction of four curriculum commonplaces; a particular subject matter, a group of students, a specific milieu and a teacher. With all of these in place, curriculum, as Craig explains (in press), is

> … what happens- what becomes instantiated – in the moments when teaching and learning fuse. In that fusion, teachers use what is in their students (learner commonplaces), their teaching situations (milieu commonplace) and themselves (teacher commonplace) to make curriculum (typically organized around the subject matter commonplace) in a way that cannot be captured in a codified knowledge base without negating the continuity of experience (Dewey, 1938) fueling the human knowing. (p. 2)

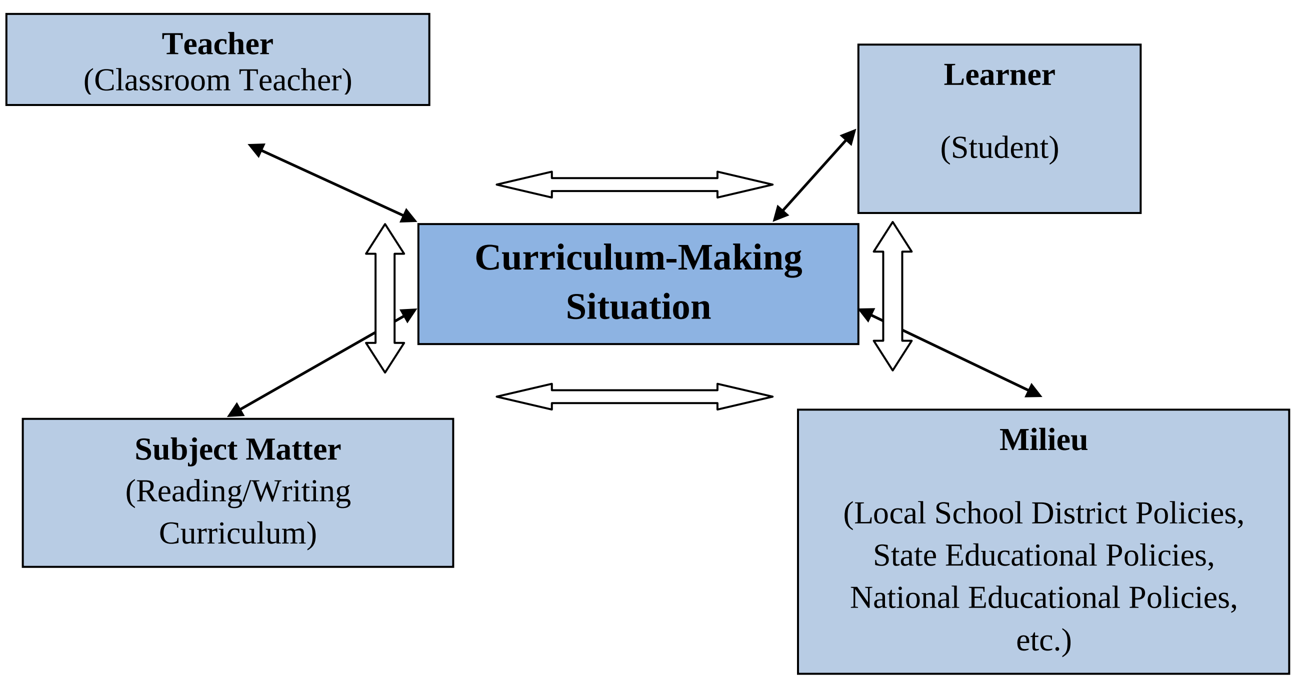

Figure 1. Schwab's Curriculum Commonplaces Craig (in press).

Also, in the case of my research study, the curriculum commonplace becomes reconfigured, placing the teacher in the adult learner (student) position, and myself in the teacher commonplace. While milieu remains quite similar, the subject matter commonplace becomes expanded to not only include science content, but pedagogical strategies and teaching dispositions as well.

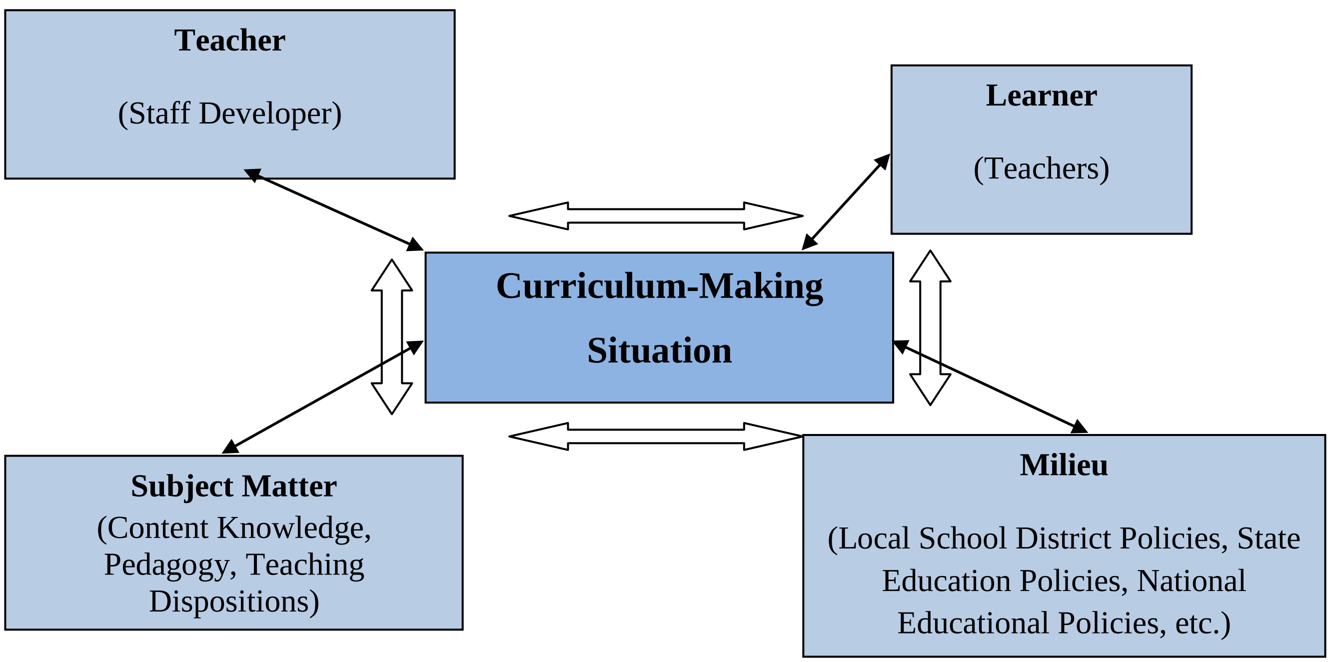

Figure 2. Changes in the Commonplaces of Curriculum Configuration.

In my view, research continues to have an important impact on our schools, particularly when ideas about the ideal are discussed. Eliciting and understanding existing beliefs and abilities held by teachers as they work with students in their classrooms is important to making positive change in education. Because there is still disagreement between educational professionals about what the enactment of inquiry should look like and accomplish in instructional settings (Anderson, 2002, Crawford, 2007; Windschitl, 2003), we must continue to seek ways to better instructional practices because our students need a significantly different preparation for work in a global economy and life in modern society. Inquiry is at the heart of reform because traditional instruction is failing to prepare too many of our students for work and higher education. This is why I have chosen to conduct my research study with in-service teachers, investigating the pedagogical strategies needed to teach science as inquiry.

Chapter Three: Methodology

Introduction

After many years of rigorous experimental research that emphasizes quantitative methods for gaining information to inform educational practice, such studies clearly indicate that we have yet to identify good educational practice and consequently have made very little progress toward actually attaining effective educational practice in this country. Torbert (1981), in his influential work, *Why Educational Research Has Been so Uneducational,* clearly shows that rigorous experimental research simply does not inform the conditions practitioners face.

The No Child Left Behind Act (NCLB), signed into law in 2002, aimed to revolutionize American public education; however, since its inception, educators have been facing an increase in accountability pressures. At the very heart of NCLB is the demand for evidence that the nation's teachers are doing a good job, as well as an equitable one, of educating our youth in the public schools. The primary source of confirming evidence comes from students' scores on high stakes standardized tests. Educators, since the arrival of the No Child Left Behind Act, are now, more than ever, being appraised on the basis of their ability to get students to "sparkle" on high-stakes achievement tests (Popham, 2004). If students test scores rise, teachers are deemed successful. Likewise, if scores fail to rise, teacher are squarely labeled as ineffective, which is a very simplistic, input-output mechanism that does not illuminate the infinitely complex teaching-learning act.

Quantitative analysis of test scores cannot bring to light the intricacies of what is happening in our schools and in teacher-learner relationships. Thus, it is not helpful in formatively guiding educational practice and policy. In order to more clearly understand what is happening in schools, researchers must make use of qualitative methods so as to gain a more nuanced understanding of various aspects of education, and of the people whose behavior policies are designed to affect. Qualitative research uses a naturalistic approach that seeks to understand phenomena in context-specific settings. Through better understanding of the experiences, circumstances, motivations and diversity of people, researchers can inform efforts to improve the focus and fit of programs aimed at making positive improvement in educational practice.

This inquiry uses the ideology and structures of narrative inquiry in order to elucidate the research puzzles of this study: exploring the effectiveness of inquiry-based professional development on science teachers' beliefs and classroom practices of inquiry-based science instruction. From Schwab (1958) to the AAAS (1989) and the NRC (1996), inquiry has been promoted as central to the teaching and learning of science. The National Science Education Standards (NSES, 1996, 2000) specifically advocate for instructional reform that supports K-12 students in developing the abilities necessary to do scientific inquiry. If inquiry is the central tenet to good science teaching (NSES) and is understood by so few Crawford (2007), Jorgenson and Vanosdall (2002), Keys and Bryan (2001) and Windschitl (2003) it is beneficial to delve into teachers lives and experiences in an attempt to understand the gap between the recommendations of theory and actual practice. This study aims to illuminate how teachers' perspectives and abilities on teaching science as inquiry shift as they participate in a comprehensive professional development program which aims to improve content and science pedagogical understandings of those that participate. Here, in Chapter Three, I describe the research approach, justifying the choice of methodology; the context of the research; and procedures and tools used to collect and analyze data from a variety of resources.

Narrative Inquiry

Clandinin and Connelly (2000) describe the characteristics of narrative inquiry as "a way of understanding experience" (p. 20). This process differs from other forms of inquiry as it involves, "a collaboration between the researcher and the participant, over time, in a place or series of places, and in social interactions with milieus" (p. 20). Elbaz (1991) anchors the role of story in describing teachers' knowledge.

> Story is the very stuff of teaching, the landscape within which we live as teachers and researchers, and within which the work of teachers can be seen as making sense. This is not merely a claim about aesthetic or emotional sense of fit of the notion of story with our intuitive understanding of teaching, but an epistemological claim that teachers' knowledge in its own terms is ordered by story and can best be understood that way. (p. 3)

Narrative has been recognized as a way of uncovering aspects of one's own construction of knowledge (Lyons & LaBoskey, 2002). Connelly and Clandinin (1990) state "humans are story telling organisms who, individually and socially, lead storied lives. Thus, the study of narrative is the study of the ways humans experience the world" (p. 2). In this inquiry I will tell and re-tell stories that signify and convey the individualist nature of the teacher participants. These narratives will serve to describe the experiences of the individuals, which in turn, will inform the structure of understanding science, that is, how the participants perceive the reality of enacting science instruction in their professional lives. This construction of knowledge can be tied to Connelly and Clandinin's (1988) term, "personal practical knowledge." This knowledge is developed within an individual as they make sense of a present situation, allowing past experiences to work toward a solution for a future goal. Personal practical knowledge is the moral, affective and aesthetic way of knowing life's educational situations (Clandinin & Connelly, 1988).

Context of Inquiry (Setting)

The teachers in this study are all participants in a professional learning plan developed and funded through a Texas Teacher Quality Grant. This professional learning plan, meant for teachers in rural school districts found on the boundaries of Houston, TX, incorporates what research has identified as effective practice for adult learning in that the professional development will be sustained and on-going. According to the plan, these rural teachers will participate in a three credit hour graduate level course on science education occurring in Summer 2010, which will be followed with sixty hours of additional professional development in the 2010-2011 academic year.

Teachers working at high need schools as identified by the Texas Education Agencies Academic Excellence Indicator System (AEIS) will be targeted for participation in this professional development. According to the state, high need campuses are identified by meeting any one of the following criteria:

- Is located in an area in which the percentage of students from families with incomes below the poverty line is 30 percent or more;
- Is located in an area with a high percentage of out-of-field teachers, as defined in section 2102 of ESEA;
- Is within the top quartile of elementary schools and secondary schools statewide, as ranked by the number of unfilled, available teacher positions at the schools;
- Is located in an area in which there is a high teacher turnover rate; or
- Is located in an area in which there are a high percentage of teachers who are not certified or licensed.

Participants teaching in high need schools have significant challenges to overcome and consequently need even more sophisticated abilities to teach students who have fewer educational resources at home, those who are new English language learners, and those who have learning difficulties. Clearly the goals of this professional learning plan aim to develop and support teachers, those teaching in challenging environments, to teach in more powerful ways.

In an effort to ensure this program is pertinent to participant's needs, teachers were asked to complete an application, after attending an informational meeting where the goals and objectives of the learning plan were sketched, and invited to participate in the year-long, comprehensive, science professional development. Multiple measures were used to select teachers to participate in the professional development program, including establishing content need, in part, by reviewing teachers' undergraduate transcripts. Teachers with less than six hours of undergraduate course work in physics were deemed deficient in physics content knowledge and thus were given strong consideration to participate. Participants were also administered a physics pre-assessment to help further determine content deficiency. Additionally, applicants completed a brief questionnaire which allowed them to articulate why they should be considered to participate in the professional development program. Teachers expressing a strong desire to improve their pedagogy were given priority in the selection process.

The summer graduate course was taught by the researcher (me) and a co-instructor, Paige Evans, a fellow Executive Ed.D. - seeking student (now Dr. Paige Evans), and was designed to build physics content knowledge and to teach research-based, effective pedagogical approaches to teaching science. The content focus was on physics principles including properties of matter, heat, and temperature and instruction was delivered through an inquiry-based approach utilizing the 5- E Instructional Model (see Figure 3).

Phase	Summary
Engagement	The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
Exploration	Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.
Explanation	The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
Evaluation	The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

Figure 3. Summary of the BSCS 5E Instructional Model.

Throughout the summer professional development, teachers were engaged in a variety of inquiry-oriented physics activities that address the identified content as well as reflective and collaborative discussions where they were provided with opportunities to experience and make sense of physics in the role of a learner.

Monthly professional development will continue into the 2011 academic year and will continue to build on the content established during the summer professional development focusing primarily on physics with integration of chemistry. Productive science pedagogy will continue to be a primary focus. Teachers will continue to collaborate via a blog and will utilize the Northwest Regional Lab to share instructional plans and effective classroom learning tools.

Because motivation affects the amount of time that people are willing to devote to learning (Bransford, Brown & Cocking, 1999) it is imperative that the principles of adult motivation are addressed in the professional learning program. Adult learners are motivated to learn by a variety of factors including cognitive interest, personal advancement, external expectations, social welfare, social relationships and utility of learning (Loucks-Horsley, Love, Stiles & Mundry, 2003). These principles of motivation are extremely important to ensure that teachers' are engaged participants, and as such, have the best opportunity to learn new content and science pedagogy. To establish cognitive interest and social welfare, teachers will be recruited via a brief introductory meeting where the current state of science education, including less-than-stunning statistics of American students' performance on international assessments in science, despite the huge U.S. investment in education (particularly the sciences), will be shared. Teacher participants will receive advancement by receiving instructional resources, stipends for attendance, graduate school tuition, and meals at all meetings. This professional development program will enable teachers to develop high quality instructional plans; those that promote greater levels of understanding and involvement that will be immediately applicable in their own classrooms and thus experience the utility of this program. The social component of motivation will be addressed as teachers participate in a science learning community where there will be many opportunities for face-to-face interaction, collaborative learning, discussing and solving problems. Additionally, the South Texas TQ Science blog will be used to further facilitate participant reflection and collaboration. As Darling-Hammond and McLaughlin (1999) note, "As recent research has argued, the possibilities for individual teacher learning increase greatly as professional communities move from individualistic or 'balkanized' cultures to 'collaborative' cultures, and towards what can be described as 'learning communities'" (p. 380).

Participants

Upper elementary school teachers' (grade 5) who teach self-contained science, middle school and/or junior high school science teachers, and high school science teachers participate in the Teacher Quality Grant initiative. Since the goal of the targeted rural school districts and the proposed Teacher Quality Grant proposal is, in part, to increase teachers' content knowledge in physics through sustained science content development as well as to improve classroom instruction, the current initiative necessarily focuses upon physics content development and improvement in science pedagogy.

The principals and central office administrators of the targeted rural schools and districts have encouraged all science teachers to participate in the professional development program meant for 25 carefully selected participation. When funding notification was received, the school district was immediately notified. A letter was sent to each school district's superintendent and distributed to science teachers. The registration form was sent with the notification letter, which applicants completed and returned in order to participate.

The selection committee for the Professional Development program includes the Project Directors, the Assistant Superintendent for Curriculum and Instruction from one of the rural school districts and the science master teachers. Teacher applications, content pre-tests, and undergraduate transcripts were reviewed by the committee. The available slots were first allocated to Wharton ISD. Bay City ISD was also asked to identify high need teachers, based upon certification, or lack thereof, and classroom instructional practice, as was Rice ISD, and Louise ISD, all rural high need school districts. Administrators from Westbury Christian School and Saint Michaels Catholic School were also sent the letter of notification of the Science Professional Development and teachers who meet the criteria of not being highly effective and or qualified as per NCLB were invited to participate. Selection remained open until twenty-five teachers had been accepted and confirmed their intent to participate. Participants were asked to submit a letter of commitment. The criteria for the selection rubric was the willingness to attend the summer graduate course, to attend 70 percent of all the professional development sessions offered during the academic year, to agree to be observed teaching in their classrooms, to develop innovative science lesson plans, to actively participate in the on-line blog, and to be an active member of the South Texas Science learning community (see Figure 4).

Selection of Teacher Quality Grant Participants Rubric			
Evidence of Need	**Low (0 points)**	**Moderate (1 pt)**	**High (2 pts)**
Schools AEIS Ranking			
Undergraduate Transcripts			
Pre-Assessment			
Application			
Letter of Commitment			

Figure 4. Selection of Participants Rubric.

Purposeful sampling of participants will be used for this study, for as Miles and Huberman (1994) said, “You cannot study everyone everywhere doing everything” (p. 27). In typical qualitative studies, a researcher employs purposeful selection of participants in order to find individuals that will best help the researcher understand his or her research problem (Creswell, 2003; Glesne, 1999). In order to narrow my focus to two-three teacher participants, I will collect and analyze all teachers' journals and documents, and conduct an initial interview of each teacher to help determine the two or three most suitable participants for this study.

My Role as Researcher and Participant

My role in this inquiry is as a researcher and instructor in the graduate science course (C&I 6300) taught in the summer of 2010 and during the professional development offered during the 2010-2011 academic year. All students in the class will be expected to participate in all of the course requirements including the inquiry activities as part of their course work however; participation in the study will not affect the participants' grades.

Being a human instrument requires that my role and bias be addressed. Recognition of bias demonstrates the researcher is aware of beliefs that might influence analysis of data and keeps the resulting narrative open and honest (Creswell, 1998). As Glesne (1999) stated, "every time you decide to omit a data bit as unworthy or locate it somewhere, you are making a judgment" (p. 134). Because judgments are dependent upon the researcher one must be aware that this may influence how data is analyzed and interpreted. The researcher must understand his or her own biases when interpreting the data (Bogdan & Biklen, 2003).

It's important to note that I will be working collaboratively with researcher, Paige Evans. Mrs. Evans and I are co-instructors of the graduate course as well as the professional development sessions. In the analysis of the data from this study, efforts will be made to frame the stories within common influence categories while maintaining the individuality of each participant's experience. As the organizers of the teachers' narratives, Mrs. Evans and I will have to make choices about what material is presented; however, work will be taken back to participants for response in order to create narratives reflective of the teacher's experiences and not ones solely supported by mine or Mrs. Evans particular views of science education. Inconsistencies and contradictions may occur in the narratives of teachers as they do in all human stories as circumstances shift and narratives are told and re-told, lived and re-lived.

Procedures and Tools – Data Collection

For this inquiry, I will utilize a variety of narrative resources which will portray the thoughts, feelings, emotions and realities of the individual participants in the professional development program. Personal practical knowledge is the moral, affective and aesthetic way of knowing life's educational situations (Connelly & Clandinin, 1988). Keeping this in mind, an integral part of this study will be to explore the experiences, as storied and restoried by the individuals who lived them, and will be illuminated through journal writing, conversations, interviews, observations, and documents (see Figure 5).

Type of Sampling	**Setting**
Journal writing	Graduate course, professional development
Conversations	Classrooms, courses, blogs, e-mail
Interviews	Designated meeting rooms on campuses
Observations	Teachers classrooms
Instructional Plans	Graduate course, professional development

Figure 5. Sources of Data to Analyze.

Multiple sources provide the opportunity for triangulation and the possibility for each set of data to confirm, deny of corroborate the other sets (LeCompte & Schensul, 1999). Further, triangulation means each research questions will be answered by more than one data source (see Figure 6).

Triangulation of Data		
Tools used for data collection	**Number of Participants**	**Frequency of Collection (for each participant)**
Journal entries	2-4	10-15
Interviews	2-4	5
Observations	2-4	5-10
Instructional plans	2-4	3-5
Conversations	2-4	On-going

Figure 6. Triangulation of Data.

Interviews

Personal interviews and personal communications will provide the opportunity to gather data from the participants about their opinions, beliefs and feelings in their own words. Open-ended interviewing will provide access to the context of behavior and allow me to understand the meaning of behavior (Seidman, 1991). Conducting interviews will help me understand the experience of participants and the meanings they construct from that experience. Because this study involves understanding participants' descriptions of their experiences and their understandings and abilities of inquiry, personal interviews will be a valuable source of data.

In conducting interviews, I will follow an approach described by Siedman (1998) that uses open-ended questions. Seidman's approach requires a researcher to first obtain the interviewee's focused life history to provide the context for the experiences in the study. Next the researcher should attempt to bring forth details of the participants' experiences. And finally the participant should be encouraged to reflect on the meanings emerging from those experiences. Further Siedman (1998) posits that there is no "recipe for the effective question" (p.77). He states:

> The truly effective questions flows from an interviewer's concentrated listening, engaged interest in what is being said, and purpose in moving forward…. Effective questioning is so context-bound, such a reflection of the relationship that has developed between the interviewer and the participant, that to define it further runs the risk of making a human process mechanical. (p. 77-78)

The following strategies for interviewing are proposed by Siedman (1998) and will be utilized during the interview process:

- Ask questions when you don’t understand.
- Trust your instincts and follow your hunches.
- Explore the participant’s experience, but beware of inserting the interviewer’s agenda.
- Avoid leading questions.
- Ask open-ended questions.
- Follow up, but do not interrupt.
- Ask participants to talk as if they were someone else or respond to you as if you were someone else.
- Ask them to tell a story.
- Ask them to reconstruct rather than to remember.
- Do not take the ebb and flow of the interview too seriously.
- Rarely share your own experiences.
- Avoid reinforcing responses, either positively or negatively.
- Explore laughter; it may reflect nervousness or be indicative of something else going on.
- Tolerate silence.

Individual Journals

Journals are a powerful way for individuals to give accounts of their experience (Clandinin & Connelly, 2000) and are another source of teacher stories. Gess-Newsome (2002) found journaling was an effective tool in explicitly teaching scientific inquiry; therefore, it will be used in this study to make participants’ aware of their learning experiences and help me understand participants' experiences with inquiry. As part of the curriculum enactment process, teachers will be asked to make record of their learning experiences in their personal journals. Three elements of the reflection process, returning to the experience, attending feelings, and re-evaluating the experience, are guidelines to be used to create reflective questions for participants (Boud et al., 1985). Periodically teachers will be given prompts around which to construct a response. Additionally teachers will be given opportunities to freely respond in their journals making reference to anything they have learned about themselves as teachers, pedagogy, content and/or beliefs surrounding their professional practice. Journals will provide teachers with opportunities to record and reflect on their own experiences, creating a forum through which they could restory, thus broadening and burrowing into their personal practical knowledge gleaned from their experiences.

Participant Observations and Field Notes

Participants will be observed as part of an on-going process through the duration of this study. Observations will consist of visiting teachers in their classrooms and experiencing the lives' of the participants as much as possible. Teachers, on the onset of the study, will be made aware of the need to visit their classrooms; however, entry will occur slowly so as to build rapport with each teacher.

In this study I will use field notes as a recording tool (Glesne, 1999). Information collected during observations will be focused on elements of the physical setting, ascertaining the materials, space and equipment available to teachers to conduct science, as well as the pedagogical approaches used by teachers. Descriptive field notes, recording a description of the events, activities and people, as well as reflective field notes, recording my personal thoughts, insights, hunches, or ideas that emerge during the observation, will be utilized. These field notes are a written account of what the researcher experiences, observes, and thinks as he or she collects data in the study (Bogdan & Biklen, 2003).

Jotted notes also will be utilized to keep track of observations. Notes will be in the form of key words or phrases written down at the time of the observation to help remember a description or thought when the notes were written (Glesne, 1999). Jotted notes will allow me to walk around during activities, interact with students, and make thorough observations without being distracted by keeping detailed notes. Immediately after the observation, I will expand the field notes with as much detail as can be remembered, using the jotted notes as a reference.

Documents

Valuable sources of information will be obtained through documents utilized during the implementation of this inquiry. Relevant to this inquiry will be teaching documents in the form of science instructional plans developed by each teacher. Teachers will be asked to develop science lesson plans that they intend to utilize in their classrooms with their students. These instructional plans will reflect teachers' intended pedagogical approach to delivering instruction. Teachers will submit written reflections directly related to the planning and implementation of inquiry-based lessons along with teacher-chosen video clips of their own inquiry-based teaching. Additional documents used in this inquiry will be a pre- and post-course survey where teachers will reflect on their beliefs and opinions regarding teaching science as inquiry.

Data Analysis

Narrative inquiry is a form of empirical investigations where the stories, themselves, are a means of conducting research and a form of research interpretation (Connelly & Clandinin, 1990). Humans, individually and socially, lead storied lives. People shape their daily lives by the stories of who they and others are and they interpret their past in terms of their stories. Story is a gateway through which a person enters the world and by which their experience of the world is interpreted and made personally meaningful.

Through close affiliation with the participants in the professional learning plan, data in the form of storied artifacts, as previously described in this chapter, will be generated. Connelly and Clandinin (1990) say of stories and people, "People by nature lead storied lives and tell stories of those lives, whereas narrative researchers describe such lives, collect and tell stories of them and write narratives of experience." It is through learning from each other that the researcher and participant can begin to understand specific experiences within the context of stories told and retold by teachers. Consequently, I will use the artifacts detailed in this study including interview transcripts, journals, observation and field notes, and other documents to generate field texts which will illuminate the narratively constructed experiences of teachers in the professional learning plan. Thus while I have a broad sense of the narrative horizons I will examine, I will utilize the story constellations approach, a fluid form of inquiry, and consequently the events of teachers lives will unfurl naturally.

Once field texts have been gathered three interpretive devices, broadening, burrowing and restorying, will be employed to create the research story for this inquiry. The stories of practice will be collaboratively storied back and forth between the teachers and me, the researcher, and understandings of the lived experiences will emerge through continual conversations and written narratives. Together, the teachers and I, through ongoing dialogue, both oral and written, will story and restory their practices. New recollections will change the story over time and the new story will be lived out in practice—providing no other revisions are made to it in the meantime. The teachers' in this study, through collaborative story telling about their practice, explore the reality that lies within.

Participant's journal entries, interview transcripts and the notes from classroom observations will be used as sources for understanding changes in beliefs and attitudes toward science instruction as well as changes in understanding scientific inquiry. Craig (2007) describes broadening as a process which, "sets up the general context within which school reform events take shape and helps to paint the temporal and social/contextual horizons within which the fine-grained accounts of teachers' knowledge begin to take on meaning" (p.180). Teachers' life stories, as illuminated through these narrative tools, will be analyzed to determine the influences and complexities of the teachers' professional knowledge landscapes.

Burrowing (Connelly & Clandinin, 1990) is the reconstructing of events from the point of view of the central participants involved in the research study. After emergent themes are identified, three participants will be selected and their stories will continue to be collected and further analyzed resulting in more narrowed themes rising that tell the point of view of the person at this point and time. Thus the process of writing the inquiry and the process of living the inquiry are coincident activities tending to shift one way or the other yet always working in tandem.

Some teachers choose to live out their teaching lives behind closed doors with the children. Their stories of what education is to them may only be told in "safe places" because they may conflict with the stories mandated by others. Teachers may hide their stories of teaching because they fear reprisal or loss of prestige from those positioned above. Accordingly and to ensure confidentiality, participant's identities in this inquiry remained confidential and anonymous by using pseudonyms for every given name and fake names for the schools in which the teachers worked as well.

Summary

This chapter detailed the methods and procedures used to illuminate the stories told and retold as science teachers, participants in a year-long professional learning program, make sense of their professional development experiences and confront the barriers of implementing science as inquiry in their classrooms and with their students. The narrative inquiry methodology has been described in which data, collected through interviews, journals, observations and documents, is thick in description and through which analysis will, in Chapter 4, elicit themes and assertions which address the research puzzles of this study.

Chapter Four: Teachers' Constructions of Inquiry

Introduction

The analyses of my research study on in-service teachers' experiences with scientific inquiry are presented in this chapter. Two teachers, Linda and Janet, participated in an inquiry professional development program including a summer graduate course funded through a Texas Teacher Quality Grant and a full year of academic workshops. The main goal of the graduate course and professional development was to assist teachers in growing their conceptions and enactments of inquiry-based practices in their classrooms. This study was guided by my curiosities around how science teachers' attitudes and teaching abilities change when taught science content through an inquiry-based approach.

The study's participants experienced learning and teaching science as inquiry as described in Chapter Three. Using the field texts outlined in Chapter Three, I now analyze Linda's and Janet's journey through their yearlong inquiry experience by telling and retelling their stories in their own terms—with my reflections woven throughout.

Inquiry Modeled in the Summer Institute

The summer course immersed participants in developing their understanding of physics principles. In the morning sessions teachers participated in inquiry investigations which emphasized learner-directed inquiry that could be performed with or without a laboratory. Teachers worked together in small groups where they explored the principles under development. The instructors of this course, colleague Paige Evans and I, modeled the process of teaching science as inquiry. Participants engaged in the process of developing their conceptual understandings of physics driven by their own questions, procedures, and analysis. Furthermore, the activities stressed the importance of supporting interpretations with data as opposed to simply answering questions frequently found at the end of traditional, cookbook lab activities. Nightly reading assignments from the book *Inquire Within* by Douglas Llewellyn (2002) as well as other inquiry articles reinforced the goals of the summer course.

Inquiry Modeled in Academic Year Workshops

The teachers were invited to participate in eight academic year workshops and were provided a small stipend for attendance. During the workshops teachers engaged in a variety of inquiry-based activities where they continued to develop and refine their understanding of learning and teaching utilizing an inquiry approach. Activities focused on teachers forming testable questions, collecting and analyzing data, and using evidence to support and communicate their conclusions. Additionally teachers created inquiry-based lesson plans to use in their classrooms. These lesson plans were evaluated using the Essential Features of Inquiry rubric found in the book *Inquire Within* (Llewellyn, 2002). Lessons aligning with the essential features would have students taking responsibility for developing scientifically oriented questions, giving priority to evidence, formulating explanations from evidence, connecting explanations to scientific knowledge and justifying their explanations. Collaboratively the teachers determined the extent to which the lessons contained the baseline essential features of inquiry and discussed how the lessons could be improved and used in their classrooms.

The Case of Linda

Demographic Information

Linda, a non-Hispanic White female, was in her sixth year of teaching during the 2010-2011 school year. Linda had a degree in Archaeology and completed an alternative certification program (ACP) to earn her teacher certification. As opposed to an undergraduate teacher preparation program which includes opportunities for student teaching and mentorship by an in-service teacher, Linda reported that her ACP did very little to develop her skills and abilities to be an effective teacher. She did not recall receiving any instruction on effective pedagogy in her program, rather she felt she was left entirely on her own to determine how to best instruct her students. Linda felt that she has had to work very hard to learn effective instructional approaches to teaching science through attending professional development workshops and seminars, by collaborating with her colleagues and by reading relevant trade books and research.

Linda's belief that she had been ill-prepared to teach science which spurred her to seek out best practices in science education is reminiscent of my own early years as a teacher. As I indicated in Chapter One, I spent many years seeking to better understand effective pedagogy – specifically inquiry-based instruction to teach science. Though Linda and I participated in vastly different teacher preparation programs, we coincidentally both felt unprepared to teach students and consequently spent a great deal of time exploring and making meaning of instructional practices.

Linda is currently teaching eighth grade science but also has experience teaching seventh grade science and has taught seventh grade remedial math where she instructed more than 130 students who had failed the math section of the Texas Assessment of Knowledge and Skills (TAKS) the previous year. Linda expressed her view that math was more difficult to teach than science primarily because of the immense pressure of preparing all students to be successful on the math section of the TAKS test. As mentioned previously, The No Child Left Behind Act (NCLB), aimed to transform American public education; however, since its commencement, educators have been facing a swell in accountability pressures. At the very core of NCLB is the demand for confirming evidence that teachers are doing an excellent job of educating our youth. The chief data source is students' scores on high stakes standardized tests mandated by the state. Linda was keenly aware of the judgments placed upon her based solely on her ability to get her students to "shine" on high-stakes examinations. She disclosed that she was specifically selected by her campus administrators to move from teaching seventh grade remedial mathematics to teaching eighth grade science because she had been judged effective at getting many of her seventh grade students to pass the math section of the TAKS test. At the same time Linda was proving successful in seventh grade mathematics, her junior high school accountability rating became jeopardized due to poor performance by eighth grade students on the science portion of the TAKS exam. As a result, Linda was selected specifically to teach eighth grade science for the singular purpose of increasing the number of students passing the science section of the middle school TAKS test. On the section of the application to participate in the inquiry professional development program, teachers were asked to describe why they should be selected to participate. Linda shared her feelings about this experience:

> I felt proud that my administrators had confidence in my teaching abilities, but I felt tremendously burdened by the pressure of getting the majority of my students to be successful on the state science assessment. I knew that this was the ultimate goal of my administrators and there was a small part of me that felt like it was one of the most significant accomplishments I could achieve with my students. But as the reality of preparing the students to be successful on the science TAKS turned into worksheets, vocabulary and memorizing facts about science, I quickly found myself wondering if science is more than preparing for a test. I want to prepare my students to learn and understand science and enjoy it. I want to learn how to make science meaningful for my students. I don't want them to think science is just success on a test.

Linda has clearly experienced teaching the way so many teachers teach science – rotely and didactically – but she believed there was more to teaching science and she expressed real desire to learn how to teach science more effectively.

Linda has always taught in rural school districts. She currently is teaching at the only junior high school in her system. This small district also has three elementary schools, two intermediate schools, and one high school. The demographics of the junior high school where Linda teaches are found in figure 7.

Linda's School Demographics			
Grades	Students per grade	Enrollment and Staffing	Student Demographics
7-8	7th grade - 309 8th grade - 314	Total Teachers 52	White 236 Black 106 American Indian 2 Asian 8 Hispanic 271

Figure 7: Linda's School Demographics.

At the beginning of the summer course this projects first inquiry was explored: "Do teachers who attend and participate in comprehensive professional development which is delivered in an inquiry format, change their attitudes and dispositions of teaching science as inquiry?"

Initial Beliefs

Linda's early conceptions of inquiry are evident in the inquiry-based instructional survey that was administered prior to the summer course. Linda, when asked what she considered to be the key elements of inquiry-based instruction responded with, "Presenting students with opportunities to do hands-on experiments." Linda enters the inquiry professional development program with the sincere belief that inquiry-based science equates to students being immersed in laboratory experiences. As discussed in Chapter Two, inquiry, as defined by AAAS and NSES, encompasses much more than providing students with the opportunity to do hands-on science. In authentic inquiry situations students must generate their own questions, develop procedures to solve problems, use tools to gather, analyze and interpret data, and propose answers and explanations based on this evidence. Many teachers present science activities as highly structured experiences for students and Linda's early conceptions of science as inquiry seem to emanate around simply putting out the equipment for students to utilize as they followed "cookbook" style lessons.

Furthermore, Linda's response on the inquiry pre-assessment indicated that she disagreed with the statement that inquiry-based instruction represents best practices in secondary science instruction and commented that, "Many students lack the prior knowledge or practical experience that is needed to tackle problem solving." Interestingly, Linda's response gives critical insight into her belief that teaching science as inquiry is not feasible because many students are not prepared to learn science in this venue. Linda's initial idea is in opposition to the recommendations put forth by both the NRC (1996) and the AAAS (1993) who propose that learning through inquiry is applicable to all students regardless of age, gender, academic ability, interest or aspiration. The NRC (1996) states that, "The ability to think creatively and critically is not solely for the high-achieving student. Inquiry-based instruction can and should be taught equitably at all levels" (p. 221).

Additionally when asked on the pre-assessment of inquiry if inquiry-based learning is a distraction in secondary science classrooms and does not contribute to learning, Linda responded that she disagreed - leaving the choice of strongly disagree not chosen. Although Linda states she disagrees with the statement that teaching science as inquiry is not a distraction in how science is taught, she is not deeply convicted of her assertion.

Early ideas of how Linda planned to conduct inquiry-based learning in her classroom according to the pre-assessment of inquiry survey revealed that she planned to do 2-3 labs weekly and have students work in cooperative groups. While Linda's early ideas of implementing inquiry-based instruction lack detail and specificity, it is note-worthy that she intends to provide multiple lab opportunities for her students each week. Embedded in this response is the belief that students must be active participants in learning science. Also nestled in this response, I find Linda to view herself in the role of teacher-as-curriculum-implementer. As the implementer of curriculum, Linda is left to the dictates of what the state curriculum would direct.

Transitioning Beliefs

The two-week summer course was designed with the intent to allow in-service teachers an opportunity to experience learning science content through an inquiry-based approach as well as to develop an understanding of ways they could shift their instruction in their own classes from teacher-directed instruction toward student-centered instruction incorporating strategies for teaching science as inquiry. The course consisted of two sessions each day: a 4-hour morning inquiry workshop where teachers experienced learning new science content, in this case physics, through a carefully crafted inquiry-based approach and an afternoon session where teachers were provided the opportunity to make sense of their learning experiences through collaborative discussions, reflection on their experiences and emerging understandings of teaching science as inquiry, and work toward applying their new understandings by developing lesson plans which were infused with inquiry for use with the students they teach.

Teachers in the summer session quickly found themselves immersed in building their understanding of physics topics around which many people hold misconceptions – specifically the similarities, differences and relationships among mass, volume and density. Situated as a student in this environment, Linda experienced learning physics principles through an inquiry-based approach.

Linda's journal entry recorded at the end of the first day of the summer class reveals an early, yet substantial, restorying in understanding the importance of empowering students. Linda writes, "No formal introduction was made for the material we learned today. We simply dove right in. There was a natural discovery process involved and what influenced me the most was making the discoveries myself." This entry reveals the discrepancies that Linda experienced in two critical areas. First, Linda is surprised that there is no formal introduction to the material she was taught. Expecting that instruction begins by first presenting everything known on the topic, Linda discloses her belief that the role of the teacher is one of an information provider who views students as passive learners - those who come to the classroom to know and master a fixed body of information determined by the state. But the second part of her reflection yields a powerful, personal revelation. Linda's exclamation that making the discovery herself had the greatest influence on her has opened the door to the realization that perhaps there is a new and possibly better way to construct understanding.

Further into the summer inquiry course, Linda reflects on her learning and contemplates how her new understandings apply to her as a teacher. In her journal she writes, "The first activity we did today was a rather clever method for introducing mass and conversions. The assignment could be simplified but most importantly I must remember - DO NOT help. Make them figure it out." This powerful statement shows how Linda's experiences as a learner of physics are being considered for application to her instructional practice. She is noticeably undergoing a change in belief as she expresses that students must be allowed some freedom to learn, even to struggle to learn, without her direct involvement. Readers will recall from Chapter Two that the focus in an inquiry classroom is on what learners are doing, not on what the teacher is doing. Learners should be doing the intellectual work of making sense of the data and creating scientific explanations. Linda's reflection indicates that she is beginning to entertain the idea of learning as a constructivist activity where students are afforded the opportunity to construct their knowledge.

Many conversations were exchanged during the summer course allowing continual insight into Linda's evolving understanding about teaching science as inquiry. After an engaging morning session which began with a discrepant event (a mind-engaging activity where students observe unexpected results that are contradictory to their normal experience or anticipation) regarding heat and temperature, Linda and I had the opportunity to personally discuss the impact of the learning experience. During this conversation Linda shared with me that the discrepant event had left her wondering if all authentic inquiry must begin with a student noticing something new or surprising. Sensing that Linda was on the verge of enhancing her understanding, although desperately wanting to respond to her with my absolute affirmation, I reflected the question back to her asking her why she felt like noticing something new or surprising was important in learning. Linda zealously responded:

> It just seems like it's the beginning of the whole inquiry process. It seems like a very circular process. The teacher poses a question or problem, and the students question their own knowledge and experiences and can then develop ways to arrive at an answer. The teacher's role should not be to deliver information; the

> teacher's role should be as a coach or facilitator, as a guide ensuring that the students are on the right track and helping them make adjustments in their thinking if it appears that they are following a misconception. It just seems so logical that students get hooked into really having questions if they notice something that perplexes them.

Linda's immersion into the role of a student in the discrepant event had unmistakably led her to an insightful understanding about the importance of developmental questions which lead students to be invested in their learning.

It is interesting to note in this exchange that Linda expresses the importance of the teacher generating questions which students can then become interested in answering. At the heart of inquiry-based instruction it is ultimately the student's questions which drive the investigation. According to the Exploratorium, inquiry is an approach to learning that involves a process of exploring the natural or material world that leads to asking questions. The inquiry process is driven by one's own curiosity, wonder, interest, or passion to understand. While Linda has certainly experienced a deeper understanding of teaching science as inquiry through the realization of the important role of driving questions, I find myself wondering if she may be holding on to some of her instructional beliefs, those rooted in tradition, because in her way of thinking it is ultimately the teacher, not the students, who generate the questions.

Late in the summer course Linda has the opportunity to share with the class her plans to enact inquiry-based instruction with her students through the development of a science lesson plan. As Linda prepares to disclose the critical attributes of her lesson she purposefully prefaces her presentation by explaining that the primary goals for her students, those that drive the lesson plan, include developing her students' abilities to be curious, imaginative, innovative, skeptical, persistent, patient, and diligent. It is plainly evident that Linda has restoried her beliefs regarding the goals for her students' science education. Prior to the inquiry professional development Linda was very concerned about her students' success on the state's high stakes examination. Her focus has indeed shifted and she is inherently concerned about providing opportunities for her students to develop the critical skills and dispositions necessary to solve complex problems.

At the conclusion of the summer course Linda's final reflection illuminates the powerful impact the inquiry course has had on her beliefs about teaching science as inquiry. Readers will note that Linda's traditional beliefs about teaching have shifted toward a more constructivist approach. Linda writes:

> I have never studied a topic the way I've approached learning physics through inquiry but it has allowed me to gain a deeper understanding of the material. I'm accustomed to learning via lecture and independent practice. I teach my students the same way. Now I have to wonder if this method I've always used results in true understanding. The obvious conclusion is that it does not. Looking ahead I feel energized about how I'm going to apply inquiry in my classroom. It will have to be a gradual process, but my students, once they feel confident working together and knowing that mistakes are part of the process, will likely embrace the process and ultimately become better thinkers.

Indeed, there are strong indicators within this statement which illustrate that Linda has engaged with the material from the inquiry course, and has restoried her teaching beliefs to come more in line with a constructivist pedagogical approach to learning and teaching.

Utilizing Piaget's constructivist theory of learning, Linda's journey through the inquiry-based summer course afforded her the opportunity to experience disequilibrium with regard to her beliefs about how people learn as well as her beliefs surrounding effective pedagogy. Linda is beginning to make sense of this newly learned information and her existing traditional schema of teaching is being restructured with a more constructivist approach to pedagogy.

A major change in Linda's conception of teaching science as inquiry is evident in the responses given on the post inquiry assessment which was administered at the end of the summer course. Readers will recall that on the pre-inquiry assessment when asked the key elements of inquiry, Linda's response indicated that the teacher is "responsible to present problems for students to study." In the post-inquiry assessment, Linda now indicates that the key element of inquiry-based instruction is, "…prompting the students to pose their own questions. Students naturally will build their understanding of topics utilizing their experiences and knowledge and this will help shape what they learn." Further she expresses that, "Inquiry-based instruction, I now see, is critical to developing independent, confident thinkers." Linda has clearly re-structured her initial conceptions of how people learn and her new beliefs have transitioned from a teacher-directed form of instruction to a much more student-centered form, which aligns much more directly with an inquiry-based approach to teaching.

Transitioning into Practice

At the onset of the 2011-2012 academic year this projects second inquiry was explored - specifically how did the teachers' conceptions of inquiry, which were built in the summer course, translate into teaching science as inquiry to the students they taught in their own classrooms.

After the first month of school, teachers participating in the inquiry program gathered for the first after school professional development. Energy was high as the teachers reconnected as friends and colleagues. Many informal conversations were had about how the school year had started and the teachers were inquisitive of each other's early attempts and success at enacting science utilizing the inquiry approach they had learned the past summer.

At this time teachers were asked to reflect in their journals describing an inquiry-based lesson which they had implemented this year. Linda's reflection states:

> When I introduce chemical reactions, I normally give two to three days of notes that exhaustingly cover the topic. We then do a lab that shows the reaction of vinegar and baking soda. This year I introduced the topic with a demonstration. I made "green fire." It's a showy demo that generated a lot of excitement and questions. I turned those questions around and posed them to my students. So far, my students have taken notes only three times this year, everything else has been inquiry-based.

Linda's response offers evidence of her ability to put into practice what she has learned from the summer course. The reader will recall in Chapter Three the 5E model of instruction, frequently utilized in inquiry-based lessons, was described. With regard to the engagement section of the lesson cycle, the teacher helps students become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. It is evident that Linda has adopted the understanding of the significance of engaging students as a powerful "invitation" (Schwab, 1962) into scientific inquiry.

During an intermission Linda and I engaged in an informal conversation where she shares that she continues to be grateful for the experience she had during the summer course. When I prompted her to reflect on what had impacted her most significantly she responded:

> The sequence of the learning activities has really had a profound impact on how I think about doing science with my students. It has changed my perspective. I've always thought it so important to start with giving kids all the background knowledge that they could handle. It was important to read the book and define the terms from the book before doing any labs. That's the way I was always taught science. In the summer course we started by investigating first. Seeing and doing science first felt so different in the beginning but I learned how those experiences set the stage for me to truly make sense of the concepts for myself.

As this exchange is unpacked, rich insights are gained. Linda fully discloses that she teaches the way she was taught. The reader will recall from Chapter Two that this is the case for many teachers. Loucks-Horsley et al. (1998) argued that it is "difficult, if not impossible, to teach in ways in which one has not learned" (p.1). The inquiry course has challenged Linda to think about how restructuring a lesson can make a difference on students' comprehension. Having experienced learning this way herself and having attempted to bring it into her personal story of teaching, she feels more confident that this is good for her students.

Linda's experience is very similar to my own first experience learning inquiry through inquiry-based activities. As readers will recall, my attendance at the Exploratorium's Inquiry Institute made a significant impact on my ability to comprehend the intricacies of inquiry-based learning and had a profound impact on my ability to teach utilizing an inquiry-based approach. My experiences as a learner and a teacher have taught me that in order for teachers to fulfill the diverse and complex role of teaching science as inquiry, they need science learning experiences that will enable them to navigate this different terrain in science teaching, where scientific inquiry is the norm and not the exception. As Fullan (1996) states, "You cannot improve student learning for all or most students without improving teacher learning for all or most teachers" (p. 421); teacher and student learning are inextricably linked. Clearly it is significant to experience learning new concepts through an inquiry-based approach.

In the spring semester I had the opportunity to visit Linda's classroom on several occasions. Linda teaches in a laboratory classroom which was renovated many years ago and was configured as a chemistry lab. The room has both lecture and laboratory facilities. Around the laboratory area shelves and cupboards revealed many tools necessary to do science explorations. The lab area also contained sinks with running water, gas jets, and a fume hood – all conducive to conducting scientific investigations. Posters depicting science concepts and ideas cover the walls around the room and student work is displayed on various cork boards.

On one particular day I was observing as Linda was teaching a lesson on chemical weathering and erosion. The students came into her classroom with a sense of excitement anticipating the opportunity to work in the lab that day. As the bell for class rang, Linda quickly moved into action depicting a sense of urgency to make good use of the time that she had with her students. Quickly students were engaged into the lesson through Linda's challenge to them to think about why the Statue of Liberty is less massive and less defined today than it was when it was first constructed. After raising the students' curiosities about the topic for the day, Linda proceeded to move students into the laboratory where they were given the opportunity to "mess about" with several variables that impact erosion. Students, although they did not generate their own questions, were allowed to develop the procedures necessary to conduct several different investigations allowing them to formulate an understanding of the topic at hand. Students throughout the laboratory were observed eagerly brainstorming hypotheses, recording their observations, collecting and analyzing data and formulating conclusions. These observations confirm that Linda is capable of carrying out inquiry in the way advocated by the National Science Education Standards (1996).

After the lesson I had a chance to interview Linda allowing me to delve into her perceptions of how the summer class and follow up professional development had impacted her classroom practices. Our discussion unfolded this way:

Perri: How do you feel the summer class has impacted your teaching?

Linda: I feel my style of teaching has completely changed. I now realize that teaching is not a passive endeavor. Kids can't be expected to just take notes.

They need to be active in their own learning. I definitely feel like I've improved in my questioning tactics and I'm much more aware that I can't jump in and just give kids an answer when they are feeling a little frustrated with the process. I've learned that this point of frustration can be really beneficial to students as they build their understanding.

Perri: What from the summer had the most significant impact on your teaching?

Linda: Being put into an environment as a learner had the greatest impact on my understanding. Being asked to learn science through doing science was a new experience for me. It seems so simple but yet the experience was so powerful. Actually stepping into the role of a learner taught me how valuable learning like this can be. When I had to make sense of the physics concepts through investigation I felt the change. I learned!

Linda's communication continues to illuminate the powerful effect experiencing science as a learner has had on her understanding of science as inquiry. She no longer is correlating scientific inquiry with hands-on activities rather her focus is now on engaging the mind in problem solving and reasoning. Linda is operationalizing her own definition of what it means to learn.

Our conversation continued:

Perri: You mentioned TAKS. Does TAKS affect your ability to teach science as inquiry?

Linda: In some ways it does. There is so much material to cover on TAKS and truthfully TAKS doesn't really ask the students to be good scientists or problem solvers it simply asks students to remember a lot of information. I feel like there is way too much in the curriculum and in order to cover it all I am not always able to go to the depth with some concepts as I'd like.

Perri: That makes sense. Do you feel like you have any other barriers to teaching science as inquiry?

Linda: Sometimes I feel like I am the barrier as well. Sometimes I get to the point where I feel like it really would be easier to just tell them the answers. But I'm really working on that. I honestly believe that kids learn more when they are given the opportunity to make sense of concepts themselves. So I have to continue to work on me as well.

Linda has changed both her beliefs and her teaching practices as a result of her participation in the summer course and the yearlong professional development. Linda reports that she frequently incorporates inquiry-based instruction in her classroom and that her students are more excited and engaged in learning science than ever before. Classroom observations reflect Linda's students demonstrating their abilities to conduct scientific investigations. Further, when Linda was asked in a final, informal conversation how her practice has changed she responded:

> I know the difference between rolling out a cookbook, teacher-centered lab and immersing students in student-centered, inquiry-based learning. I know it's important for students to generate questions and for me to not give step-by-step instructions. Knowing the difference has allowed me to make the best choices in how I teach kids.

Linda, throughout her experiences in the inquiry class and professional development, has come to both value an inquiry-based teaching approach and has developed critical skills necessary to teach utilizing this constructivist approach. Although Linda has illuminated obstacles that make teaching science as inquiry a challenge, she is firm in her belief that this method is good for students and is committed to expanding her use of inquiry in her classroom.

The Case of Janet

Demographic Information

At the time of this study, Janet was in her sixth year of teaching having taught seventh grade science for three years and was working on completing her third year of teaching eighth grade science. Janet attended a prestigious college with the intent of becoming an engineer. After a tough first semester, she changed her plans and set her sights on becoming a teacher. Janet's undergraduate degree was in Agricultural Education and she completed a semester long student teaching appointment in a small district outside of San Antonio, Texas. As Janet reflected on her student teaching program, she shared that she taught with three different teachers all within Agricultural Education. She found this to be very helpful because she was privy to a variety of perspectives on how to teach. Janet felt her student teaching program was quite rigorous. The most challenging part of her program was developing lessons as there were no curricular resources from which to draw.

Janet attended high school in a small rural school district and graduated as salutatorian. She explained that she was a very studious person, and she earned good grades primarily through memorizing vast amounts of material and regurgitating it for her teachers on tests and projects. This, she later realized, left her significantly under prepared to attend college and likely helps to explain her difficulty in the engineering program, which is known to require excellent science, math and problem solving skills. Readers will recall the many reports, including *Rising above the Gathering Storm* (2007), *A Nation at Risk*, (1983), and *An Imperiled Generation: Saving Urban Schools* referenced in Chapter Two that illuminate the appalling job our public schools are doing to prepare students to be critical thinkers and problem solvers, ready to tackle challenges as productive members of our modern-day global society. The U.S. ranks near the bottom of the world on international assessments, most notably the PISA examination, reputable for testing students' problem solving and application skills and abilities.

Janet currently teaches in the rural school district where she was once a student herself. Her mother is a teacher at the same school and they enjoy working side-by-side one another in the only middle school in their small town. There are currently 730 students in Janet's middle school and Figure 8 depicts the ethnic diversity represented:

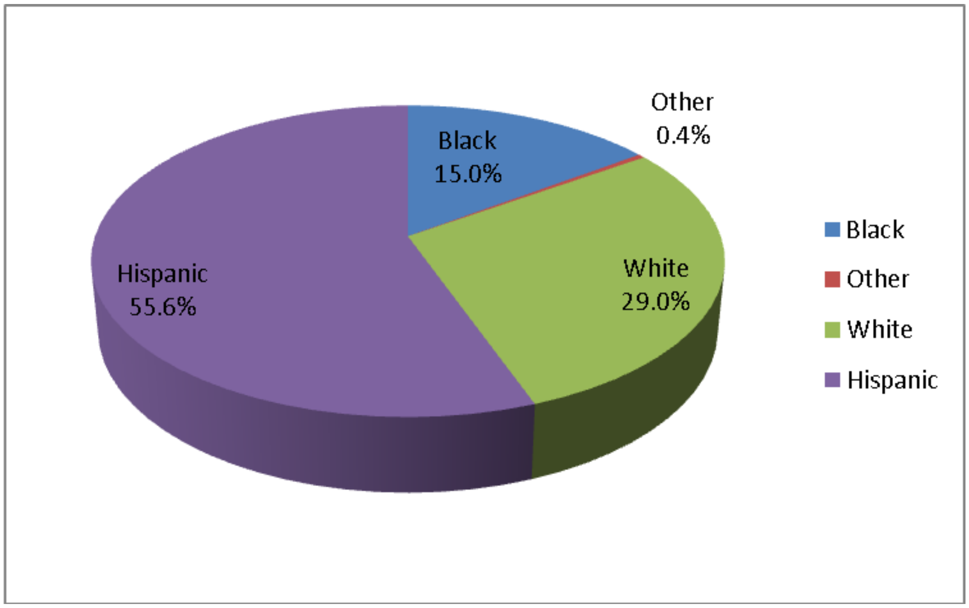

Figure 8: Janet's School's Ethnic Representation.

Initial Beliefs

Prior to attending the inquiry professional development program, Janet's response on the pre-inquiry survey to the question, "What do you consider to be the key elements of inquiry-based instruction?" revealed that she equated inquiry with students utilizing a hands-on approach to learn. This is a noteworthy response as it lends insight into Janet's understanding of inquiry prior to participation in the inquiry program. Initially she does not disclose a deep understanding of teaching science as inquiry. As I reflect back on my own experiences as a teacher struggling to understand inquiry-based science instruction, I too had a firm belief that if students were engaged in any lab activity that required the manipulation of materials, they were indeed doing good science. Equating inquiry with hands-on science is a common myth shared among science educators. As Llewellyn (2007) informs us:

> Providing students with an opportunity to do hands-on science does not necessarily mean they are doing inquiry. Many science activities are very structured. They tell the students what questions to answer, what materials to use, and how to go about solving the problem. In most cases, they even provide charts or tables to record the observations, measurements, or data. Although most inquiry activities are hands-on, not all hands-on activities are inquiry-oriented.

In further analysis of the pre-inquiry survey, when asked how she plans to implement inquiry-based learning next semester, Janet plainly responds, "I'm not sure. I'll know more after this class." This powerful yet simple statement depicts Janet, prior to the inquiry professional development, as a teacher who has not yet conceptualized what teaching science as inquiry involves.

Especially interesting are Janet's responses on the pre-inquiry survey regarding her beliefs about inquiry-based instruction representing best practices in secondary science. Janet responds that in *theory* she agrees that inquiry-based instruction represents best practice in science instruction however, in *practice* she disagrees that inquiry-based instruction is best practice. Nestled in these statements I find Janet, prior to the inquiry course, to either be grounded in the traditional practices of teaching science or in some borderland place. Believing that inquiry-based instruction is good only in theory yet not relevant to practice, Janet clearly does not believe this approach to teaching and learning holds sufficient merit to embrace fully. As discussed in Chapter Two, many teachers believe that the role of science teaching is to impart to students the accumulated knowledge of a discipline. Quickly Schwab's mockery of science education comes to mind as he posited that science in schools was being taught as a mere "rhetoric of conclusions" and that discoveries in science merely meant the replacement of one rhetoric of conclusions with another. That's what reform tends to do—trump one best practice with another with neither achieving the universal results sought.

The Summer Course

Janet was a willing and enthusiastic participant in the summer inquiry course. On the first day of the course, Janet arrived considerably earlier than the other participants giving us an opportunity to talk briefly. As part of our conversation, Janet shared with me that in her school the teachers were required to use a recently purchased curriculum known as C-Scope to teach science. When I asked Janet to elaborate about the mandatory use requirement, she said, "The administrators on my campus think all teachers should be doing the exact same things in their classrooms." This response provides evidence that Janet is situated in an environment where her administrative supervisors don't value teachers as "minded-professionals" (Dewey, 1938). Readers will recall that Dewey (1938) believed teachers were guided by their own intelligences, ideas, and understandings and Schwab (1961) depicted teachers as "agents of education, not of subject matter" (p. 128).

Once immersed in the summer course content, discussions, and reflections, Janet's story of inquiry begins to make some shifts. Several days in to the summer course, Janet reflects on her learning and the application it has for her as a teacher. She writes:

> Over the last five years of teaching, I have struggled with following a model of teaching that wants students to inquire/explore first. Today's lesson was very powerful from a student and teacher perspective. I saw how misconceptions that students have with simple concepts can be changed because I personally confronted my own misconceptions today.

Janet's reflection depicts a powerful personal experience with learning through inquiry. She clearly states that she has struggled with allowing students the freedom to explore and build understanding based on experiences prior to direct instruction. But the way she personally experienced learning early in the summer course has facilitated a change in her perspective of inquiry-based learning.

When opportunity to talk with Janet about her response arose, I asked her why she struggles to let students' initiate their learning by exploring first. She shared what had held her back was the firm mindset that kids cannot learn in that format and as a result she defaulted to *giving* students information. When I asked her if she still felt strongly that students shouldn't begin with an exploration she replied, "I'm thinking differently now. If I can learn, really learn, through open exploration, so can my students." Here, readers see Janet is beginning to restory her values surrounding inquiry-based instruction and her experiences as a learner are significantly impacting her turning toward a more constructivist model of teaching and learning.

Further into the summer course, participants were asked to read an excerpt of Richard Feynman's (1997) influential work, *Surely You're Joking, Mr. Feynman! Adventures of a Curious Character.* Through his experiences in Brazil, Dr. Feynman believed that the system of education in Brazil was incredibly flawed. The students memorized facts, but when asked to apply the knowledge to everyday life, could not. Feynman posits that one cannot be regarded as truly educated if all one can do is regurgitate facts. A student must be able to apply knowledge to new and novel situations to truly claim they *know* something.

This article had a powerful impact on Janet's understanding the important role that inquiry-based instruction can have on student's critical thinking and problem solving abilities and the ramifications this can have on society and our environment. In her journal, as she compares direct instruction with inquiry-based instruction, she observed:

> Students in Brazil were memorizing the information but couldn't apply the knowledge. Inquiry-based learning leaves a larger impact on students. It is favorable because of the impact on student learning and the ability for students to become better problem solvers and critical thinkers. Students will be asked to make decisions that directly impact the Earth. Lacking true understanding of science will lead to poor decisions.

Janet's reflection reminds me of the film *A Private Universe* where a filmmaker took a camera into a crowd of graduates during the 1987 commencement of Harvard University and posed a simple question: "Why is it hotter in summer than in winter?" The results, depicted in the film, revealed that only two of the twenty-three Harvard graduates polled could answer the question correctly. These staggering results are alarming - even the most elite students are not in command of rudimentary facts about our world.

Toward the end of the summer course Janet creates the graphic organizer found in Figure 9 in her journal.

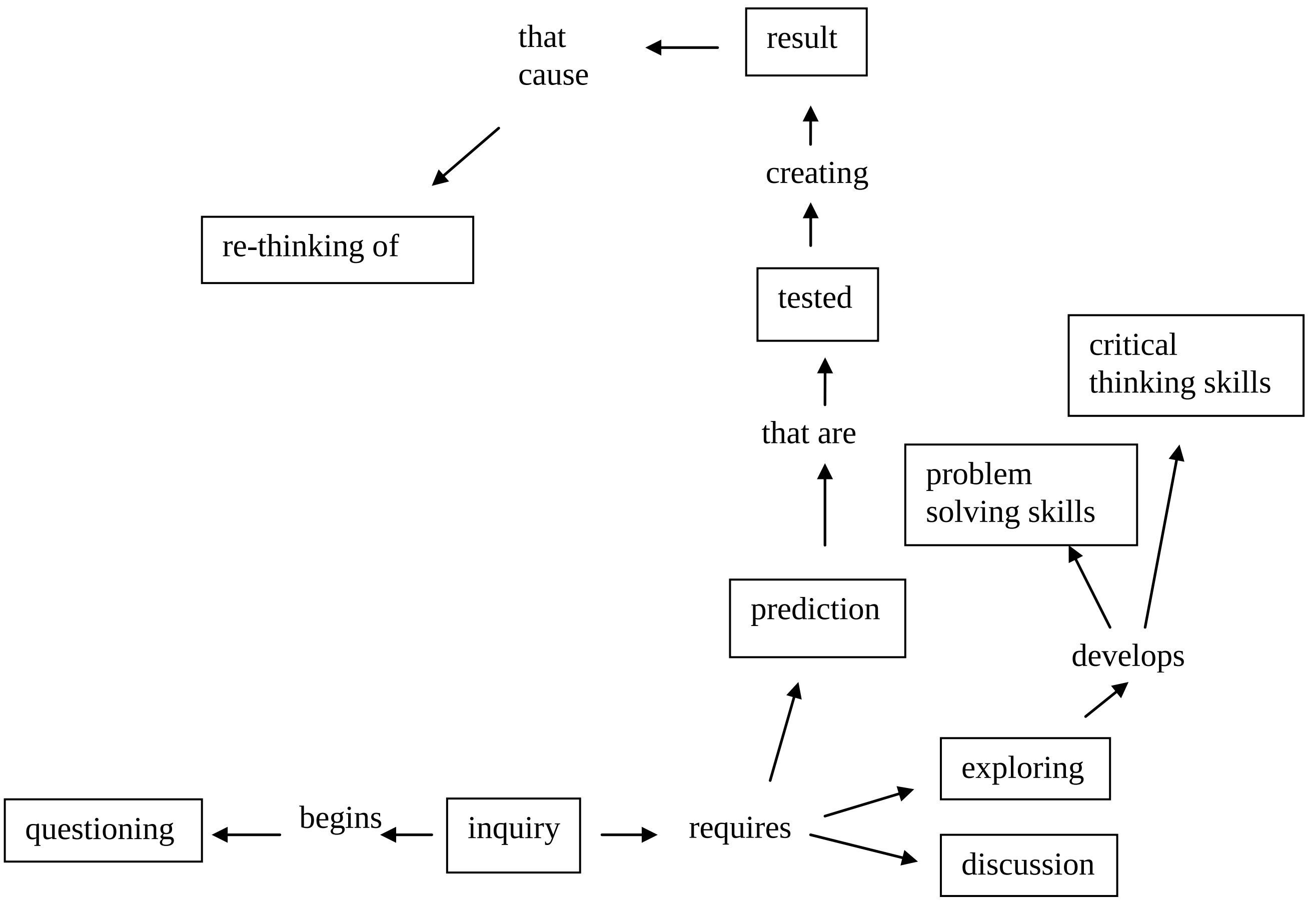

Figure 9. Janet's Concept Map Describing Inquiry.

This visual representation, when compared to Janet's early conceptions of science as inquiry which equated to students involved in hands-on experiences, shows a significantly more developed understanding of a constructivist approach to teaching and learning. Especially noteworthy are her depictions that inquiry develops problem solving and critical thinking skills in students. Furthermore, inquiry-based instruction affords students the opportunity to collect data and generate results that may lead students to rethink their original ideas. These big ideas, articulated clearly in Janet's inquiry concept map, fall neatly in alignment with the National Science Education Standards of inquiry – namely asking questions, planning and caring out investigations, collecting and analyzing data, and using data to develop explanations.

At the end of the course, participants took the post- inquiry survey and Janet's responses reveal how her ideas about inquiry-based instruction have grown and changed throughout the summer course. Janet, when asked what she considers to be the key elements of inquiry-based instruction, now asserts that, "Students are actively engaged in learning. Students are asking the questions and teachers are facilitating the learning. All students are engaged." Additionally, Janet now agrees that in practice inquiry-based learning represents best practice in secondary science instruction—at least for her in her unique teaching situation. No longer is inquiry-based teaching simply a theory with no relevant application as her response indicated on the pre-inquiry survey. And finally, when asked how she plans to enact inquiry-based learning in her classes in the future Janet replied, "A majority of the lessons I teach will follow inquiry. My goal is to change the way I teach – to facilitate learning. Also, some lessons could be moved toward total student-centered instead of partial student-centered." Clearly Janet's experiences, evidenced by her responses, reveal a shift in perspective. Janet's definition of inquiry is more elaborate, she believes inquiry-based instruction represents good instruction, even best practice, and she intends to teach by employing this approach in the future.

Transitioning into Practice

After the completion of the summer course, teachers participated in phase two of the yearlong professional development. Several weeks into the academic year Janet and her colleagues attended the first professional development session. Janet shared with me early that evening that the school year had begun well and she was enjoying putting into practice what she had learned from the summer course. I was encouraged by her zeal and asked her to share with me what, from the summer course, she thought had made the most significant impact on her teaching practices. Janet responded that for her:

> The greatest impact from the summer course was coming to the understanding that I need to facilitate learning instead of preaching content. I now use questioning in my classroom instead of just giving answers. I want my kids to be curious and ask questions about the world around them.

Janet's new understanding of teaching science as inquiry appears to have become part of her personal story of teaching and is concurrently becoming lived in her classroom. Her response lends support to the idea that she is working to make students the center of the learning environment.

Janet's reference to utilizing questions as a strategy with her students is a very important component of an inquiry-based classroom. Questioning lies at the heart of inquiry and is a habit of mind that should be encouraged and developed. According to *Inquiry and the National Science Education Standards* (NRC 2000), "Fruitful inquiries evolve from questions that are meaningful and relevant to students."

As the school year moved forward, Janet continued to put into practice teaching science utilizing an inquiry-based approach. Representative of this is the example she shared with me of a unit she created which addressed the physic concepts of speed and motion. The goal for the students was to discover critical physics concepts through designing and building their own roller coasters. Janet proudly disclosed that this was a change to the way she had taught this unit in the past – usually she provided students the directions on how to build the roller coaster and directed them on what they should observe, what things they should change, and what to measure. I was inspired by her loosening of the reigns of the design of the project and during an interview followed up with her concerning her perceptions of her experience. Our exchange went this way:

Perri: What did you think was most positive about the roller coaster lesson?

Janet: That it made kids responsible for their learning. They had to *think* their way through it.

Perri: That's really excellent. How did the kids respond to this lesson?

Janet: The students were interested in it but at times they were really frustrated by it. They wanted me to just give them the answers. Sometimes they would tell me they don't know what to do next or how to do it. I know this was hard for them because they are not used to learning this way.

Perri: What did you do?

Janet: I didn't give in. I encouraged them and reassured them and tried to use their ideas to point them in the right direction. It wasn't easy. I think sometimes it was harder for me than it was for them.

Perri: What was hard for you?

Janet: Mostly it was hard overcoming my belief that kids can't learn without all the hand-holding I'm used to doing. I had to stay true to what I've experienced. If I can learn this way so can they. I want them to learn to be critical thinkers and that means they have to be asked to think.

In the aforementioned exchange, readers see Janet making strong comparisons between her old teacher self and her teacher self and her preferred method of inquiry appears to sit right at the heart of her decision making. Janet's convictions are strong that she, as the teacher, bears the responsibility for providing opportunities to her students that stimulate critical thinking and problem solving skills. Readers will recall from Chapter Two the strong message sent to schools from the New Commission on the Skills of the American Workforce (2007) which emphasized the dire need to develop students creative and innovative abilities necessary to propel this country into the future.

My conversation with Janet continued to unfurl:

Perri: Were there any barriers to teaching this lesson?

Janet: Yes, time was a barrier. I couldn't allow this unit to consume our entire year. Even though all the students' questions had not been answered, I still had to move on to other curricular topics.

Perri: Yes, that's hard.

Janet: Another barrier was the parents. They liked the unit and all but they didn't like that the students weren't receiving all A's for their work. It was challenging figuring out how to assess students work in this lesson.

Perri: That's an excellent point. Assessment is a part of inquiry we haven't addressed but a topic that we need to explore in the future.

Janet's experience with her inquiry-based lesson, although not without problems as readers can see in the above exchange, depicts clearly that she understands important inquiry-based instructional components and that these understandings are being executed in her classroom.

Toward the end of the yearlong professional development, Janet made a point of drawing the following to my attention:

> I feel like I've had success in guiding my students to be inquiry type thinkers. It has taken some time to change their way of thinking and I haven't gotten them all the way there. I still have a lot of work to do at becoming more efficient at developing and restructuring my lessons. Even though I feel like I am still using some traditional instruction I am trying to make all my lessons more student-centered.

Janet's experiences in the inquiry program, as the aforementioned passage suggests, represent a transformation of beliefs and practices surrounding science as inquiry. Janet has restoried her ideas from those rooted in traditional and didactic practices to those embracing a student-centered, constructivist approach to teaching and learning more in line with the NSES guidelines. Her teacher self has been significantly implicated. Of additional paramount importance to Janet was the experience she had as a learner in this approach. Prior to the inquiry program, Janet found it difficult to articulate the attributes of inquiry-based instruction and further did not believe it had merit as an instructional approach. Janet realizes that there are obstacles to overcome as teachers embrace an inquiry-based approach, yet she has now evolved into a teacher enacting a student-centered approach to learning and is living out her beliefs with the students in her charge.

Conclusion

A review of two teachers' stories as they lived and experienced a yearlong inquiry-based instructional program suggests each experienced a transformation in their perspectives of inquiry and their abilities to employ this form of instruction in their classrooms. The evidence depicted in this chapter strongly suggested that this learning experience, in itself, was transformative for both Linda and Janet. The possibility that engaging teachers in inquiry-based learning, teaching and reflection, in an effort to transform their understanding of science as inquiry as well as their ability to teach using this constructivist model, is important. As a science teacher educator, I feel this outcome is promising and can be instrumental in developing a foundation to support the expansion of preservice science teachers' conceptions of inquiry-based instruction as well as to facilitate their constructivist teaching abilities. Engaging in the processes of learning science content through an inquiry-based approach may transform preservice teachers perspectives into viable lived practices in line with the goals of the NSES and AAAS.

Chapter Five: Discussion

Introduction

This doctoral thesis research presented exemplars in the inquiry professional development program. Two teachers entered as learners in a professional development experience and then transitioned back into their role as teachers, enacting their understandings of teaching science as inquiry in their own classrooms with their students. Having walked along side of Linda and Janet, I am now in the position as a leader of the program to analyze the experiences they lived through this program.

My goal in this study was to make meaning of science teachers' attitudes and abilities regarding teaching science as inquiry as they engaged in a year-long professional development experience which aimed to situate them as learners of both science content and pedagogy. Furthermore, I hoped to elucidate barriers which impeded these teachers from implementing inquiry-based science in their classrooms with their students.

In Chapter Four, I presented two teachers stories, Linda's and Janet's, which surfaced from the collection of artifacts generated by teachers participating in the inquiry professional development program. Through the use of narrative inquiry tools including interviews, observations, journaling, and conversations, I found that Linda's and Janet's lived experiences within the scientific inquiry professional development program yielded several common themes. These themes are presented in three sections in this chapter. The first section addresses the curiosities that guided this study presenting descriptions of Linda's and Janet's experiences with scientific inquiry and their understandings and abilities that developed. The second section examines the barriers teachers typically experience in implementing science as inquiry in their classrooms, and the final section presents implications of this research study for science teacher educators in leadership roles such as myself.

Remembering the Inquiry Program

The inquiry professional development program in this study was meant to include the features of inquiry at a level that is more similar to practices of scientists than is common in most teacher professional development and was enacted to facilitate change in teachers' beliefs and enhance the use of inquiry-based practices in their own classrooms. Teachers need to be confident with the content and processes they are to facilitate with their students. The importance of professional development providing teachers with rich opportunities to explore the learning they need to facilitate with students may serve to assist them in translating inquiry practices into their own classrooms. A number of researchers (Birman et al., 2000; Darling-Hammond & McLaughlin, 1995; Loucks-Horsley et al., 1998) have posited how important it is that professional development experiences provide teachers with rich content, model good pedagogy, and provide teachers opportunities to practice what they are learning. Furthermore, readers will recall that valuing teachers as minded professionals positions them as creators of their own expert knowledge and, consequently, they become more than curriculum implementers, they become curriculum makers. As Craig (2010) tells us,

> Teacher as a curriculum maker is an image that acknowledges the teacher as a holder, user, and producer of knowledge, a self-directed individual who takes the curriculum as given and negotiates it in an active relationship with students to

> address their needs as learners and, to the extent possible, meet the requirements outlined in stated curriculum documents. (p. 867)

Impact of the Course - Comparing Stories

The inquiry professional development program sought to orchestrate learning such that the teachers, positioned as learners, would have opportunities to experience science as inquiry and that it would become a part of the way they think about instructing students. Dewey (1933) referred to inquiry as a "habit of mind"; that is, he viewed inquiry as a comprehensive way of thinking. Consequently the way teachers think about instruction will impact the way they plan for and deliver instruction.

Linda and Janet entered the inquiry professional development as willing and excited learners but with limited understandings of the critical components, those supported by the National Science Education Standards, of teaching science as inquiry. On the pre-assessment survey of inquiry-based instruction Linda responded that science as inquiry was put in motion when teachers, "Present students with opportunities to do hands-on experiments." Janet's response was very similar as she reported that inquiry-based science occurs when, "Students are working through hands-on activities." Both teachers' early conceptions of science as inquiry equated to involving students in hands-on learning. Readers will recall my own early practices for teaching science, tightly tied to the practice of simply rolling out science materials, including pre-developed laboratory sheets, complete with questions to investigate, procedures to follow and questions to answer. Just as I was unprepared to teach utilizing constructivist approaches to learning, those that emphasize the importance of putting students in charge of their learning, so were Linda and Janet prior to the inquiry-based professional development.

Though changing one's instructional beliefs and abilities from traditionally situated to inquiry-based is not as easy as erasing the chalkboard, the yearlong inquiry-based professional development program, lived, storied and restoried by Janet and Linda, facilitated a tremendous shift in their understanding of teaching science as inquiry which then translated into inquiry-based instructional practices occurring in their classrooms. At the end of the summer component of the professional development program, Linda and Janet had evolved into teachers that understood that the heart of inquiry-based learning is exemplified when students, through their curiosities, generate their own questions, develop procedures to investigate these problems, carefully collect, organize and analyze information and communicate results. Both Linda and Janet, on the post inquiry survey, depict how they have restoried their conceptions and no longer equate science as inquiry with simple hands-on activities. Linda states, "Teachers must prompt students to pose their own questions and to act as a facilitator as students work their way through solving problems." Janet summarizes science inquiry by stating, "Students are actively engaged in asking questions and are afforded opportunities to solve them." Collectively, Linda and Janet paint a clear picture revealing their new understandings of how instruction must change from merely providing cookbook activities to engaging students' cognitive abilities. Both teachers recognize that students must be at the center of constructing their understandings.

Linda and Janet reveal that the most powerful experience that led to shifting their understanding was immersion into the role as learners of science content through pedagogy that modeled science as inquiry. Readers will recall Linda's powerful revelation as a student learning physics:

> I have never studied a topic the way I've approached learning physics through inquiry but it has allowed me to gain a deeper understanding of the material. I'm accustomed to learning via lecture and independent practice. I teach my students the same way. Now I have to wonder if this method I've always used results in true understanding. The obvious conclusion is that it does not.

Janet echoed a similar exclamation:

> Over the last five years of teaching, I have struggled with following a model of teaching that wants the students to inquire/explore first. Today's lesson was very powerful from a student and teacher perspective. I saw how misconceptions that students have with simple concepts can be changed because I personally confronted my own misconceptions today.

Both Linda and Janet, having experienced learning physics through inquiry, have grown in their understanding of inquiry-based science. Purposefully being exposed to phenomenon which engaged their curiosity, fostering the development of questions, predictions, plans, and explanations proved to be powerful learning experiences that built understanding of science as inquiry for these teachers. Readers will recall Dewey (1938) tells us our experiences serve as a great teacher and the knowledge gained through rich experiences allow people to solve current and future problems.

As summer ended so did the first phase of the professional development program and Linda and Janet transitioned from learners back to their role as teachers. The understandings of science as inquiry, gleaned through personal experiences and rich meaning making activities in the summer course, were planned to be utilized. In planning to teach students, Linda designed lessons that started by engaging students' curiosities and consequently increased the chances of her students developing questions to solve. She resolved to not "jump in" and just "give answers" when students appeared to be stuck. Janet, too, chose to utilize her newly acquired inquiry understandings in her classroom by providing students rich opportunities to design and investigate problems. Inquiry-based lesson plans, developed by both teachers, revealed the removal of directive procedures and pre-developed data tables, evidencing the importance of student-driven learning. Furthermore, readers will recall that both teachers, upon completion of the inquiry program, believed inquiry-based instruction enhanced students' critical thinking and problem solving abilities.

Barriers

The second theme that emerged through this study was the variety of school-based factors that teachers experienced in their professional landscapes scattering a myriad of obstacles in their endeavors to implement best instructional practices in their classrooms.

Resources

Packaged curricular resources, including science textbooks, can be barriers to teaching science as inquiry. Research studies on teaching practices suggest teachers appear to rely heavily upon textbooks when making decisions about what and how to teach (Bellen, Bellen & Blank, 1992; Roth, Roffie, Lucas & Boutonne, 1997; Sanchez & Valcarcel, 1999). For example, in a survey of teachers in Spain, researchers Sanchez and Valcarcel

(1999) found almost all of the teachers (92 percent) used textbooks as a basic reference for their planning units. Textbooks served as the only guide for 33 percent of the teachers, and for most of the teachers (59 percent), textbooks served as the "basic pillar of the lesson" (p. 499).

Unfortunately, hands-on activities recommended by many science resources are typically presented in a prescribed step-by-step instructional format. As discussed in the *National Science Education Standards* (NRC, 1996), when science teachers move beyond worksheets and step-by-step procedures in order to engage students in inquiry, they must constantly struggle to guide student inquiry toward curriculum goals. As pointed out by Crawford (1999), this ongoing demand for improvisation during teaching can be expected to create a substantial stumbling block for science teachers.

Readers will recall that Linda and Janet are both teaching in districts where science teachers are mandated to teach science utilizing a sole and specific curricular resource. Both teachers, in order to teach science as inquiry, bear the responsibility of recreating the lock- step curricular resources given to them so as to provide students inquiry-based experiences in their classrooms. Consequently this presents a multiplicity of significant challenges for both teachers. Not only must they generate new and innovative ideas utilizing constructivist approaches to teaching they must find the time, in an already very busy professional life, in which to develop and create rich, inquiry-based lesson plans. All of this must take place amid competing, and sometimes conflicting, demands present on the professional knowledge landscape of schools and the personal landscape of home and family demands.

As a result of this barrier coming to life in Linda and Janet's lived experiences, I reflected on the need to enhance the professional development program. Developing inquiry-based lessons does not necessarily require reinventing the wheel. Many traditional labs and activities can fairly easily be modified into inquiry experiences by simply restructuring the activity, by inserting engaging phenomenon and through reversing the order of the lesson. By including a component designed to help teachers understand techniques that can be employed on prescriptive curricular resources allowing them to shift to more student-centered learning experiences, this barrier can be addressed, and possibly reduced, for many teachers.

Assessment Conundrum

Readers will recall that both Linda and Janet were positioned into their teaching roles primarily to ensure that students in their schools met success on the science section of the 8th grade TAKS test. Assessment traditions and conventional assessment for public accountability in the U.S. have relied heavily on the belief that assessment for public accountability leads to academic improvement. Linda and Janet both came to rebuke this assertion; in fact they came to the conclusion that the problem solving and critical thinking skills necessary to be successful in an inquiry-based classroom did not match the required skills necessary for success on the state mandated grade eight high stakes science test they had to administer to students. The state test requires students to work independently and to identify facts, concepts and vocabulary. It does not allow students to problem solve collaboratively, participate in generating questions, devise procedures and collect and analyze data. Linda, in her journal, reflected, "The objectives on the

TAKS test are a mile wide and an inch deep. Students will never be able to do anything more than become acquainted with the content."

Linda and Janet, as evidenced in their conversations and journal reflections, both feel the TAKS test is a deterrent to their ability to implement inquiry-based instruction in their classes. As they both entertain utilizing constructivist methods of learning and teaching that include engaging students in considerably more laboratory activities, those utilizing student-centered instructional approaches that focus students' attention on the applications of science knowledge to technology, societal issues and students concerns, they realize that fostering these skills involves a form of learning that is not measured well with tests commonly used in their schools. Consequently the teachers feel torn to choose between teaching the skills that students need to become powerful learners and teaching what is necessary to be successful on a grade level test. Though Linda and Janet both feel strongly about developing their students problem solving abilities they feel the mandated state and local assessments have the potential to undermine their reform efforts as well as jeopardize their reputations as teachers, as viewed by both adults and children.

Enhancing the Experience

As the developer and instructor of the inquiry program, and as a narrative inquirer, I've had many opportunities to reflect upon the characteristics of the year-long experience; contemplating ways to improve the professional development for teachers. The inquiry professional development program had many successes and many of the components would be critical to continue as the program is repeated in the future. The focus on immersing teachers into the role of learner proved to be one of the most powerful aspects positively impacting participants understanding of science as inquiry and promoting change of teaching behaviors. Additional factors that were extremely valuable included: time for teachers to make meaning of their experiences through journaling and dialogue, opportunities for constant interactions between participants and instructors, development of lesson plans, and classroom observations with feedback.

But as I moved through this year-long experience with Linda and Janet, observing and reflecting carefully through storying and restorying their experiences, I came to better understand the realities and the barriers of enacting science as inquiry and thus ideas evolved on how to enhance the professional development experience in the future. With the increased understanding comes the responsibility for action. Below I articulate some enhancements that could be made to improve the inquiry program. I present these enhancements, having to do with learning, lessons and community, through using action verbs in the sub-headings to reflect the call to action I discussed earlier.

Assess Learning

Teachers in the inquiry program expressed deep levels of concern about how to grade students learning on the skills they sought to develop. Readers will recall that Janet expressed that her parents and administrators were upset that students were not earning A’s on all of their science assignments. Good assessment practices are integral to informing teaching and learning, as well as measuring and documenting student achievement, but in the current climate of high-stakes testing and accountability much emphasis has been placed on summative assessments. Consequently the teachers in the professional development program expressed their uncertainly as to how to evaluate their students achievement on the skills they were trying to develop.

As a former science teacher, administrator and current science teacher educator, I am keenly aware that there are many different ways teachers can evaluate student knowledge. Many teachers are knowledgeable of classic forms of assessment that include multiple choice, true/false, and matching items. But my experiences teach me that these traditional types of tests are often not conducive to measuring students problem solving and critical thinking abilities. If teachers are going to utilize assessment effectively, work needs to be done to build understanding that assessments should measure what is most highly valued and not what is most easily measured; assessment should measure scientific reasoning and not rote knowledge. Helping teachers explore a variety of assessment strategies including: performance-based assessments, journals, portfolios, written reports, and multimedia presentations, is critical to improving teachers understanding of how to assess science as inquiry and is a much needed component of the professional development experience for teachers.

Shift Lessons

Because many science resources are often highly-structured, teachers bear the responsibility of creating lessons that allow for student-centered learning. Having asked teachers to develop inquiry-based lesson plans as part of their experience in the program, teachers were quick to realize the time investment required to invent their own teaching resources. Having learned the critical attributes of inquiry-based science teaching was an important and valuable skill gained by the teachers however; alleviating teachers concerns about the need to develop an entirely new set of curricular resources is imperative.

As this program is re-enacted and restoried in the future, teachers will be taught critical strategies for converting cookbook activities into more student-driven investigations. As teachers realize that prescribed activities no longer meet their instructional goals it will be imperative to know that a step-by-step lab activity can be moved toward a more inquiry-based investigation in a variety of simple ways including:

- asking students to conduct the investigation prior to receiving background information on the task thus allowing the experience to not be simply a confirmatory experience
- having students generate personal questions they have at the conclusion of any activity that they've experienced
- requiring students to develop their own data tables and
- removing pre-develop laboratory procedures

Teaching higher levels of inquiry requires additional research and planning because this is an exercise that requires deeper intellectual engagement into the topic. As teachers learn simple strategies to turn some of their lessons toward more student-centered approaches they'll gain momentum in creating a classroom culture that embraces teaching and learning science as inquiry.

Build Communities

The power of collaboration was an important component of the inquiry professional development program. Teachers greatly appreciated the opportunities to work in groups as they solved science problems, discussed their learning and the implications this had for teaching, as well as the many other formal and informal opportunities to dialogue together. In the year they spent together they formed collegial bonds that were imperative to developing an understanding of inquiry as well as implementing inquiry-based teaching.

Unfortunately, at the end of the year-long inquiry program teachers no longer had a formal reason to continue to come together as professionals, though they desired to maintain their professional relationships. Because isolation is a deterrent to innovation and reform, teachers need to have a way to continue the “conversations” beyond the boundaries of a professional learning experience. With the technological innovations available today, future inquiry programs will afford teachers the possibility of staying connected via e-communities, video conferencing, blogs, and wiki spaces thus enabling teachers to continue to build on their understandings of teaching and learning through a community which was initially established through the inquiry program.

Next Steps

In my current role as a science master teacher and leader of the *teach*HOUSTON program, an innovative teacher preparation program for math and science majors, a primary goal is to enhance preservice science teacher’s understandings of and their abilities to implement science as inquiry. Just as in-service teachers hold strongly to their traditional beliefs about teaching, so also do preservice teachers. Preservice teachers do not enter teacher preparation programs as blank slates; they bring with them a wealth of K-12 experiences, many of which are passive in nature, from the classrooms in which they were students. Their school experiences have set the foundation for the constructs of their beliefs about teaching and about the ways students learn.

Instruction about science teaching for preservice teachers must include rich opportunities for students to re-think their strongly engrained conceptions about science teaching and learning. The inquiry professional development program, created for and implemented in this study, lays a strong foundation for the creation of an undergraduate science methods course with this purpose in mind. Utilizing the approach modeled in the inquiry professional development, students would be immersed into an active role of learning science – one that allows them to experience phenomenon that piques their curiosities, encourages them to generate and explore questions of intrinsic interest and engage in reflective practices about teaching and learning. A course of this nature holds promise for changing the way novice teachers teach science. As Kagan (1992) informs us:

> If a program is to promote growth among novices, it must require them to make their preexisting personal beliefs explicit; it must challenge the adequacy of those beliefs; and it must give novices extended opportunities to examine, elaborate, and integrate new information into their existing belief systems.

Plans for teaching a new course, Science as Inquiry, in the *teach*HOUSTON program are already underway. Effective in the fall semester of 2011, the course will be available as an elective option to students already in the program. Taking the insights from what was learned in the inquiry professional development program, the curriculum is being enhanced and readied for a semester long implementation with preservice science teachers. Recruitment for the course is currently underway with a goal to recruit 20 prospective science students into the class. This class will be positioned such that students have had course work introducing them to effective inquiry-based teaching prior to taking this course but will also have courses requiring field work remaining such that application of the learning will be evident in to the development of lessons in those future classes.

The ultimate goal in developing the Science as Inquiry course in the *teach*HOUSTON program at the University of Houston is to improve the understanding and ability of science teachers' skills in the classroom. Developing highly qualified teachers is imperative if we are to improve our educational outcomes in this country. If this course proves to have a positive impact on enhancing preservice teachers' understandings and abilities to implement science as inquiry the results would be significant to informing the practices of all 22 universities which are currently replicating the UTeach program.

As I continue in my role as a science master teacher/leader working with preservice teachers, I plan to passionately continue my research into the intricacies of science education utilizing the reflective understandings gleaned from this study to enhance the preparation of future science teachers. Additionally, I plan to continue to work with in-service science teachers, as well as campus and district administrators, as I develop and refine inquiry learning experiences such that teachers and educational leaders will develop their understanding of science as inquiry and will become a voice of change to those around them.

Concluding Thoughts

In the introduction to this thesis, the educational landscape in the U.S., according to national reports, assessments and research, clearly painted a portrait of an educational system in need of improvement. Science and mathematics education is particularly targeted for improvement as proficiency in these areas is critical for a nation whose prosperity depends upon innovation and technological advancements. This study is important because the findings support the view that inquiry-based professional development allows science teachers to develop their understandings about science as inquiry and those understandings are translated into constructivist practices in classrooms. If we, as science educators, are to make positive contributions toward changing the quality of education, I believe we need to loudly make the case that none of us benefit by keeping students confined to traditional approaches to learning. If "no child left behind" is to be more than empty rhetoric, we will need changes that support a 21st century approach to teaching and learning. By developing highly skilled teachers, including preservice teachers, that understand and embrace the pedagogical requirements necessary to get all children to learn deeply, it is not only possible, but probable, that America will make significant improvements in its educational endeavors.

References

Allington, R. (2002). *Big brother and the national reading curriculum*. Portsmouth, NH: Heineman.

American Association for the Advancement of Science. (1989). *Science for all Americans: Project 2061*. New York: Oxford University Press.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1-12.

Ball, D. L., & D. K. Cohen. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In *Teaching as the learning profession: Handbook of policy and practice,* eds. L. Darling-Hammond and G. Sykes, 3-32. San Francisco: Jossey-Bass.

Bellen, J. J., Bellen, E. C., & Blank, M. A. (1992). *Teaching from a research knowledge base: A development and renewal process*. New York : Macmillan.

Birman, B.F., Desimone, L., Porter, A.C., & Garet, M.S. (2000). Designing professional development that works. *Educational Leadership*, 57, 28-33.

Bogdan, R. C., & Biklen, S. K. (2003). *Qualitative research for education* (4th ed.). Boston: Allyn and Bacon.

Boud, D., Keogh, R., & Walker, D. (1985). Promoting reflection in learning: A model. In D. Boud, R. Keogh, & D. Walker (Eds.), *Reflection: Turning experience into learning* (pp. 18-40). London, U.K.: Kogan Page 3939.

Bransford, J. D., Brown, A. L., & Cocking, R. R., eds. (1999). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academy Press.

Carlsen, W.S. (1988). *The effects of science teacher subject-matter knowledge on teacher questioning and classroom discourse.* Unpublished doctoral dissertation, Stanford University, Stanford, CA.

Carnegie Foundation for the Advancement of Teaching. (1988). *An imperiled generation: Saving urban schools*. Princeton, NJ: Author.

Clandinin, D.J., & Connelly, F.M. (2000). *Narrative inquiry: Experience and story in qualitative research.* San Francisco: Jossey-Bass.

Cohen, D. K., & Kill, H. C. (1998). *State policy and classroom performance: Mathematics reform in California*. CPRE Policy Brief No. RB-27. Philadelphia: Consortium for Policy Research in Education, University of Pennsylvania.

Coleman, J.S., Campell, E.Q., Hobson, C.J., McPartland, J., Mood, A.M., Weinfeld, F.D., & York, R.L. (1966). *Equality of educational opportunity.* Washington, DC: US Government Printing Office.

Connelly, F.M., & Clandinin, D.J. (1988). *Teachers as curriculum planners: Narratives of experience.* New York: Teachers College Press.

Connelly, F.M., & Clandinin, D.J. (1990). Stories of experience and narrative inquiry. *Educational Researcher, 19*(5), 2-14.

Coutinho, M.J., Oswald, D.P., Best, A.M. (2003, February). Disproportionate identification of students with learning disabilities. *Research Brief*. Retrieved April 12, 2005, from http://www.ascd.org/publications/researchbrief/volume1/v1n3.html.

Craig, C.J. (2007). Story constellations: A narrative approach to contextualizing teachers' knowledge of school reform. *Teaching and Teacher Education 23*, 173-188.

Craig, C. (2010). Teacher as curriculum maker. In C. Kridel (Ed). *The encyclopedia of curriculum studies*, Vol. 2 (pp. 867-869). Thousand Oaks, CA: Sage Publications.

Craig, C. J., (in press). Teacher professional development through a teacher-as-curriculum maker lens. In M. Kooy & K. van Veen (Eds.) *Teacher learning that matters*. New York: Springer.

Crawford, B. A. (1999). Is it realistic to expect a preservice teacher to create an inquiry-based classroom? *Journal of Science Teacher Education*, *10*(3), 175–194.

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

Creswell, J. W. (1998). *Qualitative inquiry and research design*. Thousand Oaks, CA: Sage Publications.

Creswell, J. W. (2003). *Research design*. Thousand Oaks, CA: Sage.

Darling-Hammond, L.& McLaughlin, M. W. (1995). Policies that support professional Development in an era of reform. *Phi Delta Kappan*, *76*(8), 597-604.

Darling-Hammond, L., Wise, A.E. & Klein, S. (1999). *A license to teach: Raising standards for teaching.* (pp. 16-48). San Francisco: Jossey Bass.

Darling-Hammond, L.& McLaughlin, M. W. (1999). Investing in teaching as a learning profession: Policy problems and prospects. In L. Darling-Hammond and G. Sykes (Eds), *Teaching as the learning profession: Handbook of policy and practice*, 376-411. San Francisco: Jossey-Bass.

Darling-Hammond, L. (2010). *The flat world and education*. New York: Teachers College Press.

DeBoer, G. (1991). *A history of ideas in science education.* New York: Teachers College.

Dewey, J. (1902). *The Child and the curriculum.* Chicago: University of Chicago Press.

Dewey, J. (1933). *How we think*. Chicago: Henry Regnery.

Dewey, J. (1938). *Experience and education*. New York: Simon and Schuster.

Dimmock, C. and Walker, A. (2005). Education leadership: Culture and Diversity. Thousand Oaks, CA. SAGE Publications.

Elbaz, F. (1991). Research on teacher's knowledge: The evolution of a discourse. *J. Curriculum Studies* 23(1), 1-19.

Ferguson, R.F. (1991). Paying for public education: New evidence on how and why Money matters. *Harvard Journal on Legislation, 28*(2), pp. 465-498.

Ferguson, P. and Womack, S.T. (1993). The impact of subject matter and education and coursework on teaching performance. *Journal of Teacher Education,44*(1), 55-63.

Feynman, R. P. (1997). *Surely you're joking, Mr. Feynman! Adventures of a curious character*. New York: W.W. Norton.

Fullan, M. (1996). Turning systemic thinking on its head. *Phi Delta Kappan*, 77, 420-23.

Gess-Newsome, J. (2002). The use and impact of explicit instruction about the nature of science and science inquiry in an elementary science methods course. *Science & Education, 11*(1), 55-67.

Glesne, C. (1999). *Becoming qualitative researchers*. New York: Longman.

Goldberg, M. F. (2001). *Discrimination, Racism, and Poverty*. Retrieved March 25, 2003, from Association of Supervision and Curriculum Development database.

Goldhaber, M. & Brewer, D. (1999*). Does teacher certification matter? High school certification status and student achievement.* Unpublished manuscript.

Guton, E. & Farokhi, E. (1987). Relationships among academic performance, basic skills, subject matter knowledge and teaching skills of teacher education graduates. *Journal of Teacher Education, 38*(5), 37-42.

Halford, J. M. (1996, Summer). Policies of promise. *Urban Education*. Retrieved April 12, 2005, from http://www.ascd.org/publications/infobrief/issue5.html.

Haycock, K. (2001). Closing the achievement gap [Electronic version]. *Educational Leadership*, *58,* 6-11. Retrieved April 12, 2005, from http://www.ascd.org/publications/researchbrief/volume1/v1n3.html.

Haycock, K., & Chenoweth, K.. (2005). *Choosing to make a difference.* Retrieved April 12, 2005, from American School Board website: http://www.asbj.com.

Ingersoll, R.M. (1999). The problem of underqualified teachers in American secondary School. *Educational Researcher, 28*(2), 26-37.

Jerald, C. (2002). *All talk, no action: Putting an end to out-of-field teaching*. Retrieved April 12, 2003, from The Educational Trust website: http://edtrust.org.

Jorgenson, O., & Vanosdall, R. (2002). The death of science? What we risk in our rush toward standardized testing and the three R's. *Phi Delta Kappan,* 83, 601-605.

Kagan, D.M. (1992). Implicaitons of research on teacher belief. *Educational Psychologist, 27*(1), 65-90.

Kazempour, M., (2009). Impact of inquiry-based professional development on core conceptions and teaching practices: A case study. *Science Educator*, *18*(2), 56-8.

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

LeCompte, M.D., and Schensul, J.J. (1999). *Designing and Conducting Ethnographic Research*. Walnut Creek, CA: AltaMira.

Levitt, K. (2002). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Teacher Education 86* (1), 1-24.

Lewis, A. (1996). Breaking the cycle of poverty. *Phi Delta Kappan*, *78*, 186-188. Retrieved April 3, 2003, from Gale Group Professional Collection database.

Llewellyn, D. (2002). *Inquire within: Implementing inquiry-based science standards.* Thousand Oaks, CA: Corwin Press.

Llewellyn, D. (2007). *Inquire within: Implementing inquiry-based science standards.* 2nd ed. Thousand Oaks, CA: Corwin Press.

Loucks-Horsley, S., Stiles, K., & Hewson, P. (1996). Principles of effective professional professional development for mathematics and science education: A synthesis of standards. NISE Brief, 1, 1-6.

Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. E. (1998). *Designing Professional Development for Teachers of Science and Mathematics*. Thousand Oaks, CA: Corwin Press, Inc.

Loucks-Horsley, S., Love, N., Stiles, K.E., & Mundry, S. (2003). *Designing professional development for teachers of science and mathematics education* (2^{nd} ed.). Thousand Oaks, CA: Corwin.

Lowery, L. (1998). How new science curriculums reflect brain research. *Educational Leadership 56* (3): 26-31.

Luft, J. A. (2010). Building a bridge between research and practice. *Journal of Research in Science Teaching*, *47*(7), 765–767.

Lyons, N. & LaBoskey, K. (2002). *Narrative inquiry in practice*. New York: Teachers College Press.

Matson, J. O., & Parsons, S. (1998). The nature of science: Achieving scientific literacy by doing science. In W. F. McComas (Ed.), *The nature of science in science education* (pp. 223-230). Dordrecht, The Netherlands: Kluwer Academic Publishers.

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The nature of science in science education* (Vol. 5, pp. 3-39). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Michaels, S., Shouse, A. W., Schweingruber, (2008). *Ready, set, science.* Washington, DC: National Academy Press.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis*. Thousand Oaks, CA: Sage Publications.

National Academy of Sciences, (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future.* Washington DC: National Academy Press.

National Center for Education Statistics (NCES). (2005). *NAEP trends on-line.* Washington, DC: U.S. Department of Education, National Assessment of Educational Progress.

National Commission on Excellence in Education. 1983. *A nation at risk: The imperative for education reform* (Report No. 065-000-001772). Washington, DC: U.S. Government Printing Office.

National Research Council (1996). *National science education standards.* Washington, DC: National Academy Press.

National Research Council (2000). *Inquiry and the national science education standards; A guide for teaching and learning.* Washington DC: National Academy Press.

Perkes, V.A. (1967-1968). Junior high school science teacher preparation, teaching behavior, and student achievement. *Journal of Research in Science Teaching*, *6*(4), 4,121-126.

Popham, J. (2004). Curriculum, instruction, and assessment: Amiable allies or phony friends? *Teachers College Record*, *106*(3), 417-428.

Roth, W. M., Roffie, C. J., Lucas, K. B., & Boutonné, S. (1997). Why may students fail to learn from demonstrations? A social practice perspective on learning physics. *Journal of Research in Science Teaching*, *34*(5), 509–533.

Sánchez, G., & Valcarcel, M. V. (1999). Science teachers' views and practices in planning for teaching. *Journal of Research in Science Teaching*, *36*(4), 493–513.

Schwab, J. J. (1958). The teaching of science as enquiry. *Bulletin of the Atomic Scientists*, *14*, 375-379.

Schwab, J. (1960). Enquiry, the science teaching and the educator. *The Science Teacher*, *27*(6), 6 – 11.

Schwab, J.J. (1961). *The teaching of science as enquiry*. Cambridge, MA: Harvard University Press.

Schwab, J. (1962). The teaching of science as enquiry. In J. Schwab & P. Brandwein (Eds.), *The teaching of science* (pp. 3-103). Cambridge, MA: Harvard University Press.

Schwab, J. J. (1960/1978a). The practical: translation into curriculum. In I. Westbury & N. Wilkof, (Eds.), *Science curriculum and liberal education: selected essays* (pp. 365-383). Chicago: University of Chicago Press.

Seidman, I. E. (1991). *Interviewing as qualitative research*. New York: Teachers College Press.

Seidman, I. E. (1998). *Interviewing as qualitative research: A guide for researchers in education and the social sciences.* New York: Teachers College Press.

Strauss, R.P. & Sawyer, E.A. (1986). Some New Evidence on Teacher and Student Competencies. *Economics of Education Review, 5*(1), 41-48.

Sund, R.B. & Towbridge, L.W. (1967). *Teaching science by inquiry.* Columbus, OH: Charles Merrill Books, Inc.

Supovitz, J.A., & Turner, H.M. (2000). The effects of professional development on science Teaching practices and classroom culture. *Journal of Research in Science Teaching 37*(9), 963-980.

Thompson, C. L., & Zeuli, J. S.. (1999). The frame and the tapestry. In L. Darling Hammond & G. Sykes (Eds) (*Teaching as the learning profession: Handbook of policy and practice,* (pp. 341-375). San Francisco: Jossey-Bass.

Torbert, W. (1981). Why educational research has been so uneducational. In P. Reason & J. Rowan (Eds). *Human inquiry: A sourcebook of new paradigm research* (pp.141-151). New York: John Wiley & Sons.

U.S. Department of Education. (1998). *Attaining excellence: A TIMSS resource kit.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

U.S. Department of Labor. (2006) *Number of jobs held, labor market activity, and earnings growth among the youngest baby boomers: Results from a longitudinal survey.* Washington, DC: Bureau of Labor Statistics. Retrieved July 22, 2010, from: http://www.bls.gov/news.release/pdf/nlsoy.pdf

Weiss, I. R., Pasley, J. D., Smith, P. S., Banilower, E. R., & Heck, D. J., (2003). *Looking inside the classroom: A study of K-12 Mathematics and Science Education in the United States.* Chapel Hill, NC: Horizon Research, Inc.

Welch, W. W., Klopfer, L. E., Aikenhead, G. E., & Robinson, J. (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education,65* (1), 33-50.

Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality.* Retrieved July 5, 2010, from http://www.ets.org/research/pic.

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research*, *72*(2), 131-175.

Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science education, 87*(1), 112-143.

Appendix A: Inquiry-Based Instruction Survey

Inquiry-Based Instruction Survey

Name: ___________________________
Years of Teaching Experience: ______
Grade Level /Subject _______________

1. What do you consider to be the key elements of inquiry-based instruction? In other words, how would you recognize inquiry-based teaching in a secondary science classroom?

2. Rank how much you agree with each of the following statements.

   a. In theory, inquiry-based instruction represents best practices in secondary science instruction; all instruction should be done in this format.

      Strongly agree Agree Disagree Strongly Disagree

      Comment:

   b. In practice, inquiry-based instruction represents best practices in secondary science instruction; all instruction should be done in this format.

      Strongly agree Agree Disagree Strongly Disagree

      Comment:

   c. Inquiry-based instruction represents one of a spectrum of valuable approaches to instruction. Good secondary science instruction should include both inquiry-based instruction and non inquiry-based instruction.

      Strongly agree Agree Disagree Strongly Disagree

      Comment:

d. Inquiry-based instruction should serve as an overlay to traditional instruction, providing a connecting framework. It enhances traditional instruction but is not critical in secondary science classrooms.

Strongly agree Agree Disagree Strongly Disagree

Comment:

e. Inquiry-based learning is useful as a motivator to get students to learn material. Inquiry-based learning should serve as a reward in secondary science classrooms but is not a way to convey content to students.

Strongly agree Agree Disagree Strongly Disagree

Comment:

f. Inquiry-based learning is a distraction in secondary science classrooms. This format of instruction does not contribute to learning.

Strongly agree Agree Disagree Strongly Disagree

Comment:

3. Briefly describe how you plan to implement inquiry-based learning next semester (if at all). Please include the source for any curriculum materials you will be using.

4. What do you see as possible barriers to implementing inquiry-based learning into your classroom?

Appendix B: Consent to Participate Form

UNIVERSITY OF HOUSTON VICTORIA
CONSENT TO PARTICIPATE IN RESEARCH

PROJECT TITLE: The Impact of an Inquiry-Based Course on the Beliefs and Practices of In-Service Teachers
You are being invited to participate in a research project conducted by the University of Houston Victoria Investigators. This research project will be part of a doctoral dissertation. This research project is being conducted under the supervision of Dr. Nora Hutto.

NON-PARTICIPATION STATEMENT

Your participation is voluntary and you may refuse to participate or withdraw at any time without penalty or loss of benefits to which you are otherwise entitled. You may also refuse to answer any question. If you are a student, a decision to participate or not or to withdraw your participation will have no effect on your standing.

PURPOSE OF THE STUDY

The purpose of this study is to examine outcomes related to C & I 6300. You have been asked to participate in the study because you are a participant in this class. The duration of the entire study will be from the time the participant enters the course until June 10, 2011. This study will address significant educational issues, primarily whether an inquiry-based science course, when successfully implemented, can increase the quality of science instruction.

PROCEDURES

You will be one of approximately 17 subjects to be asked to participate in this project.
If you agree to be in this study, we will ask you to do the following things:

- Participate in an interview/focus group.
- Take a pre-test and post-test over science content.
- Answer questions about your overall satisfaction with the course.
- Participate in journal writing as part of the C & I class.
- Write two inquiry lesson plans.
- Allow observations of lesson plans by researchers.
- Fill out an exit survey when you complete the course.

Total estimated time to participate is no longer than what is expected as a participant in the C & I 6300 class.

CONFIDENTIALITY

The following procedures and safeguards guide research staff in the protection of privacy and confidential information of study participants.

- The records of this study will be stored securely and kept confidential. Authorized persons from the University of Houston, members of the Institutional Review Board, and study sponsors, have the legal right to review your research records and will protect the confidentiality of those records to the extent permitted by law. All publications will exclude any information that will make it possible to identify you as a subject. Throughout the study, the researchers will notify you of new information that may become available and that might affect your decision to remain in the study.
- All data and materials, including recordings, will be kept for at least three years after the completion of the study.
- If you consent, the data resulting from your participation will be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate you with it, or with your participation in any study.

RISKS/DISCOMFORTS

The risk associated with this study is no greater than everyday life.

BENEFITS

There is no direct benefit of being in the study. However, you may be exposed to information that may help you in the future.

ALTERNATIVES

Participation in this project is voluntary and the only alternative to this project is non-participation.

PUBLICATION STATEMENT

The results of this study may be published in professional and/or scientific journals. It may also be used for educational purposes or for professional presentations. However, no individual subject will be identified.

SUBJECT RIGHTS

1. I understand that informed consent is required of all persons participating in this project.

2. All procedures have been explained to me and all my questions have been answered to my satisfaction.

3. Any risks and/or discomforts have been explained to me.

4. Any benefits have been explained to me.

5. I understand that, if I have any questions, I may contact Perri Segura at 713-743-4969. I may also contact Dr. Nora Hutto, faculty sponsor, at 362-570-4254

6. I have been told that I may refuse to participate or to stop my participation in this project at any time before or during the project. I may also refuse to answer any question.

7. ANY QUESTIONS REGARDING MY RIGHTS AS A RESEARCH SUBJECT MAY BE ADDRESSED TO THE UNIVERSITY OF HOUSTON COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS (361-570-4374). ALL RESEARCH PROJECTS THAT ARE CARRIED OUT BY INVESTIGATORS AT THE UNIVERSITY OF HOUSTON ARE GOVERNED BY REQUIREMENTS OF THE UNIVERSITY AND THE FEDERAL GOVERNMENT.

8. All information that is obtained in connection with this project and that can be identified with me will remain confidential as far as possible within legal limits. Information gained from this study that can be identified with me may be released to no one other than the principal investigator, Perri Segura and her faculty sponsor, Dr. Nora Hutto. The results may be published in scientific journals, professional publications, or educational presentations without identifying me by name.

I agree to participate in this study. Yes _____ No ______

I HAVE READ (OR HAVE HAD READ TO ME) THE CONTENTS OF THIS CONSENT FORM AND HAVE BEEN ENCOURAGED TO ASK QUESTIONS. I HAVE RECEIVED ANSWERS TO MY QUESTIONS. I GIVE MY CONSENT TO

PARTICIPATE IN THIS STUDY. I HAVE RECEIVED (OR WILL RECEIVE) A COPY OF THIS FORM FOR MY RECORDS AND FUTURE REFERENCE.

Study Subject (print name): ____

Signature of Study Subject: ____

Date: ____

I HAVE READ THIS FORM TO THE SUBJECT AND/OR THE SUBJECT HAS READ THIS FORM. AN EXPLANATION OF THE RESEARCH WAS GIVEN AND QUESTIONS FROM THE SUBJECT WERE SOLICITED AND ANSWERED TO THE SUBJECT'S SATISFACTION. IN MY JUDGMENT, THE SUBJECT HAS DEMONSTRATED COMPREHENSION OF THE INFORMATION.

Principal Investigator (print name and title): ______________________________

Signature of Principal Investigator: ______________________________________

Date: ____