BLACKBURN-MORRISON, KIMBERLY D., Ph.D. Three Case Studies of Three High School Teachers' Definitions, Beliefs, and Implementation Practices of Inquiry-based Science Method Including Barriers To and Facilitators of Successful Implementation. (2005)
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This study involved three teachers in various stages of implementation of inquiry-based science method. The cases were chosen because one participant was a novice in using inquiry-based science method, one participant was in her second year of implementation, and the third participant was experienced with inquiry-based science method. The cases were set in a rural high school in three different science classrooms. One of the classrooms was a regular biology class. One of the classrooms was an honors oceanography class and another was an advanced placement environmental science classroom. Data sources included interviews, observations, and document collection.

Interviews, observations, and document collection were used to triangulate data. Each classroom was observed five times. Interviews were conducted at the beginning of the semester with each participant and at the end of the semester. Follow-up interviews were conducted after each observation. Documents were collected such as each teacher's lesson plans, student work, and assignments. Data was initially organized according to the research areas of teacher's definition, teacher's beliefs, teacher's barriers to implementation, and teacher's enablers to implementation. Then, patterns emerging from each of these cases were organized. Lastly, patterns emerging across cases were compared in a cross-case analysis.

Patterns shared between cases were: Participants related inquiry-based science method with hands-on learning activities. Participants saw students as the center of the

learning process. Participants had positive beliefs about constructivist learning practices that were strengthened after implementation of inquiry-based teaching. Facilitators of successful implementation of inquiry-based science method were positive student motivation, students' retention of knowledge, and a positive experience for lower level students. Barriers to successful implementation were teachers not having complete control of the classroom, upper level students having difficulty with inquiry, time and curriculum being a factor, and teachers feeling unprepared to teach this methodology.

The researcher culminated the study with practice and policy implications and reasons for further research. Overall, the findings were that these teachers in various stages of implementation with little training in this methodology were able to successfully implement inquiry-based science method based on the reform movement's definition despite barriers to implementation.

THREE CASE STUDIES OF THREE HIGH SCHOOL TEACHERS' DEFINITIONS, BELIEFS, AND IMPLEMENTATION PRACTICES OF INQUIRY-BASED SCIENCE METHOD INCLUDING BARRIERS TO AND FACILITATORS OF SUCCESSFUL IMPLEMENTATION

by

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APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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Philippians 4:13

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Introduction

Educational reform has been prevalent in the United States for many decades. Sputnik served as a change catalyst for schools in the late 1950's as did *A Nation At Risk* (National Commission on Excellence in Education, 1983) in the early 1980's. As Goodlad, Klein, and Associates' "Behind the Classroom Door" (1970) and Sarason's (1990) "The Predictable Failure of Educational Reform" illustrated the failure of classroom implementation, reformers began called for more intellectually demanding curricula and practices.

With reform of the late 1980's gaining momentum, "standards-based" reform started taking shape. The American science community recognized the need for improving science learning, and according to Beasley (2000), systemic reform of science education in the United States was a national priority with the federal government calling for new teaching strategies. In 1991, the president of the National Science Teachers Association asked the National Research Council to begin developing standards for science education.

The National Science Education Standards produced in 1996 outlined what science students in grades K-12 needed to "know, understand, and be able to do." The national standards were developed by professional scientists and educators, these standards suggested strategies for the improvement of science teaching (Bybee, 1997). They also outlined what the current scientific community feels are essential aspects of science literacy.

The current science standards call for a “more intellectually demanding content and pedagogy for everyone” (Spillane, Reiser & Reimer, 2002,p.1). The National Science Education Standards promote inquiry as the “central strategy for teaching science” (Keys & Bryan, 2001). This call for standards-based reform requires “several fundamental changes in the way education is practiced” (Beasley, 2000) and teachers must accept external standards for what is quality student performance. This push for inquiry-based teaching as being central to the teaching of science in the 21st century puts the responsibility on teachers to implement this instruction in their classroom.

Spillane, Reiser and Reimer (2002) recognized that the collective teacher’s ability to make sense of this standards-based reform is crucial in understanding how to effectively create change in teachers’ practices. Understanding how teachers cognitively make sense of inquiry, what teachers believe about inquiry teaching, and how this is seen in the teacher’s every day experiences will be crucial to understanding teacher change with regard to inquiry (Spillane, Reiser & Reimer, 2002; Keys & Bryan, 2000). Research shows that changes similar to what reform based standards request is difficult to put into practice (Anderson &Helms, 2000). Therefore, teachers who implement reform-based initiatives need to be studied under “real world” conditions (Anderson &Helms, 2000; Anderson, 1998, Keys & Bryan, 2000).

Statement of the Problem

This case study employed qualitative data collection procedures in order to answer the following research questions:

1. How do teachers define inquiry-based teaching?
    a. How do these definitions change over time?
    b. How are these definitions impacted by their beliefs about how students learn?
2. How do teachers who are transforming their practice from traditional methods of teaching enact inquiry-based teaching?
3. What are the factors that enable the teachers and factors that hinder the teachers from enacting inquiry-based teaching?
    a. How do these factors change over time?
4. What are similarities and differences between the teachers' definitions of and factors with inquiry-based teaching?
    a. What might explain these similarities and differences?
5. How do the hindering factors and enabling factors of the three teachers inform other researchers?

Research Design

This study was designed as three individual case studies with a cross-case comparison all three. Yin (1994) defined case study as a study of a contemporary phenomenon and outlined steps in observing a case such as developing the research questions, identifying propositions for the study and specifying the unit of analysis. Stake

(1995) disagreed with Yin's definition of case study and saw case study as a qualitative research design which follows a more exploratory research method of data collection in which you gather information such as what is the nature of the case, what is it's historical background and what are other contexts which affect the case. Stake argued that:

> it is almost impossible to get acquainted with the case before designing the study. So the researcher makes a flexible list of questions, progressively redefines issues and seizes opportunities to learn the unexpected (Stake, 1995, p. 28-29).

In agreement with different aspects of both definitions, Merriam's definition of case study was used for this case because she defined case study as "…an intensive, holistic description and analysis of a single instance, phenomenon, or social unit"(Merriam, 1988,preface p. 8). She noted that a case is something that can be "fenced in" or studied. She also wrote of a case study being an entity that can be studied by looking at specific areas of the case that informs questions needed to be answered but allows the researcher to be open to the data as it unfolds. A case study, as defined by Merriam, allows the researcher to observe a process in which the case is involved and gives guiding questions to indicate what exactly the researcher will be observing during data collection. The researcher has a focus for the study but will not be proving or disproving a hypothesis. Rather, the researcher will understand the case and conditions surrounding the case. The researcher will not be so focused that he/she is unable to see other areas of the data but will have direction in the types of data collected. Merriam explains that case study is chosen if one looks at a process such as a new innovation being implemented as is shown in these three cases. I was able to look at each of these three cases individually and cross-categorically to view the process of implementation of inquiry-based science method.

Significance of the Study

This study was designed to address three gaps in understanding how teachers make sense of current science education reform initiatives and how this sense-making affects their beliefs and classroom practices. This study explored three teachers' definitions of inquiry-based science instruction, the day-to-day implementation process of inquiry, and the effect implementation had on their beliefs and practices related to inquiry-based teaching. Below, I describe each of these gaps in the literature in more detail.

Understanding *Teachers'* Definitions of Inquiry

Although inquiry-based learning dates back to Dewey (Dewey, 1938) in which he believed children learned from activity in real-world problem solving, teachers were encouraged to teach science as a body of knowledge. Hands-on activities typically stressed one scientific method in which science students should find the "right" answers (Crawford, 2000). The National Research Council challenged this notion of learning science and encouraged a method of student projects that taught the students to think for themselves. They outlined using inquiry based science teaching as a method which is propelled by student questioning, designing a way to answer those questions, manipulating data to discover answers and articulating their findings. Yet, the National

Research Council standards do not outline how to implement this method by providing specifics for the classroom teachers.

Keys and Bryan (2001) outlined a proposal of a research agenda for studying this theory to practice gap by stressing the importance of studying teachers' beliefs about inquiry. These authors argued that for implementation of current reform initiatives to work, we must understand the ways teachers go about operationalizing the broad concepts embedded in the reform. They argued that researchers must look through the lens of teachers in their local context implementing inquiry and observe their use of tools, language and social organization. Keys and Bryan felt this was vital to our understanding of the teachers' sense-making. In addition, Spillane, Reiser and Reimer (2002) stated that " the process by which implementing agents come to understand policy, the understanding that results and the consequences of those understandings for policy implementation is rarely analyzed (p. 5)."

<u>Understanding the Day-to-Day Implementation Process</u>

Understanding teachers' beliefs and practices while they try to change their teaching strategies from teacher-centered to student-centered instruction is seldom researched (Crawford, 2000). There is little research to outline what, if any struggles these teachers had in implementing this method. According to a study by Alper (1994), some teachers struggled to enact inquiry-based teaching because they feel incapable of providing the materials and information the students needed to be able to use this process. Keys and Bryan (2001) told us that teachers in this change process will experienced tensions, and my study helps enlighten and inform on just what those tensions may be.

"High School teachers beliefs about curriculum constraints have been reported to influence their inquiry practices" (Keys & Bryan, 2001, p. 638). My study addressed a need to understand teachers' struggles and triumphs in the implementation process. This study attempted to come to an understanding of what these three teachers defined as inquiry-based teaching and successes and barriers they faced as they enacted reform-based instruction. Teachers situated in science classrooms dealing with reform-based student-centered initiatives must be studied to see the effects this reform has on their belief system as well as their classroom. Putnam and Borko (2000) argued that situative perspectives allow us to see what we believe and how we apply it in particular contexts. Research needs to occur where we can see change through the individual classrooms of these teachers who face their everyday environment, how they are socially situated, and how they use language and tools (Putnam & Borko, 2000). Attention needs to be paid to teachers experiencing change consistent with the reform agenda and what kind of authentic activities occur in those classrooms, which is often called the ordinary classroom practices.

We need to look at what teachers believe and what they do. Efforts to enact inquiry have been described by researchers recently, but what occurs in the day-to-day events of these classrooms has not been thoroughly researched (Crawford, 2000). Research must be done in classrooms where teachers attempt to design and carry out authentic, full-inquiry projects (Crawford, 1996). This study was designed to study the three classrooms and provide rich, thick descriptions of each classroom during the implementation process.

Understanding How Implementation Affects Teachers' Beliefs and Practices

This study also looked at how the implementation process affected teachers' beliefs and practices related to inquiry. Many researchers felt that beliefs about student learning must be addressed prior to implementation of new methods. Fullan (2001) argued that significant educational changes consist of changes in beliefs. Some researchers found that beliefs of teachers must be in line with the change prior to implementation (Haney, Czerniak, & Lumpe, 1996; Tobin, Tippin & Gallard, 1994). Others argued that it can occur as the implementation is occurring (Fullan, 2001; Morrison, 2002). I found in a prior study that a teacher changed her beliefs about inquiry-based teaching and student learning as the semester progressed. She implemented inquiry-based teaching strategies and discovered that students learned significantly through this method. Her beliefs changed as implementation occurred. This study proceeded on the assumption that teachers' beliefs can change to align with reform-based initiatives as they enact the method. This study also attempts to see if that occurred in this situation. Spillane, Reiser, and Reimer (2002) stated that teachers or implementing agents must come to understand their practice, and this may change their beliefs in the process. The researcher looked at three high school classrooms where reform-based changes were encouraged by the system, where the teachers enacted student-centered methods with an inquiry-based learning focus. This study will describes the classrooms and addresses this need to understand how the beliefs of teachers during a reform-based change affected their practice. It reports how the change was implemented over a semester and what changes occurred during that time. It addresses what successes in implementation were present and what barriers to implementation were present.

Data Collection

I collected the following kinds of data:

- I collected field notes during observations of lessons being taught in the classroom. I observed five lessons for each teacher during the course of the semester as I focused on each teacher's activities before and during the class to prepare and deliver the lessons. I also focused on the structure of the lessons, paying attention to the following aspects of classroom instruction: 1. What was the overall structure of the lesson? (i.e., What were the identifiable parts of the lesson and how much time was spent on each aspect of the lesson?) 2. How was the teacher teaching the lesson? (Was the teacher lecturing, using the board, answering questions individually, and providing resources to answer student questions?). 3. What were the ways the students participated in the classroom activities?
- I took field notes during a departmental meeting in which inquiry-based teaching or student-centered learning was discussed. I paid attention to discussions involving this methodology and how the teachers made sense of inquiry-based science method. This data provided me with a better understanding of the ways teachers' sense-making of inquiry was socially situated and constructed.
- I audiotaped interviews with each teacher formally at the beginning and end of the study (45 minutes each). In addition, I talked with each teacher informally for about

15 minutes after each of the 5 observations to gain insight about their reflections about the observed lesson. I asked questions in the short, informal interviews. These questions were:

1. Do you feel that this lesson was a good inquiry-based lesson? Why or why not?
2. How did the students respond to this lesson? (Probe for evidence).
3. What are parts of the lesson that worked well and parts of the lesson that did not work well? Why do you think this occurred?
4. If you did this lesson again how would you change it?
5. Have you discussed using inquiry-based science method with other teachers in this department informally or during departmental meetings?
6. If so, what sort of things did you discuss?

Formal interviews used the following open-ended protocol:

1. Tell me a little bit about your science teaching history and experience. (How did you get to be a science teacher? How long have you been teaching? What attracted you to science?)
2. How would you define inquiry-based teaching for someone who Who is unfamiliar with the method?
3. How do student's best learn science? (Can you give an example of a lesson/unit that you taught where students really learned the concept?)
4. What do you see as the benefits and drawbacks of inquiry-based teaching?
5. What kinds of struggles have you faced in implementing this inquiry-based teaching? What kinds of successes have you had?
6. What are the ways you have implemented inquiry-based science in your classroom? (Can you give an example of a really great inquiry-based lesson that you taught? How did it go? What would you do differently next time?)

- I collected classroom documents including lesson plans, worksheets, handouts and student products. I paid attention to such details as planning of lessons, evaluation of plans, and how the teachers evaluated the success of the plans.

These sources of data provided insight into the teachers' belief structures. This addressed my research question concerning how these teachers' definitions of inquiry-based teaching were impacted by their beliefs about how students learn. I placed the beliefs in two categories for analysis: core and peripheral beliefs as defined by Haney and McArthur (2002). The core beliefs are defined as beliefs stated by and enacted by the informant. The peripheral beliefs are defined as beliefs stated by the informant but not enacted.

Data Analysis

I conducted data analysis by coding each case separately first and then conducted a cross-case analysis. In this multiple case study, the "within-case analysis" and the "cross-case analysis" (Merriam, 1998) occurred. The within-case analysis treated each case as a comprehensive case in and of itself. Then I did a comparative analysis between the three cases. While the individual cases provided thick descriptions of the implementation process for each teacher, the cross-case analysis was conducted to illuminate critical issues related to enacting inquiry-based instruction touted by reform initiatives. I analyzed the data using open coding as described by Strauss and Corbin (1990). The open-coding process is the process of breaking down, examining, comparing, conceptualizing, and categorizing data. I took the data apart by sentences or paragraphs and then listed them in related areas. The open codes from my data were "Teacher's

Definition of Inquiry," "Teacher Beliefs", "Successes with Implementation," and "Barriers to Implementation". Then, I used axial coding (Strauss and Corbin, 1990) to focus each category into subcategories that were more precise within the category. An example of a subcategory is "beliefs" that was broken into "core beliefs" or "peripheral beliefs". Then, I related patterns and emerging data and discussed my findings comparing it to the research of what is already known. Analysis of the cases show how these teachers' areas of enactment of inquiry-based teaching compared to the five essential areas of reform definition of enactment of inquiry-based teaching.

CHAPTER II

REVIEW OF LITERATURE

This chapter presents a theoretical framework for my study, a definition of inquiry-based science method and a review of relevant literature, that relates to teacher change, teacher beliefs and ties of these two areas to Science education.

Theoretical Framework

A framework for these three individual case studies is built from a combination of cognitive constructive and socio-cultural constructive perspective. According to Von Glaserfeld (1996), teacher's knowledge and beliefs about inquiry stems from cognitive constructivism. A cognitive constructivist view addresses the knowledge and beliefs of the knower, and maintains the preposition that knowledge and beliefs are continually constructed. A constructivist paradigm believes that the "view of the world [is] that multiple realities exist that are time and context dependent" (Guba & Lincoln, 1989, p.161). This framework holds the belief that knowledge is not something that exists as an entity that must be achieved, but that it is a constructed understanding that is influenced by surroundings and interactions. This framework is based on the belief that teachers' experiences and surroundings influence their understanding, in this case, of inquiry-based teaching. Keys and Bryan (2000) outline that "knowledge is not independent of the knower; knowledge is understanding physical and abstract objects in our experience"(p.633). The cognitive aspect of this study focuses on how the participants process knowledge through observation of implementation practices and through the participants expression of thought processes through interviews.

The socio-cultural aspect of this framework outlines that teachers are affected by their surroundings, and that they are situated, as they make sense and implement inquiry. This framework illustrates how participants are make sense of the reform initiative of inquiry. As the individual participant is constructs knowledge, he/she also teaching in social settings. Constructing knowledge and teaching practices are not exclusive, but interplay with each other. Keys and Bryan (2000) stated that "…a socio-cultural lens can be applied to research on inquiry-based instruction by examining how teachers implement inquiry within the cultural context of their local situations, and how tools, language and social organizations are used by teachers"(p.633).

There are recent ideas that all thinking and learning is situated within contexts that affect the learning process, and that the environment plays a large role in how knowledge is perceived and applied. Schwandt (1994) wrote that we live in a "complex world of lived experience from the point of view of those who live it"(p. 118). Putnam and Borko (2000) referred to this as a "situative perspective"(p.4) which is a socio-cultural way of looking at learning. The three social aspects of this perspective are outlined by Putnam and Borko (2000) as:

- Situated in a particular physical and social contexts
- Social in nature
- Distributed across the individual, other persons and tools

This perspective suggests that researchers look at how participants interact with their environments, administrators, other teachers, and students, and how they use tools in an everyday setting. Hall and Hord (2001) recommended that change is influenced by the context of the school, and that the individual teacher is the main factor in change. This socio-cultural constructive perspective encourages the researcher to look at the local setting for the implementation practices, and how the local environment of central office, administration, and other teachers may affect the implementation process. Researchers must look at how teachers are given information concerning implementation of inquiry, where they are trained, what kind of training they receive, and how they share this information with other colleagues. And last, this perspective asks the researcher to look at the individual classroom, how other people affect this classroom and the authentic activities that occur within the classroom. The authentic activities are ones, which occur on a regular basis and are defined as “ordinary practices of a culture”(Brown, et. al, 1989, p.34). This gives insight into how teachers are situated within and influenced by their environment. The socio-cultural lens of looking at the classrooms, where implementation of inquiry-based science method is implemented, will best serve using qualitative means of research. Qualitative means allows for researchers to study the social dynamics as well as how knowledge is constructed as it is situated within the daily occurrences of the classroom.

Definition of Inquiry-based Science Instruction

Inquiry is used throughout the National Research Council’s National Science Education Standards (2000). It is referred to in three contexts (Anderson and Helms, 2000):

- Inquiry as a descriptor of scientific research
- Inquiry as a type of teaching
- Inquiry as a mode of student learning

Inquiry, in this study, discusses inquiry as a type of teaching and relates to inquiry as inquiry teaching or inquiry-based science method. Some reference to inquiry learning is discussed, but is not the focus of this study. Inquiry teaching is explained in terms of what type of learning environment that the teacher creates. This methodology does not follow a one-two three step process, but rather the teacher creates an environment in which inquiry learning thrives. The National Research Council (2001) outlined five essential features of classroom inquiry.

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

Drayton and Falk (2001) outlined, in “Tell-Tale Signs of the Inquiry-Oriented Classroom”, that an inquiry-based classroom meets the needs of a world, in which, “scientific knowledge is expanding exponentially”(p.24). Inquiry teaching addresses the fact that there is “exponential growth in scientific knowledge, the central role in science of theory and evidence, and the diversity of the subject matter"(Drayton and Falk, 2001, p. 25). Drayton and Falk continued to explain that these five elements of an inquiry classroom will "emphasize[s] that science is the process of gaining knowledge (especially of the natural world), and that gaining knowledge is not the accumulation of facts but the development and enrichment of theories, explanations and rigorous stories about how the world works"(p. 26). And so, investigation is a "natural part" of the inquiry-based classroom, and student questioning is an integral part of the inquiry learning environment.

Haury (1993) explained inquiry-oriented science instruction as a teaching orientation that encourages students to investigate to satisfy curiosities, and that individuals involved in inquiry find they "construct mental frameworks that adequately explain their experiences"(p. 2). He wrote, "There is no authentic investigation or meaningful learning if there is no inquiring mind seeking an answer, solution, explanation, or decision"(p.2). The main goals of an inquiry-based classroom are for the student to retain content in a usable form, acquire skills in data gathering and analysis, and understand how the knowledge of the year's subject is created (Drayton and Falk, 2001).

The students in an inquiry-based classroom actively take a role in the classroom, collaborate with one another, and make the most of resources available to them to satisfy their curiosities. The classroom is an active place, in which, students have questions they need to answer, resources are available for their use, and students can communicate their findings. “An inquiry-oriented classroom is in some sense a culture” (Drayton and Falk, 2001, p. 27).

When looking at an inquiry-based classroom one sees:

- A “driving question” encompassing a real-world problem
- Investigations and artifacts that allow students to learn concepts, apply information, and represent knowledge in a variety of ways
- Collaboration among students, teachers and others in the community so that participants can learn from one another
- Use of cognitive tools that help learners represent ideas

(Marx, Blumenfeld, Krajcik, Blunk, Crawford, Kelly, Meyer 1994, p. 518).

Activities within an inquiry classroom may last part of one period, one entire period or multiple periods. Teachers sometimes choose the “driving question” or allow students to choose the question or the question is understood. The students often choose the best way to discover the answers by creating a workable plan for data collection and analysis. The methods of data collection, representation, and analysis will be to a degree a negotiation between students, with coaching or scaffolding from the teacher (Marx, et. al, 1994).

Students grappling with data is evidence that inquiry learning is taking place. Students collect evidence, evaluate evidence and/or record findings. Students actively engage in the learning process. The teachers also engage in the learning, modeling to the students how to investigate, grapple with data and explain hypothesis. The teacher is modeling the behaviors of a scientist within an inquiry teaching environment (Crawford, 2000).

The inquiry-based learning environment created by the teacher is conducive to inquiry learning and allows students to question, analyze, and explain data. The environment has an overriding question present as investigations occur, encouragement is given to students to collaborate, discuss and present findings.

Teacher Change

In this section, there is a discussion of reform initiatives that occurred in the last decade, how teachers make sense of this reform, and why there is a need to look at the day-to-day implementation practices of teachers.

Reform Initiatives

"The need for the systemic reform of science and mathematics education in the USA has become a national priority" (Beasley, 2000, p. 39). The community at large asks for fundamental change in the way that science is taught in order for its citizens to compete in the world. American students are compared with students all over the globe by international standards and fall short. The United States federal government began national curriculum reform initiatives beginning in the late 1950s (Fullan, 2001). Over the past decade, "unprecedented efforts to reform the quality and content of instruction in America's schools" (Spillane, Reiser, & Reimer, 2002, p.1) took place. Attempts to change the way education has worked delivered for generations, reformers and politicians are calling for drastic change in the methods teacher's use to teach. The National

Research Council produced several drafts of Science standards that were formulated by scientists, teachers, teacher educators, and others to begin making substantial changes in the way science is taught. Central to these standards in teaching science is "a focus on inquiry" (NRC, 2000) These standards refer to inquiry in terms of student inquiry learning and teacher inquiry-based teaching strategies.

Teachers' Sense-making

As the public calls for more intellectually demanding schools, teachers have the responsibility of taking the standards and applying them in their individual classrooms. Reform movements demand this, but give little practical information as to how it is to be done in these classrooms. Standards are difficult to put into practice and "…generally fall far short of the mark" (Anderson and Helms, 2000, p. 6). There is much research that outlines that reforms of this nature are difficult to implement (Anderson, et al., 1994). Little research has been done to outline exactly how and why it is difficult to implement, what percentage of teachers are successful at it, and how many actually choose to use it. (Anderson, 1998). Therefore, research needs to focus on daily occurrences within classrooms.

Spillane, Reiser, and Reimer (2002) or asked that the seldom-explored area of how teachers are make sense of this reform be investigated. These researchers outline a research agenda concerning how teachers are make sense of the reform initiative. They ask researchers to look at interaction of their existing cognitive structures (including knowledge, beliefs, and attitudes), their situation, and policy signals. The interaction of these three areas, according to Spillane, Reiser and Reimer help us to understand how teachers interprete reform initiatives.

Many researchers have discovered that to understand how teachers comprehend reform initiatives and begin applying them is often based on their own understandings, beliefs, and attitudes (Carey, 1985; Markus & Zajonc, 1985; Rumelhart, 1980; Schank & Abelson, 1977). Werner (1980) says successful implementation of new methods occurs if teachers share an understanding of "implied presuppositions, values, and assumptions which underlie a program" (p. 62). But the "process by which implementing agents come to understand policy, the understandings that result, and the consequences of those understandings for policy implementation are rarely analyzed explicitly in conventional implementation models" (Spillane, Reiser, Reimer, 2002, p. 5).

Often, teachers take information and categorize it in existing schemas and expect methodology to be one way and pay more attention to information that confirms this expectation (Klayman & Ha, 1987; Olson, Roese, & Zanna, 1996). Teachers may look at new reform initiatives and frame their understanding of those based on their "views of discipline, views of students, and ideas about what it means to teach science"(Spillane, Reiser, and Reimer, 2002, p.8).

These cognitive aspects of the teachers' understanding of reform may be based on what they know previously about the method. Teachers often try to assimilate new methods into already existing understandings of older methods which cause the new method to disappear (Flavell, 1963). For instance, when inquiry teaching is introduced to some teachers they see it as similar to hands-on and often it may take on a hands-on quality instead of an inquiry quality. The experience of the teacher is critical to understand what effect that experience has on implementation. Cohen and Weiss (1993) wrote that when research is used in policymaking, it is mediated through users' earlier knowledge. Teachers take what is already in their cognition and will apply it to guide new ideas and events (Rumelhart, 1980). Von Glasersfeld (1989) stated that this is an active process, not a passive process and is constantly working to be created. The teachers create their understanding as they process through the methodology.

The situation that teachers find themselves in affects the understanding of reform initiatives, as well. Their state education system, as well as their local system, influences implementation, and on a more specific level their individual classroom situations can affect the way they implement reform-based methods. Spillane, Reiser and Reimer (2002) called this "situated cognition" and wrote that the multiple dimensions of a situation influence the teacher's sense making and can be a critical component of how teachers implement a reform method. Some researchers argued that a closer look must take place these cognitive dimensions are situated for the individual (Brown, Collins & Duguid, 1989; Resnick 1991; Zerubavel, 2000). These studies are necessary to understand exactly how teachers understand the reform initiatives.

Looking at the teachers' specific situation helps to understand what is affecting these teachers' sense making of the reform initiative. Teachers' understandings which are situated within specific environments affect their understanding and these teachers' thoughts and actions are situated in schools that have norms, rules and definitions of the environment, both constraining and enabling action (DiMaggio & Powell, 1991; Scott & Meyer, 1991).

Often, teachers share information with teachers around them and this plays into their sense making (Stein & Brown, 1997). The organizational structure of their schools also plays into the teachers opportunities to share ideas about reform initiatives. The situative aspect allows researchers to observe if environmental factors, such as these, affect teachers' sense making.

Since what teachers are asked to do will influence their methodology, looking at policies that affect teachers' practice is important when considering implementation processes. National and State Education guidelines filter down to the individual classroom and observing what the teachers are doing daily illustrates how these guidelines affect their specific instruction. National and State standards may or may not be conducive to the methodologies being asked for by the reform movement. Haney and McArthur (2001) found the teacher's need to adhere to local science curriculum a major obstacle for several teachers trying to implement inquiry. Studying the individual teacher's situation and paying attention to their local, state and national guidelines sheds light on this area. "A cognitive perspective contributes to our understanding of implementation of policy by unpacking how implementing agents construct ideas from and about state and national standards"(Spillane, Reiser, & Reimer, 2002, p. 29).

Spillane, Reiser, and Reimer (2002) continued to write that along with this socio-cultural perspective that researchers must observe the teachers as their practice unfolds in their daily classroom and schools. They asked that in addition to looking at the teachers' knowledge structures and beliefs that researchers also explore their activity structures. Researchers should specifically look at classrooms in which teachers attempt to put inquiry-based science curriculums into practice. Studying teachers who are implementing inquiry-based scienceis “extremely valuable” (Keys & Bryan, 2000, p. 642) to inform others about the process. This allows researchers to observe the “emergence of teachers’…sense-making about reform science as situations evolve” (Spillane, Reiser, and Reimer, 2002, p. 5).

<u>Day-to-Day Implementation</u>

Observing classrooms of teachers who attempt to implement inquiry-based science gives the socio-cultural perspective described earlier. An approach of watching the classroom from the day-to-day perspective allows us to understand the implementation process as it unfolds in the local setting.

> As yet, we have little knowledge of teachers’ views about the goals and purposes of inquiry, the processes by which they carry it out, or their motivation for undertaking a more complex and often difficult to manage form of instruction(Keys and Bryan, 2000, p. 636).

According to Duschl & Gitomer, (1997), “Teachers’ view of teaching is dominated by tasks and activities rather than conceptual structures”(p. 65). Teachers base their understanding on what happens in the classroom and on their own personal stories (Krajcik, et al. 1994). Thus, research needs to be based in the real world setting of the classroom where implementation is occurring. It provides great insight for researchers to observe the daily tasks and activities that teachers are conducting. Research needs to be conducted in the settings where inquiry-based science is being implemented. “It also needs to be conducted in diverse settings with the full range of challenges education faces"(Anderson and Helms, 2000, p. 13).

Hall and Hord (2001) outlined that teachers are affected by their teaching environment and they referred to three concepts of climate:

- *Climate*- the individuals' perceptions of a work setting in terms of a priori established concepts that can be measured empirically
- *Culture*- the individually and socially constructed values, norms and beliefs
- *Context*- (Boyd, 1992) comprised of (a) culture and (b) ecological factors

(Hall & Hord, p. 194)

"These concepts are important for understanding change in organizational settings"(Hall and Hord, 2001, p. 194). Understanding the climate, culture and context help researchers draw a better picture of what occurs in the teacher's environment. Hall and Hord (2001) also explained that often the school may adopt the change, but the individuals actually implement the change. The school environment influences the work of the individual and organizations must value and support the individuals for the change to be effective. Researchers must pay attention to these areas to see if the entire learning environment is conducive for the teachers to change or if the environment actually creates barriers to change.

Researching in the settings where change is occurs gives information concerning barriers and successes that teachers have as well as allows for reformers to understand the best practices concerning facilitating change in similar situations. The individuals involved in change are one of the main reasons change initiatives either succeed or fail (Hall & Hord, 2001; Fullan, 1993). Day-to-day action of these change agents shed light on the forces that daily affect implementation so that an understanding of how teachers make sense of this reform initiative is better understood.

Teacher Beliefs

This section addresses the need for looking at teacher beliefs as an aspect of teacher change. It explores how others have viewed teacher beliefs, and how researchers need to observe teacher beliefs when implementing inquiry-based science method.

"Educational change depends on what teachers do and think-it's as simple and as complex as that" (Fullan, 2001, p. 46). Not only must researchers focus on the day-to-day activities in the classroom, they must also focus on the thought processes of the teacher before and during implementation. Krajcik, Blumenfeld, Marx, and Soloway (1994) outlined that for teacher change and teacher learning to take place, that not only the contextual factors of the classroom need to be observed, but

> teachers' beliefs, knowledge, and experience need to be taken into consideration, because these factors influence what teachers understand, what they adopt and how they implement changes (p. 489).

Not only are there barriers outside of the teacher that they have little control over, there are also internal dilemmas with how the teacher relates to the students, teaching, and the purposes of education (Anderson, 1998).

Many researchers wrote that teachers are the change agents for reform and that a change in teachers' beliefs must occur before implementation can be successful (Bybee, 1993; Cuban, 1990; Haney, Czerniak & Lumpe, 1996; Tobin, Tippin & Gallard, 1994). Other researchers assert that a change in teachers' beliefs structures may occur as a condition of actual implementation of reform-based methodology (Fullan, 2001, Hall & Hord, 2001, Morrison, 2002). Fullan (2001) argued that:

> the implications [to deal with beliefs] include the need for addressing them on a continuous basis through communities of practice and the possibility that beliefs can be most effectively discussed after people have had at least some behavioral experience in attempting new practices(p.45).

According to Anderson (1998), beliefs are formed as implementation is occurring and should be considered in the context of the "real world classroom". Fullan (1991) also suggested that change is a subjective process. Individuals will gain personal meaning from the "changes they experience".

> Adults bring to the learning situation a variety of experiences and skills, attitudes and knowledge; that they need to be convinced of the reasons for learning something that they want to control their own learning; that intrinsic motivation is most important…(Conners, 1990, p.21 and 22).

This effects how they accept the new knowledge of reform-based initiatives and what they do with that newly formed knowledge in their own classroom.

Keys and Bryan (2000) called for a research agenda focusing on teacher's knowledge and beliefs. They argued there is a gap in that the reform movement calls for change initiatives such as inquiry-based science method to be central to teaching science, yet, does not address how to change teacher beliefs to align with this reform agenda. Teacher beliefs are important as teachers implement new practices. How teachers feel about inquiry-based science has a direct effect on how they use inquiry in their classroom. If they agree with the premise of inquiry then that expedites their implementation of the method. Pajares (1992) wrote that beliefs are "the best indicators of the decisions individuals make throughout their lives"(p. 307). Belief structures play a key part concerning curriculum and instruction. (Nespor, 1987; Richardson, 1996). Nespor (1987) wrote that teachers rely on their core belief system when making decisions, thus this belief system needs to be understood in order to understand the teachers' decisions. Teachers belief system is complex, and teachers constantly make decisions based on their belief system. Teachers' beliefs influence such areas as knowledge acquisition and defining and selecting the task at hand (Clark, 1988; Nespor, 1987, Richardson, 1996).

Curriculum reforms are affected by teachers' beliefs and understandings of the reform (Bryan, 1998; Brickhouse & Bodner, 1992). Beliefs as to how science is best learned will affect how teachers implement inquiry-based science. If teachers see science as an objective body of knowledge that is best learned by following the "scientific method" (Brickhouse, 1990; Duschl & Wright, 1989; Gallagher, 1991), then, they will often not implement inquiry effectively. If teachers are more "problem-based" in their belief of how science is taught, then their approach to teaching science will be different (Brickhouse, 1990).

> Teachers hold personal beliefs that inquiry promotes the scientific thinking and learning autonomy they want for their students; yet, enacting inquiry is mediated by cultural beliefs, such as transmission and efficiency. These dual belief sets cause tension for teachers who are attempting to use inquiry-based instruction (Keys and Bryan, 2000, p. 636).

There is a large body of research that encourages researchers to continue to include beliefs when researching inquiry-based science implementation. The belief of the teacher has a direct affect on how inquiry is used in the individual classrooms. Haney and McArthur (2001) probed the questions "What are the beliefs of the prospective science teacher regarding constructivist teaching practices and are these beliefs consistent with subsequent classroom practice?"(p. 799). These questions brought attention to teacher's beliefs about the constructivist way of teaching as they implemented a new constructivist practice. It was discovered that "implementation of teaching beliefs relies heavily on the self-reflection of teaching behaviors as related to student learning"(Haney & McArthur, 2001, p. 799). As teachers observe what happens during the change process their beliefs may adjust based on their students' learning. Ladewski, Krajcik and Harvey (1994) discovered that teachers' beliefs about teaching and learning were important as they began implementing project-based science. Often, the dilemmas and barriers teachers face when implementing inquiry-based science method have a direct connection to their beliefs about students, teaching and the purposes of education (Anderson, 1998).

Ties to Science Education

As researchers explore teacher change and teacher beliefs in the realm of science education, a reform agenda emerges to help us better understand what areas are yet to be explored. As we read that reform calls for changes in the ways that teachers teach, and teachers begin to implement new methodology, such as inquiry-based teaching, we see that teachers have difficulty knowing exactly how to implement this type of teaching. Anderson and Helms (2000) outlined that:

> The results of research on reform do not give a definitive picture of…how teachers can best be engaged in reassessing values and beliefs and taking responsibility for acquiring new professional competencies, how to realize 'science for all'(p. 3).

These researchers call for a research agenda when studying implementation of inquiry-based science method. This research should:

- Be approached from multiple perspectives
- Be conducted in the 'real world'
- Focus on interventions into conventional school practice
- Not assume change can be driven from the top down
- Be interpretive in nature
- Focus on student roles and student work
- Give major attention to teacher learning
- Attend to parents' concerns

- Be approached systemically

Many other researchers call for a similar perspective when studying implementation practices of inquiry-based science method resulting in an agenda based in a 'real world' setting looking at the "language and conceptual tools of social, situated, and distributed cognition provid[ing] a powerful lens for examining teaching, teacher learning and the practice of teacher education in new ways" (Putnam & Borko, 2000, p. 12). Watching teachers in action gives insight into how teachers begin making sense of reform initiatives as Blumenfeld, Krajcik, Marx and Soloway (1994) discovered that "enactment proved crucial to developing teachers' understanding and advancing collaborative conversation"(p. 549).

Researchers must observe this developing understanding to see how teachers make sense of inquiry and implement it. This area must be approached from several perspectives and see exactly how each case is situated within the local environment, such as cultural factors, organizational factors, political factors and philosophical factors (Anderson & Helms, 2000).

Crawford (2000) wrote:

> Needed are more reports of studies that focus on the day-to-day events in the real world of classroom life. Everyday events are often left to the imagination of the classroom teacher ending in frustration from attempting inquiry-based strategies (p.918).

Conducting 'real world' observations allows researchers to see what the teachers face on a daily basis as they implement inquiry. Observers can see which factors help or hurt the process. The researchers can focus on teachers that change conventional school practices and watch the daily practices of the classroom to view how and if teachers work through their shift in roles from primary information giver to a facilitator of knowledge, and how and if they create a learning environment where the students are in charge of their own learning. Researchers can observe how teachers "confront their personal values and beliefs as they relate to the reforms recommended in the *Science Standards*" (Anderson & Helms, 2000, p. 10).

As researchers observe the day-to-day implementation process of inquiry-based teaching, successes and barriers may emerge in those particular classrooms. This may inform the argument concerning what encourages teachers to implement inquiry-based teaching and what proves to make it difficult for them to implement this strategy. Some of the successes teachers have with inquiry-based teaching is that inquiry engages students in the active search for knowledge (Igelsrud & Leonard, 1988). It has proven to demonstrate positive effects on students' cognitive achievements (Shymansky et al., 1983; Shymansky et al., 1990; Mechling & Oliver, 1983) (NSF). It is also seen as effective for disadvantaged or slow learners (Carpenter, 1963; Bredderman, 1982).

Many of the barriers that emerged in prior research are (Marx, Blumenfeld, Karajcik, Blunk, Crawford, Kelly, Meyer, 1994; Anderson, 1998):

- Teachers want to control their lessons
- Teachers trying to cover state or district curriculums find it difficult to use inquiry
- Time to do inquiry activities
- Teachers wanting to maintain order

- Teachers feeling unprepared to teach this method

As teachers face barriers, this will in turn affects their sense-making, and there must be an emphasis on teacher learning, in that researchers look at teacher beliefs and teacher thought processes, as they implement inquiry, and as they face successes and difficulties.

Conclusion

As the United States has gone through decades of reform, and standard-based reform has been emerged, teachers struggle to make sense of all of these reform initiatives and decide how to make them work in their own classrooms. As researchers watch this process teachers are going through, they can observe in a systemic way and provide real answers to inform the gaps in research concerning implementation practices. How are the teachers defining inquiry-based science? What aspects of teacher learning are affecting implementation? How are teachers situated in national, local and state teaching environments, and how does that effecting implementation? How are teachers addressing their belief systems and what effect does that have on implementation practice? This research must be approached from a situative perspective where researchers see “real teachers” in the “real world” with “real problems” and “real successes and/or difficulties.”

CHAPTER III

PROCEDURES FOR DATA COLLECTION AND ANALYSIS

Design of the Study

Underlying the research design was a basic assumption that a qualitative paradigm was more applicable to the study. Qualitative research is a form of inquiry that has philosophical assumptions "that reality is constructed by individuals interacting with their social worlds"(Merriam, 1998, p. 6). The researcher's view of the world agrees with Guba and Lincoln (1989) that "multiple realities exist that are time and context dependent"(p.161). This is an interpretive/constructivist paradigm that assumes that reality is constructed within a natural setting and is affected by the world around it.

In addition to the researcher's view of the world, the nature of the research questions led to the use of a qualitative paradigm. Patton (1990) outlined the type of research questions for which qualitative methods are appropriate:

1. The focus of the research is on the process, implementation, or development of a program or its participants.
2. The program emphasizes individualized outcomes.
3. Detailed in-depth information is needed about certain clients or programs.
4. The focus is on diversity among, idiosyncrasies of, and unique qualities exhibited by individuals.

5. The intent is to understand the program theory-that is, the staff members' (and participants') beliefs as to the nature of the problem they are addressing and how their actions will lead to desired outcomes.

When evaluating the topic and research questions, a match could be made between Patton's conditions for qualitative research, the topic and research questions used here. The topic of studying implementation of a teaching strategy of inquiry-based science is nested within an educational context that is affected by environmental conditions, as well as, individuals implementing the strategy. The research questions posed were "how" and "what" questions, which focused the research on the process of implementation. The questions were also designed to look at the individual teachers and give detailed, in-depth information about the implementation process. The design of three case studies looked at three separate individuals, the idiosyncrasies of, and unique qualities of each, as well as, the teachers' belief systems. These case studies employed qualitative data collection procedures in order to answer the following research questions:

1. How do teachers define inquiry-based teaching?
    a. How do these definitions change over time?
    b. How are these definitions impacted by their beliefs about how students learn?
2. How do teachers who are transforming their practice from traditional methods of teaching enact inquiry-based teaching?
3. What are the factors that enable the teachers and factors that hinder the teachers from enacting inquiry-based teaching?
    a. How do these factors change over time?
4. What are similarities and differences between the teachers' definitions of and factors with inquiry-based teaching?
    a. What might explain these similarities and differences?
5. How do the hindering factors and enabling factors of the three teachers inform other researchers?

This study was based on case study as defined by Merriam. The study was designed as three individual case studies followed by a cross-case comparison. As the research topic and questions dictated a use of qualitative methods, case study as defined by Merriam was appropriate for the view the researcher held of the world. The process of implementing inquiry-based science method is best understood through a thorough, descriptive study of what was occurring as these three teachers attempted to implement this method. A research study designed with three case studies was chosen over one case study of the department because the three participants were at various stages of understanding and enacting inquiry-based science method, and since the entire science department was not enacting inquiry-based science method.

Merriam (1998) defines case study as a case or unit, around which there are boundaries, which might be selected, because it is an instance of some concern, issue or hypothesis. She explains that a case can be "fenced in", and you identify what you will study. Merriam further separates case study into three special features: particularistic, descriptive and heuristic. Particularistic means that this study focused specifically on the implementation of inquiry-based science method. This focused my study specifically on this method, and the effect implementation had on the teachers' beliefs and practices. My study was descriptive, in that after observations, there was thick descriptions of everyday occurrence, so that patterns emerged, and as many variables and interactions as are evident may be seen. This case study approach that I took was heuristic, in that the reader should understand the teacher enactment process better, and confirm what is known, and discovered new meaning in this area of study.

In conclusion, a qualitative paradigm and qualitative methods were used for this study because the researcher was concerned with:

- Process, rather than outcomes or products
- Meaning, how people make sense of their lives, experiences, and their structures of the world
- Data collection, the primary instrument being the researcher
- Fieldwork, where the researcher physically goes to the people, setting and site to observe or record behavior
- Descriptive research of the process, meaning and understanding
- Inductive research in that the researcher builds abstractions, concepts, hypothesis, and theories from details.

(based on Merriam, 1994)

Methodology

The study consisted of three cases and was chosen based on:

- Geographic practicality and accessibility
- Access to respondents and respondent data
- Follow up to an individual case study of one of the cases from the previous year

Districts and schools were contacted to gain consent for site participation in the study. Key participants were identified and approached for consent. In each case, an initial interview occurred, at least five observations took place, with follow-up interviews to the observations and a final interview.

Figure 1. Methodology Chronology

1. Identified the school site based on previous study.
2. Spoke with the district curriculum director to gain access to the participants.
3. Spoke with the principal of the proposed site.
4. Identified the previous participant as a participant in this study.
5. Identified three other participants in the same department.
6. Spoke with curriculum director by phone about the districts goals.
7. Scheduled interview dates with participants
8. Conducted initial interviews with each participant.
9. Conducted observations of the individual classrooms.
10. Conducted follow-up interviews of the observations.
11. Attended a department staff meeting.
12. Conducted final interviews with each participant.
13. Transcribed each interview.

Role of the Researcher

The researcher was familiar with inquiry-based science instruction from previous research in student-centered teaching strategies and an exploratory study in one of the classrooms involved in this study the previous year. The researcher knew one participant prior to the study but did not know the other two participants personally. She had not worked at the chosen research site or with any of the participants.

Selection of Sites

The researcher selected the site as a follow up to the researcher's previous year's case study of one of the participants at that site. The researcher conducted a case study the previous year with one of the participants who began implementing inquiry-based science instruction. The researcher selected the same participant and two other participants in the same department to conduct three individual case studies and a case study comparison to see if the findings from the previous study were similar. The site was also a reasonable distance for the researcher to travel and from which to collect data.

Context of the Study

This study was set in a rural high school of with 925 students. The high school had 1% of its population involved in advanced college preparation courses and 20% in career and technical courses. 26% of its students took the SAT. The year this study took place the school met its expected growth on the state report card but did not exceed expectations on end-of-course testing.

The central office curriculum director set the "student-centered classroom" as the curriculum emphasis for the past year and the present school year. The teachers in this high school were being asked to incorporate student-centered methodology into their classroom on a regular basis. The principal evaluated teachers' enactment of this method through observations. There was also a survey given to the parents of their students at the end of each semester which asked questions such as:

- Does your child's teacher use other methods of teaching than lecture?
- Does your child's teacher use student-centered activities in their classroom?

The principal observations and the surveys were designed to insure that teachers were using student-centered activities. The teachers in my study chose to use inquiry-based science method as their student-centered methodology. The teachers have had system-wide training in student-centered methodology. There was an expert teacher in the school other teachers used as a reference for student-centered methodology. The department was working through its own resources, such as handouts and the Internet, to develop a better understanding of inquiry.

There was little professional development available in inquiry-based instruction from the school system. Kathy had attended an inquiry workshop in another town. She then encouraged others in her department to begin using inquiry as she also began implementation.

The teachers were located in a new science wing of the school in which a storage area connected each classroom to another. There was a science classroom, then a storage area, then another science classroom and another storage area. Each of the classrooms had doors that opened into the storage area from inside the classroom. The teachers could open their adjoining doors and see straight through their classrooms.

Selection of Participants

The three chosen participants were each in different phases of the enactment of this method. One teacher was a novice at inquiry. He had previously lectured, but was beginning the process of making sense of inquiry and enacting it. When I asked him about inquiry in his classroom. He said, "I have never used it but I am going to try. I know it's going to change my life. You can observe it anytime you want to. I really don't know what I'm doing yet."

The second teacher began enacting inquiry teaching last year and continued to enact it this year. I completed a study in her classroom the year previous to this study. She had always used a lecture and lab method but was encouraged by her principal to begin inquiry in her classroom. The more she used inquiry-based teaching, the more comfortable she felt with the strategy. She felt the students were motivated to learn with this method, and that she accomplished as much as she had in previous years using lecture. Her understanding of inquiry developed as she enacted it in her classroom, and her chosen method of lecture and lab began to change. She was excited when her test scores were raised with this method. She said she would never go back to lecture, "And I could not go back to lecture and the old way."

The third teacher was an expert teacher. He used inquiry for several years and was "Teacher of the Year" last year in this school. The method of inquiry he described was very similar to reform-defined inquiry, but he did not call it inquiry. He taught ecology and honors science courses and planned on doing numerous inquiry lessons and projects.

I purposefully chose these three teachers for my study because each were in different stages of understanding inquiry-based teaching. They enacted it in their classroom, and they were individually grappling with an understanding of the method. This informed my study and gave insight into how these teachers, in a real world educational setting, got inquiry information, made sense of it, and enacted it in their classrooms. This information answered questions about how to begin the science education reform movement in individual classrooms.

Data Collection

Data was collected during interviews, through observations, and observations of teacher lesson plans and student work. In addition, two phone interviews were conducted with the district's curriculum specialist, as well as, e-mail conversations concerning the district priorities about inquiry-based science method. The researcher also attended the teacher meeting that occurred in the science department that semester. Two meetings were cancelled due to field trips and snow, so that there was only one during the fall semester.

Merriam (1998) stated that triangulation of data is important to draw a complete picture of what is happening in the case. Thus, the researcher chose to conduct interviews, observe the classrooms and view the participants' lesson plans, as well as collect student work products. The observations and documents were used to verify or contradict what was said in the interview, as well as give the researcher a stronger picture of what actually took place in the classrooms this semester. The observations also gave the researcher a point of reference when asking follow-up questions after the observations to clarify points within the observed lessons.

Although the researcher used grounded theory to allow data to emerge during the observations, there was a focus for the researcher in areas important to her study. Merriam (1998) wrote a checklist for observers to help focus observations since it is impossible to observe everything within the classroom:

- The physical setting: What is the physical environment like? What is the context? How is space allotted?
- The participants: Describe who is in the scene, how many people, and their roles. What brings these people together?
- Activities and interactions: What is going on? Is there a definable sequence of activities? How do the people interact with the activity and with one another?
- Conversations: What is the content of conversations in this setting? Who speaks to whom? Who listens? Quote directly, paraphrase and summarize conversations. Use a tape recorder to back up your note taking.
- Subtle factors: Less obvious but perhaps as important to the observation are

  Informal and unplanned activities

  Symbolic and connotative meanings of words

  Nonverbal communication

- Your own behavior: You are as much a part of the scene as the participants(p. 97-98).

This checklist was the researcher's reference as she made observations. The researcher’s role in observations was an “observer as participant” as defined by Merriam (1998). The researcher’s observer activities were known to the group; participation in the group was definitely secondary to the role of information gatherer. The researcher observed the classrooms and her primary role was to record what took place within those classrooms. She was able to walk around the room and listen to various conversations, based on the nature of the classes, and ask students questions as they conducted classwork. The researcher also had conversations with the participants as class was taking place.

Interviews were based on the following interview protocol, which was developed by the researcher and Dr. Heidi Carlone, Department of Curriculum and Instruction at the University of North Carolina at Greensboro, based on a review of teacher learning and inquiry-based science method as described in Chapter 2.

1. Do you feel that this lesson was a good inquiry-based lesson? Why or why not?
2. How did the students respond to this lesson? (Probe for evidence).
3. What are parts of the lesson that worked well and parts of the lesson that did not work well? Why do you think this occurred?
4. If you did this lesson again how would you change it?
5. Have you discussed using inquiry-based science method with other teachers in this department informally or during departmental meetings?
6. If so, what sort of things did you discuss?

Formal interviews used the following open-ended protocol:

1. Tell me a little bit about your science teaching history and experience. (How did you get to be a science teacher? How long have you been teaching? What attracted you to science?)
2. How would you define inquiry-based teaching for someone who Who is unfamiliar with the method?
3. How do students best learn science? (Can you give an example of a lesson/unit that you taught where students really learned the concept?)
4. What do you see as the benefits and drawbacks of inquiry-based teaching?
5. What kinds of struggles have you faced in implementing this inquiry-based teaching? What kinds of successes have you had?
6. What are the ways you have implemented inquiry-based science in your classroom? (Can you give an example of a really great inquiry-based lesson that you taught? How did it go? What would you do differently next time?)

Procedures

The initial interview with Kathy was given on September 22nd, and the final interview was conducted on December 17th. The classroom observations were between these dates. There were five observations, which lasted the entire period and follow up interviews, which were brief, occurred after each observation. The researcher was in Kathy's classroom more often than these times for brief intervals, chatting with Kathy and making informal observations of her classroom.

The initial interview with Kurt was given on October 15th. This interview had been delayed because of Kurt's involvement in football at an earlier agreed upon date. His final interview was December 18th, and five observations occurred between these dates. The researcher made other observations, but upon discovery that Kurt had only planned lecture for those dates, the researcher decided to come back when the class being observed would better inform her study. Follow-up interviews occurred after each observation.

The initial interview for Jeb was October 2nd with the final interview being December 18th. The five observations occurred between these dates and follow-up interviews were conducted after each observation. The observation on October 9th was disrupted because there was an accident that occurred in front of the school and was visible from the classroom. The students observed the accident and much of the conversation of the class involved this accident. The observation on December 16th was disrupted because the students had been out for snow for four days, and the guidance office asked to use a majority of the class for information on the AP exam.

The researcher attended a departmental science meeting on December 2. There had been two previous meetings scheduled but were cancelled due to a field trip and weather. This meeting informed the researcher how teachers within this department shared information and what type of information was shared. It also gave the researcher a better understanding of the climate of the department and school as the teachers are situated.

Data Analysis

Data analysis can be overwhelming for qualitative information gathering. Creswell (1994) and Merriam (1998) provided a guideline for this study's data analysis. Both authors described qualitative data collection and analysis as simultaneous activities with constant comparisons occurring throughout data collection. Glaser and Strauss (1967) described this technique of constant comparison as a basic strategy of looking at a particular incident in an interview, field notes or document and comparing it to another incident. This allows for the researcher to view immerging themes in the data and see if reoccurrence of the same idea happened. The researcher collected information such as interview notes, observation notes and lesson plans and compared those finding emerging categories. This constant comparing developed the categories of teacher definition of inquiry-based science, teacher beliefs about how students best learn, teacher successes with implementation of inquiry-based science, and teachers' barriers to implementation of inquiry-based science. These categories coincided with the researcher's research questions. A category that also emerged was a category about how the teachers actually implemented inquiry-based science method in their classroom. This category often cut across the other categories of definition, beliefs, successes and barriers. The simultaneous analysis that occurred with data collection also drove the questions in the follow-up interviews. Interviews were conducted to answer questions the researcher had about the observations.

Each case was analyzed separately, and then a cross case comparison was made based on the categories that emerged in each case that were similar across cases. Merriam (1998) wrote that a *within-case analysis* can occur first and a *cross-case analysis* can begin later. This cross-case comparison looked at themes that may occur across the cases, which may be similar. Merriam warns that when looking at cross-case comparisons, individual attention must be paid to the way in which each case is situated. That is why the researcher analyzed each case separately first and then compared cases.

The researcher transcribed the initial, final and follow-up interviews in each case. The researcher took notes during observations and the teacher meeting. The researcher audio-taped the interviews and observations and used the tapes for any concerns of clarity in the researcher's notes of the observations.

The researcher highlighted each category of definition, beliefs, successes and barriers in different colors throughout the transcriptions and notes. Qualitative research must show enough detail for the reader to be able to see the case clearly and so the researcher's conclusion will make sense (Cresswell, 1994; Merriam, 1998). The researcher is then asked by Cresswell and Merriam to break down this large amount of research into an easier understood schema. Marshall and Rossman (1989) referred to this as "reduction". The researcher highlighted the data concerning the teacher's definitions of inquiry-based science method in light blue, the teacher's beliefs in dark blue, the barriers in red and the successes in yellow. These highlighted colors were then cut and pasted onto a separate document for an easier read. Table 1 illustrates examples of the data analysis:

Table 1 Examples of Data Analysis

	Kurt's Case	Kathy's Case	Jeb's Case
Teacher's Definitions of Inquiry-based Science Method	"Well, I was fairly unfamiliar with it and so. And find it's a great way to get kids to know what's going on because they are going out and finding it themselves."	"That's not really inquiry, so that's where I was misled at the beginning of all this."	"With an inquiry approach you would give the students a task to perform and the equipment to perform it with but that would be all. They would have to come up with an entire method on how to

			do that. A guided inquiry type activity you would give them clues or hints as to what direction they would go in."
Teacher's Beliefs About How Students Best Learn	"It's a good way to present a lot of science. Especially with younger kids, middle grades to teach them science."	"I want them to be able to think their way through anything."	"By experiencing it…That's the whole scientific processes is the experience."
Successes With Implementation of Inquiry-based Science Method	"They realized there was an order to it. And the questions were to lead them to figure that out if they did the work they were supposed to. Everybody did seem to get it. They realized that on this row it was the same and across this period."	"They're not afraid to take chances now."	"Then it provides ownership and any time they take ownership they tend to be more focused on it and more willing to work harder to come up with a solution. More involved, they learn more because they feel like they have a bigger stake in it. That's probably one of the biggest things."
Barriers to Implementation of Inquiry-based Science Method	"The problem is they'll let the other person do it if that person accepts doing all the work."	"I want to teach them how to think…but the honors kids don't like to do that."	"It's difficult, especially well you go to workshops and you hear everything and think I'm going to go back and do this in my classroom and you realize this is hard. It takes a lot of time."

Another category emerged as data was collected and analyzed entitled implementation practices. This category began cutting across other categories in that the beliefs and definition were confirmed or contested based on how the teachers were implementing inquiry.

Table 2 Implementation Practices

	Implementation Practices
Kurt	Began the semester with some hands-on activities such as making booklets and the periodic table; Ended the semester with the students entering imaginary submarines and conducting experiments and talking with real scientists.
Kathy	Began the semester with some hands-on activities, such as making posters and some inquiry activities such as bottle projects. Ended the semester with some hands-on activities recipe cards and some inquiry activities such as eggshell lesson.
Jeb	Began the semester with inquiry activities such as bottle projects and ended the semester with inquiry activities such as video lesson and investigations.

Trustworthiness/Generalizability

No reliable, valid measures were used in these case studies, however each case was interviewed using the same interview protocol and one researcher gathered all data. Even though three cases were used in this study, the generalizability was limited, due to the qualitative nature of case study and the small number of participants. Triangulation was provided in each case through interviews, observations and documents.

CHAPTER IV

RESULTS

Kurt/The Skeptic

Background and Classroom Environment

"He was the last one of us to change his style of teaching," commented a teacher in his department. "You can't teach an old dog new tricks," was his philosophy about teaching. He felt like being a veteran teacher of 20 years, 19 of which he had taught at the school in which he was now teaching, that he was too old to try new styles of teaching. He had been a Biology teacher for many years, and over the previous two years he had added teaching Chemistry and oceanography to his teaching load. He said he was going to give inquiry a try because the other teachers in his department were so excited about it. Being the school's head football coach, he felt that he did not have a lot of extra time to invest in learning new ways of teaching and felt comfortable using lecture. Another teacher in his department described Kurt as, "very intelligent. He enjoys talking and lecturing to the kids. He is very personable, so the kids don't mind when he lectures." Kurt had always wanted to be a teacher because his parents were teachers and then administrators. He described the teaching profession as, "a great way of life."

Kurt admittedly had used lecture as his primary teaching style and felt that he was too old to learn anything new. "I'm not really into [new teaching styles] but my brother, he's really into teaching. I've been doing this twenty years. You're teaching an old dog new tricks with all of these new things." He decided to try inquiry projects in chemistry and stated that he wanted to use only inquiry projects in his oceanography class, without using lecture. Since he would be using inquiry-based teaching in his classroom daily, he did not limit me to an observation time or day. He encouraged me to observe any day because he wanted to be conducting inquiry teaching each day in this classroom. He said that trying to do inquiry was difficult for him due to the fact that he was a disciplinarian and liked to maintain order in the classroom, and he saw inquiry as students moving about in a disorganized fashion. "I'm disorganized, and at the same time I want some kind of order in the classroom. That makes it hard on me," said Kirk.

In this case, I outline Kurt's continued skepticism, as he tried to break out of his lecture shell by setting up class periods with more student-centered activities and more hands-on assignments. These assignments began to resemble the reform-based movement's definition of inquiry as he approached the end of this semester. His definition of inquiry stayed basically the same from his initial interview to his final one but the way in which he implemented inquiry changed dramatically from the beginning of school to later in the semester.

In the following vignette from my research notes, I outline what a typical class period included in the beginning of the oceanography semester. This was a senior honors course Kurt had taught for a couple of years:

Kurt's classroom contains eight lab tables with two or three chairs per table. At the sides of the room are sinks in tables connected to the walls and stools behind the tables. Near the front of the room there are two chalkboards and a pull down screen in front of an overhead projector. A periodic table is the only decoration on the wall. The rest of the walls are white with cabinets along them..

The students enter slowly, returning from lunch into the room as the bell is ringing. Some students arrive later, saying they were in the restroom. Each class period I observed there were some students who arrived late to class. Students entered talking to each other and moving to their seats, while Kurt was in the storage room. Most of the students made it into the room and in their seats about five minutes into the class period. Some of the students opened their textbook while others talked to each other.. Kurt entered the room about this time. He proceeded with class by saying:

> *"Turn in booklets. Some of you don't have them finished yet. Get them in as quickly as you can. We'll take a few minutes to see if you get these ideas in your booklet, so we can have a test in a day or two."*

The booklets had been assigned the previous week, when Kurt had handed out these directions:

OCEANOGRAPHY SUMMARY ASSIGNMENT

CHAPTER 3: "The Not-So-Rigid Earth"

Imagine that you have just been asked to write a children's book to explain "The Not-So-Rigid Earth." The book should be written for students between grades 3-5. Try to think back to the time when you were this age and incorporate information and formats that would have appealed to your interests and abilities.

Your book should include the following:

Informative Cover

Title Page

Table of Contents

Information in the following areas:

Layered structure of the earth

- *Internal layers*
- *Lithosphere*
- *Asthenospere*

Movement of the continents

- *Continental drift*
- *Pangaea*
- *Seafloor spreading*

Plate Techtonics

- ***Major lithospheric plates***
- ***Movement at plate boundaries***
- ***Subduction***
- ***Examples of features formed at plate boundaries (4 minimum)***

Be creative in presenting and summarizing the information. Your finished book will be evaluated for :

Content (accuracy and thoroughness)

Correct spelling and grammar

Neatness

Creativity and use of color

The teacher continued with class by asking the students to turn to page 86 in their text, and students were told that they would be allowed to use the booklets they had made on their upcoming test.

"Make sure you have your booklets turned in by tomorrow," Kurt continued to say. "Jon has something a kid can get excited about, a pull-out model of the earth. Then there's a map that no kid would get in the world. They aren't bad, most are pretty good."

Kurt continued class by involving students in a discussion of the inner core of the earth, talking about the size and make-up of the core:

Kurt: "How thick is the inner core?

Student: "It is a small area."

Kurt: "What's the radius of the earth?"

Student: "640 some."

Kurt: " Not just the core, but the earth?"

Student: "Does it tell us?" [referring to the textbook]

(Various students answered and joined the discussion. Some students did not participate in the discussion at all.)

Student: "Wouldn't it be all of the numbers added together?"

Kurt: "Yes….6370 kilometers is the thickness of the earth. What did we say was the radius of the core?"

Students: "1,070 kilometers."

Kurt: "1,070 kilometers."

Kurt put these amounts on the overhead and interrupted his lecture to talk to another teacher who had entered the room. Discussion of this nature, with Kurt asking questions and giving facts while the students responded, continued throughout the 90 minute period. Kurt periodically wrote figures on the overhead.

This vignette was representative of how most of Kurt's early semester class periods proceeded while using hands-on activities. Many days when I came to observe him, Kurt still lectured and held whole group discussions, rather than implementing any type of hands-on or inquiry lesson. He tried various projects that were hands-on, but not necessarily inquiry teaching, but late in the semester Kurt's class structure began to change. The vignette below described a class period in an eight-day assignment in which his students were involved. This occurred as the semester was coming to a close in December.

Students entered the classroom and began creating individual submarines, by moving tables, and chairs and aligning them within masking taped lines on the floor. The students had marked these spaces off earlier in the week. There appeared to be about eight submarines, and Kurt moved students into groups. Each sub contained three or four students. They had chosen prior to class which group they wanted to be a part. Kurt began with:

"Now you have three in your subs. What happened to your sub space? Think about it. Get out what you did yesterday…. Datasheets that were sent up to Atlantis…Focus for one week… Looking at your data sheet."

The data sheets had various numbers representing temperature, time and pressure. Students retrieved sheets and packets of information from their notes.

"In your groups, find a question [that can be answered] for each column."

Some of the student questions were: 'How does time affect temperature?' 'How much did it change in 13 seconds?' 'What is the average pressure?' Students continued to come up with questions and look over their data. Kurt walked around the groups and spoke to students about various aspects of the submarine and submersion, such as the size of the submarine, how long it takes to descend, and why no shoes could be worn in the submarine. The students conversed with Kurt about possible answers to the questions they had written in each column. The students sought information from their brochures and talked with Kurt as he walked around the room. They also talked among themselves.

This assignment continued for several days as the class gathered data from charts, looked up information, and asked questions. The class seemed to be motivated to participate and excited about the activities. They asked numerous questions and many discussions occurred during these lessons. All of the students participated in the activities, and at the end of the week, they had a tele-conference call with scientists that had actually traveled deep under the ocean. The students were able to ask the scientists questions that helped them to see if they were correct in their conclusions from this activity. Kurt was very excited about this activity. He spoke about it in a follow-up interview:

> *This was a great experience…I thought the sub was a real good idea because it does give them an area of confinement…At least they know what it feels like to be working in that space. It did work. The ones that got to talk to [the scientists] thought it was great.*

There was evidence, from these vignettes, that Kurt attempted to incorporate not only student-centered, hands-on teaching in his classroom, but that the classroom was moving toward an inquiry-based teaching classroom, with characteristics present, such as beginning with a dilemma, having the students decide what they wanted to study, allowing the students to grapple with data and make conclusions, and relating what they are doing to a real world situation (Crawford 2000). The tele-conference with the scientists made the real world connection for the students tangible. Even as Kurt's stated definition of inquiry-based teaching remained constant, his implementation of the process of inquiry teaching changed drastically.

As he neared the end of the semester, he was able to take spin-off lessons from these inquiry activities and continue to incorporate them in other lessons. For example, he asked the students to come up with organisms that they felt would survive deep under the ocean, based on some of the conditions they found. The students were asked to look at the following categories for survival of their organisms: food needs, water needs, oxygen need, reproduction needs, defense/protection ability. The students within each submarine were to describe one organism, draw a picture of it, and explain it to the class. They were to explain why and how they thought the organism would survive under the ocean. This activity illustrated that Kurt was able to take the inquiry-teaching approach and apply it to other lessons. He felt this was another way to reinforce what they had learned with the submarine lesson.

> *They loved the idea of [organisms that survive that far under the ocean]. They were interested and some came up with some [organisms] that they didn't know [actually] existed, …They didn't know that they existed, but I showed [the organisms] to them. I was kind of amazed by that…and that was another thing [this activity allowed] you to find out who your leaders are, who takes charge…This is a good way to go, especially with higher level kids that are moving on…*

<u>Definition of inquiry</u>

Kurt's definition of inquiry at the initial interview was,

> *It's a great way to get kids to know what's going on because they are going out and finding it themselves…it's a good way to present a lot of science. That's probably the best way to learn it. It's kind of like life…Hands-on is the best way [to learn science] and this is hands-on. I think it's a great way for the young…middle grades, maybe…[it's good to teach] study habits to [those getting] ready for college courses…you can do this with anything. Don't leave things vague…Make sure it's straight forward.*

He spoke frequently about hands-on activities as characteristic of inquiry, saying that students learn best by hands-on methods and that inquiry can be trial and error. He felt he could try lessons and continue to use them in future semesters if they are successful. He alluded to students participating with lab reports, making their own observations and then discussing those, although I did not see any in my observations. He felt inquiry was “play” and the students “play” with information on their own and then facilitators guide them and make sure they are on the right track.

He stated several times that inquiry-based teaching was an activity where teachers do not lecture and do not give out a lot of information, but give them activities that cause them to conduct research, either on the computer or by reading the correct answers in a textbook. He spoke of one activity in his initial interview that he felt worked well. He defined this activity as inquiry.

> *The periodic table, I felt, like they really got, because they had to make their own periodic table. They made each of the boxes on the periodic table. They had all the information on the back of it, and I left some of them blank and told them they had to find that information and find what terms we were going to need to know. The, I gave them 50 questions they had to answer once they made the periodic table. And, by doing that they started picking out that this thing had some rhyme and reason to it, and it was not just a big picture with a bunch of letters and things. They realized there was an order to it…*

He did not speak of students who formulated their own questions and developed ways to answer those questions until near the end of the semester. But, when I observed class periods near the end of the semester, Kurt asked students to develop two questions prior to reading an article for information, as described here:

"Read through page 182. Come up with two questions and write them down. I want you to speed read through them."

The students read pages and wrote two questions each, and then they are found the answers to those questions in the article.

"The next thing you are going to do is go to the iceberg section, but finish the two questions first."

The students continue reading the pages.

Kurt stated that in contrast to lecture, inquiry teaching used little speaking on his part, as the teacher. He stated that it was more group activities and thinking maps where students organized information before a collective discussion. He spoke several times about using computers during inquiry activities and felt using technology was vital in conducting inquiry activities. He said,

> *Kids go out and find it [information] themselves…I let them go find it, let them present… and do projects and figure out on their own, and then you guide them…and then we come back and talk about it. [It's] more like a college situation, where they have to find the information. I give them some things that add to it. It seems to work.*

He also said,

> *The only way you can do it is if you have computers. The topics would be there so they could get to a different source. They end up getting somewhere else,… It's amazing, you get them in a computer lab and give them an idea or topic and they'll have ten different places they are looking.*

By the end of the semester, Kurt's definition had changed little:

> *Well, it's allowing the students to find information ahead of time, before you give the information to them. That's how I feel it works and…[it] works in a mature group…and see if you can [push them] a little further. Make them inquire.*

Kurt felt late in the semester that it not only worked with middle school, but that the mature students preparing for college should be taught through inquiry. He said that college prep students needed to understand what it would be like to "…be a student a little later in life, as they get older."

Although he had not quite formulated a changed definition of inquiry after these activities described in the previous vignettes, it was obvious that his implementation of inquiry teaching moved from just student-centered activities to containing more characteristics of the reform-based definition of inquiry-based teaching. He changed the way he set the class up, the way he involved students, the way he asked questions, and the way he followed up on their answers. Kurt's inability to describe inquiry in terms similar to the reform movement's definition was not unusual according to research which states that teacher's often describe inquiry as "doing science", "hands-on science", and "real world science" (Crawford, 2000). Crawford states that teachers' definitions often get muddled when trying to implement inquiry-based science teaching.

Implementation of Inquiry-based Science

Kurt's initial attempts at introducing inquiry teaching coincided with his early definition of it. He stated that he felt it was hands-on activities and any activity in which the students had not been given prior information. Activities that allowed students to find information on their own, he considered inquiry activities. Kurt felt the teacher should set up the situation and then let students discover meaning on their own. He said,

> *You get them in a computer lab and give them an idea or topic, and they'll have ten different places they are looking. All of them have different information. I think that is a big step.*

He went on to describe inquiry teaching as,

> *I give them some information. They go find it… We won't talk about it a lot. [It's] more like a college situation, where they have to find the information. I give them some things that add to it…let them figure out what happened, and they can go research it. They can research it ahead of time.*

Most of the early semester activities were projects such as the booklet project. He assigned posters to describe things such as solids and liquids. He had the students construct charts such as the periodic table and then discover how the elements were related. When asked about inquiry, Kurt would describe hands-on activities.

> *I taught this chemistry lesson about the periodic table. They did it from scratch, the periodic table, making their own and …seeing relationships in it and they did that and the light bulbs went off and you could see they are getting why this periodic table is not just a chart. The teacher told them to look at it and it has a purpose and if they used it, you knew more about the world around you…*

Often, when he was unprepared to do a hands-on assignment, he would involve the whole group in lecture and discussions. As December brought the end of the semester, Kurt began experimenting a little more by providing videos and readings for the students, and he would ask them to develop questions prior to viewing the video or reading an article. But, he did not allude to questioning as part of the inquiry process in his interviews.

In his final interview, he continued to describe his implementation of hands-on projects as inquiry projects:

> *Interviewer: What are ways you have implemented inquiry-based science in your classroom? What are some different ways?*
>
> *Kurt: Making posters ahead of time, with solids and liquid posters. [They] need to make a poster including traits, and you give them guidelines and say, "Find this information." They make a poster, and we talk about it. We did it with bonds and we did it with the booklets with liquids. We don't spend a great deal of time lecturing. I say, "This should be in your packet, if you've done your booklet and your poster." We get a lot covered and they're responsible. If they don't have it they either go back and get it or they're not going to have the information when they are* tested.

<u>Perceived Successes in Implementation</u>

> *Well, the benefit is that when you put a kid that has the ability, it puts them in a spot where they have to find the information. If they're motivated, and grades and education is important than they're gonna do it. It's gonna teach them. They're gonna learn and probably learn more than you could have given them, because they're gonna find information you did not plan on doing.*

This was Kurt's explanation of students who were motivated to use this method to become successful. He said that inquiry-based teaching was a great way to allow the students to discover knowledge on their own. He said it was better for teachers to provide information for the students to study, than presenting it to them in lecture.

He felt this way was better because students that were motivated could choose their own way to find the information and everyone does not have to learn it the same way since they are learning it on their own. He felt this was vital because everyone learns differently.

> *They get to choose the way they want it and everybody learns it a different way. Some of them can find ways that they get the information in ways that they enjoy more than other, other ways. And that's a big benefit and gives those kids, don't lecture let them find it… It makes it a little easier on the teacher. It puts responsibility on them, it teaches them about how it will be a to be a student later in life as they get older.*

When I observed Kurt's class early in the semester as he used lecture or held whole group discussions, many of the students were "zoning out". They wrote notes to friends, slept, read other material or just didn't pay attention, as seen here in the research notes:

Teacher: What about 1,700 kilometers of transition zone; 1,000 degrees celsius. That's right isn't it?

Several students talking to each other.

11:50a.m.

Teacher: The main thing you need to remember is 4000 degrees celsius. Iron and nickel again. Where does the water come from and other material elements come from?

Discussion of outer core and using a student's model.

Discussion of the mantle.

Students giving answers periodically. (Most answers are coming from the same students.)

Most students are watching; some are talking; some are zoning out.

The teacher stays in front.

Often, Kurt would call them down and ask them to get back on task. As the structure of his class changed, the student motivation also changed and was visible to me from their interaction with Kurt and each other. This was evident in this vignette from early December.

The students are discussing in groups. The teacher has asked each group to develop an organism that could survive deep under the ocean and explain why it would be able to survive. The teacher is asking each group what their organism is [by moving throughout the room].

Teacher: Does everybody have their traits [written] down?

Student: We're about done.

Teacher: Open your oceanography book and find deep sea organisms. Can your organism survive?

The teacher is visiting each group.

Teacher: Think about what's down there to eat.

The teacher asks each group to present their organism to the class.

In the submarine activities, the students were discussed the topic of the class, gathered data and recorded answers. There was less "off task" behavior. The students were on task and receiving information vital to the class. Kurt stated that the students were excited about some of the projects near the end of the semester. Other studies have found student motivation to increase as students are involved with inquiry teaching (Heywood and Heywood, 1992; Morrison 2002). In a study by Marx, et. al. (1994), involvement of students in small group activities were evidence of positive student motivation during inquiry activities. Near the end of the observed semester, all students participated in the small group activities involved in Kurt's classroom.

<u>Perceived Challenges to Implementation</u>

Challenge 1: Kurt felt that he did not want to lose control of the classroom.

During Kurt's initial challenge to implementing inquiry-based science, he was unsure that he wanted to lose "control" of the classroom that student-centered inquiry activities involved. "I need some kind of order in the classroom," was one of the statements that expressed his frustration with losing the control of the student learning. Research illustrated this same need for "control of lessons" (Marx, Blumenfeld, Krajcik, Blunk, Crawford, Kelly and Meyer, 1994; Morrison, 2002) that other teachers in similar situations had while implementing inquiry-based teaching. A barrier to teachers discussed in a study by Marx, et. al (1994) was a need to maintain order in the classroom. Kurt planned to do hands-on classes throughout the semester but would revert back to lecture when observed.

He felt he was losing control as the principle actor in the classroom, and he was not prepared to change his role in the classroom. Anderson (1998) stated that traditionally teachers perceived their role as the principle figure in the classroom, a dispenser of knowledge, a director of student action, and students were perceived as the passive receiver. With inquiry, Anderson argued that a teacher's new role is one of facilitator, in which the teacher facilitates the student thinking and should coach student actions and display flexible use of materials. Kurt had difficulty changing from the old teacher role to the new one by observing his actions of reverting into his old habits.

Kurt stated that he believed inquiry was the best way to teach students science because it was more like the real world, but he did not always illustrate that in his actual teaching. "That's [inquiry] probably the best way to learn it. It's kind of like life. I could stand up there and tell them everything but…this is a good way to go." Yet, observations gave evidence that he continued to stand up in front of class and give information.

Challenge 2: Kurt felt some students did all the work for the group.

"For the kid that's not motivated, they're gonna wait for someone else to do it them, and they're just not gonna do it." Kurt felt that unmotivated students would align themselves with others who would do the work for them. He felt that he really needed to do less "group work" and he stated that this method was good for students who had academics as a priority but unmotivated students might try to get by without doing a lot of class work.

Challenge 3: Kurt was not sure how to implement inquiry-based science.

Implementation of inquiry-based science in Kurt's classroom began as some hands-on projects having the students complete booklets and posters. He began to implement other lessons, which aligned more with the reform definition of inquiry teaching, as outlined by the National Science Foundation, but his definition remained unchanged. In my observations of his implementation, he felt inquiry was basically a hands-on strategy. The overall question during the assignment, the grappling with data and the expressing of the conclusions the students reached may have occurred later in the semester but was absent early in the semester perhaps this was due to his lack of understanding of the definition of inquiry teaching. Other teachers in this department shared lesson plans with Kurt and tried to encourage him and keep him from becoming frustrated. During one observation, Kathy was in his classroom when the researcher arrived finding information online for Kurt to use to build inquiry lessons. But still, a barrier to his implementation was his understanding of the method, as well as his role in the method. He felt unprepared to teach the method as evident in his final interview:

> *Kurt: I don't remember having any kind of workshop, but since we're science teachers we have other workshops that have this kind of idea-the thinking map, the circle map…I haven't been prepared with any workshops.*

He had difficulty changing his role as central information giver in the classroom, and this caused conflict between his prior beliefs and present beliefs. This conflict was a barrier to Kurt's understanding of the concept of student investigations. This is similar to what Ladewski, Krajcik and Haury (1994) found, in that conflicts from prior beliefs, about how the classroom works, can interfere with a teacher's initial implementation of inquiry teaching. Even at the end of the semester, Kurt stated that, "[inquiry] is allowing the students to find information ahead of time before you give the information to them. That's how I feel it works… I think this is a hands-on way."

Kathy/The Persistent One

Background and Classroom Environment

Kathy was my second research participant. She has been a veteran teacher for 18 years in the field of science. She started her studies in physical therapy but all of her family were involved in education. Her interests in college changed and she decided she wanted to teach and coach like her family members. After teaching many different classes all in the science field she was often asked to teach new classes that she had never taught before such as anatomy. She was viewed by her colleagues as an expert teacher who related well to her students.

Kathy began to move her classroom from a teacher-centered classroom to an inquiry-based classroom where the students were the center of the classroom and were actively learning. She continually tried to find a definition of inquiry-based teaching, working to understand how inquiry teaching was "supposed" to be implemented based on the National Science Standards and how she could do that practically within her own classroom. Her case was characterized by persistence also as she struggled to use questioning to encourage her students to own more of the lessons. She struggled with being professionally unprepared to teach inquiry but seeing it as vital to her classroom. She did not want to guide the students too much and to still cover the curriculum of the Biology course in the time offered. She persistently worked to overcome obstacles to become a better teacher and she perceived implementing inquiry as one of her primary struggles this semester and the previous year

In this case I outline Kathy's need to continually improve her instruction, to seek out help and resources and to overcome challenges to find success in implementing inquiry-based teaching. The vignette below illustrates Kathy's early attempt to enact student-centered learning.

Walking into Kathy's Biology class I looked around and saw lab tables neatly lined up and set up with two or three chairs at each table. I saw student posters on the wall with collages of plant life all over the posters labeled and colorful. On the overhead to my left as I entered which is the front of the classroom is written:

> *"Place each term from the following list under your colored picture of the plant cell, animal cell or both"*

Surveying the room kids are moving in talking casually with Kathy as she stands at the door looking up the hallway as other students enter. She chatted briefly with students as they came in through the door.

Students take their seats quickly and take out notebooks, textbooks and pencils. Kathy floated through the room taking roll and asking where absent students may be. As she approached the front of the classroom where a large desk sat and a table with a sink in it in front of two large white boards, I take my stool and sit in the back right corner, my usually observation spot as she handed me a worksheet. The students were asked to take out their two worksheets. One was a worksheet that had colored pictures of animal and plant cells and another one had the following instructions:

.

Shoebox Cell

Bring items to class on Friday, October 20, 2003

(Groups of Three)

Each group will be responsible for bringing one shoebox to class to represent a plant cell. Each group will also bring other items to represent the following plant cell structures. Do not use food for any organelles.

Nucleus

Mitochondria

Vacuole

Chloroplast

Ribosomes

Cell wall

Along with the shoebox, you should turn in the following…

1. ***Cut 4 index cards in half.***
2. ***Write the name of the organelle and the object used on one side of the card.***
3. ***Write the function of the organelle and the reason the object was used on the other.***
4. ***Use one color of colored pencil for both. Do not use this color again.***
5. ***Repeat this process for all 7 organelles.***

6. ***You will have 7 cards total.***

7. ***Put the organelles and cards in the shoebox.***

You will be given one class period to assemble the cell and complete the cards. Any additional time needed will be out of class. HOMEWORK!!!!

This project will be worth a total of 70 points.

(10 pts.) Box is neat and attractive.

(10 pts.) All structure listed are included in the box.

(10 pts.) The size of the objects used are representative of the structure sizes.

(10 pts.) The number of the objects used to represent each structure is logical. EX. A cell may have only one nucleus, but have several ribosomes.

(10 pts.) The functions of the structures are accurate.

(10 pts.) The reasons for the use of the objects are logical.

(10 pts.) The project is completed and turned in by due date.

The students were seated at the lab tables and working quietly. Some were using textbooks to look up cell parts and they were labeling their colored pictures of cells.

As the students worked on the worksheets with the colored cell parts, Kathy asked them to restate the questions in their discussion of the colored pictures of the cells. These questions were:

1. *Which organelles are found only in plant cells?*

2. *What structure is the only non-living part of the cell?*

3. *Which structure is found in both cells, but in much larger plants, because plants store large amounts of water?*

After a short time Kathy went over the correct answers to the questions. The students were asked to begin the plant cell projects. Kathy used whole group discussion at this point in the lesson and talked about where the students were to put each item in the shoebox the students began to gather construction paper, string, wrap, glue, etc. Students moved freely around the classroom using resources in cabinets and on shelves. Kathy was floating throughout the room asking questions of various students,

"Why don't you make a ball and put tape on it? Did anyone bring balloons?"

"Do you notice how big the vacuole is in the plant cell?"

There was very little conversation off task if any. All of the students seemed to be working on their questions and projects.

She began moving from going from lecture and lab to an inquiry-based science classroom, which involved the students identifying what they would explore and how they would explore it. At the beginning of the semester she felt student-centered activities were necessary for inquiry-based teaching. She even defined inquiry as anything hands-on or student-centered. In this vignette students felt free to move around the room using resources for projects and asking each other and their teacher questions. This aided their ability to do inquiry within this classroom. Kathy was worried occasionally that her classroom was noisy and that some administrators may perceive that as a lack of control on her part but she felt the benefits outweighed the noise. She set an expectation at the beginning of the semester that the students would be doing student-centered learning throughout the semester. She outlined where resources were that students could use such as the computers, textbooks, and supplies which could aid them in answering questions they had during activities or to complete activities and made sure the students understood they were there for the students' use. This vignette also showed how Kathy's classroom was organized and the students remained on task. This was typical of how the organization of her classroom was each day.

This vignette also illustrated how Kathy had begun implementing some student-centered learning as well as how she continued to be persistent with controlling the students' learning. She set the class up to be student centered in that the students were designing cell structures and using objects to represent the cell parts. They also were to describe why they used these objects to represent the parts and they were to describe the function of the parts. But yet as she implemented this student-centered learning she still felt pulled to revert back to controlling the classroom by telling them specifically where to put cell parts. It was evident to see that she was working to transition from total control of the teaching process to allowing the students to discover learning somewhat. She allowed students to find out on their own what each function of the cell was which was in contrast to her previously giving all the information out in lecture form. Her transition to inquiry began here and developed even more later in the semester. This next vignette showed Kathy's class a little later in the semester as her definition of inquiry-based teaching began evolving and her classroom did also.

Kathy's classroom lab tables and students were basically in the same place they had been earlier but the way she was setting up her lesson was changing somewhat. The class had been measuring the effects of water on eggs without shells all week. She had the following question written on the board:

"Will water move in and out of the egg?"

On the overhead was written:

- *Write a procedure to determine if/why water moved into or out of your egg?*
- *Your eggs represent animal cells*
- *On the conclusion part of your lab, add a drawing of the eggs. Use arrows to show the direction the water moved. Describe what happened to the egg.*

Kathy encouraged her class to take the measurements quickly and to remember to measure mass not weight.

The students worked quickly and moved to their seats. The students received a worksheet when returning to their seats that asked them to observe two separate pieces of celery and draw what they were seeing as far as if water was moving in or out of the celery and to write down descriptions. The celery was located on lab tables on the sides of the room. Kathy moved around the classroom helping students who were making observations. Students were free to move about the class and take measurements or observations.

"If I don't do anything else I want to teach the kids to think," Kathy said in an interview. Her classroom began reflecting this transformation that she seemed to be making from a strictly lecture environment to one that encouraged the students to be curious about what they were studying.

> *Now when I took biology that was the thing, memorize photosynthesis, you memorize all this other stuff but now that's not what I want my kids to do. I want them to be able to think their way through anything. Getting them to let go and try it own their own is the hardest part, But, then if they go and take an honors class… they jump right in.*

She had begun to allow the students a little more freedom and challenge them with an overriding question to begin the class. She spoke of this class period in her final interview saying that she was doing things differently now in her class like when she was allowing the students to observe the egg osmosis she would allow them to look for 20 minutes and make observations and write down ideas. She said that she would allow them to come up with ideas and they would talk about their ideas and most of the time she felt the students were coming out with ideas that touched on areas she would have covered in lecture in the past.

The class I observed was a basically sophomore general Biology class which contained an end-of-course test and was required by all students. The ability level of the class was mixed, as was the gender of the class. As the semester progressed she would begin assignments with questions that caused the students to think about the subject introduced. Some assignments were 15-minute classroom activities to later on having weeklong investigations, which allowed the students to explore more possible explanations of phenomena.

Within the learning environment Kathy would ask questions that pertained to the real world around them. When they were learning about how run-off effects a water source she allowed the students to talk about situations on their farms. One student spoke about how that fertilizer was not spread near her family's water source and Kathy used that as an introduction to explain that wherever fertilizer is introduced to the soil it will eventually end up in a water source.

Although Kathy felt unprepared to teach inquiry she experienced success in implementation in that she began understanding that inquiry is more of allowing the students to investigate and come up with ways of discovery on their own. She also experienced success in that students seem to be motivated to learn because of the process of inquiry. She felt they no longer wanted to sleep or "zone out" but was actually interested in discovering new things.

Constantly trying not to guide the students to the point where she would tell them step-by-step what to do she wanted them to have a sense of freedom to explore what they wanted to learn but still cover curriculum required for the course. She spoke of "pulling them back in" and wrapping up their discussions but felt that most everything she had covered in lecture in previous years still got covered in their explorations. So, she felt this was a better way of getting the information to them because the students were more motivated with this kind of environment. She wanted to guide them sometimes to make sure that the curriculum was covered in the amount of time that was given. Especially this semester in that they missed a lot of school because of weather. Kathy persistently worked to have a better understanding of inquiry-based science throughout this study and she applied her new knowledge in the implementation of inquiry teaching in her classroom.

Definition of Inquiry

Kathy was in her second year of implementation of inquiry-based science and expressed her definition of inquiry early in the semester as:

> *Well, I would tell them it's an idea where students pretty much end up teaching themselves or learning the material without the teacher lecturing to them. It's a lot of long range projects. The teacher ends up being a facilitator, providing materials and ideas and it can be hands-on activities, research, or anything where the student ends up instead of sitting and copying notes, teaching themselves and each other.*

This was a rather simplistic and broad definition of inquiry. It implied that anything other than lecture or drill and practice could be defined as inquiry. Her ideas about inquiry-based instruction were not unique in that Crawford (2000) wrote that many practicing teachers call inquiry based science 'doing science', 'hands-on science' and 'real-world science'. Anderson (1998) wrote that inquiry teaching means many different things to different people. Often research studies about inquiry focus on hands-on activities that appear different than the National Science Standards definition of inquiry.

Her definition began to change as the semester progressed. She began talking about her definition and she said that she previously introduced the subject matter with lecture and followed up with a lab and then she began introducing the subject with a lab and allowed the class to draw their own conclusions. She then followed up. This referred to order of the presentation and a little bit of the way she designed the lessons. She set up lessons by having the class develop what they were going to study as the beginning activity. In one class she allowed the class to decide what they wanted to observe about leaves. They were beginning a study in transpiration. They decided they would measure the size of the leaves. Which she said was, "…great now we can lead into why some trees lose their leaves in the winter and evergreens don't lose their leaves or they stay green all winter." Where in the past she would explain transpiration now they decided how to investigate it and drew their own conclusions. Kathy was excited that the students came up with many things to investigate such as what effect heat and cold had on the leaves and that they wanted to investigate all kinds of possibilities. She said she "wanted them to be able to think their way through anything." Good inquiry teaching has one aspect defined as a teacher who sets up an situation in which students must engage in problem-solving by posing questions and exploring answers to those questions. The teacher must implement inquiry teaching by using questioning as a device to foster student discovery and allow the student to make connections between questions they have and answers they can find. Crawford called the beginning question of the activity an authentic problem. Keys and Bryan (2000) stated it as "identifying and posing questions" then "designing and conducting investigations,"(p.632) to answer those questions. Haury (2000) wrote about students needing to have their curiosities aroused by situations that are set up by the teacher and wrote that "…those curiosities [will be] satisfied when individuals have constructed mental frameworks that adequately explain their experiences."

As the semester continued she began to separate her inquiry projects. She referred to some of her inquiry projects as little inquiry projects and some as bigger inquiry projects. She described the bigger inquiry project as:

> *Interviewer: Do you feel that this lesson was a good inquiry-based lesson?*
> *Kathy: Well, it wasn't a big inquiry, it didn't take a long period of time but they actually introduced themselves to chromosomes and mitosis and meiosis*.

So, she distinguished between inquiry activities that may take a short time and actual projects that take longer. She later said that inquiry should be long term projects more than short inquiry assignments. Her definition of inquiry was evolving in that the students should come up with how to do investigations and grapple with the data. This is outlined in the National Science Education Standards. She felt that longer inquiry helped to create a better learning environment in that the students could develop more questions to answer, ways to investigate those questions and more data to explain their interpretations.

She also referred to inquiry as research in which they had not covered the topic. She began structuring her labs in a more open-ended fashion instead of saying "OK, do steps one-two three" now she was asking them what they wanted to look out, how did they want to look at it and what were their conclusion. She asked them many times to hold their questions for at least 15 minutes when they were working on a problem until they had tried to think through how to solve the problem. She said that they often did their own labs and drew their own conclusions and was excited that she could give them a blank lab sheet and they could draw up their own lab results. Where in the past she gave them steps one, two and three and they wrote in what they found she now had them write up the steps they took to reach the conclusions. Being able to articulate your findings was one key to inquiry. This would demonstrate vocabulary knowledge and conceptual understanding(Lloyd & Contreras, 1985, Haury, 1987).

Wise & Okey (1983) identified inquiry as “more student-centered and less step-by-step teacher directed learning.” It seemed as if Kathy was beginning to understand that. This was getting closer to what the NRC explained as inquiry but she was still broad in her definition. She began introducing more of the labs with an overriding question, which caused the students to be curious and investigate. She began the lesson on osmosis described earlier by having the students observe an egg without the shell for a week and describe what was going on. She stated that the students were able to observe and discover more than she was able to tell them. She felt little explanation was needed about water passing through the membrane after their observations. This is similar to what Crawford (2000) explained as beginning an activity with an authentic problem and deciding how to find answers to this problem.

She also grappled with trying to decide if some of her activities were research or inquiry because she said that in one assignment they were doing a little bit of research in their textbooks but she wasn’t sure that should be called inquiry. The fact that she was questioning research alone being inquiry illustrated that she tried to make sense of inquiry-based science. She did not just accept that all research projects were inquiry-based science. She had read a lot about research projects being inquiry on the internet but said that she felt inquiry had more to do with the way you set up the learning environment by posing questions and how you implemented the project. She felt implementation needed to ask the students questions to spur them to discover rather than just ask them to research certain aspects she outlined. This showed growth on Kathy's part in that even though she was not lecturing she realized that inquiry needed a stricter definition than what she had said earlier about anything that was not lecture was inquiry.

Fostering ownership of the classroom assignments was important to Kathy in that she constantly asked them questions that allowed them to think deeper and set up the learning environment so if they had questions about something they would look them up, ask others or investigate to find the answers. She was out for a few days with another class on a field trip and when she returned she was astounded to realize that class continued very well without her. The students had studied meiosis and mitosis and had a good understanding of it through assignments she had left. She even found out that a substitute did not show one day and class continued as normal. Crawford (2000) argued that students beginning to feel a sense of ownership in the classroom is key to being effective in implementing inquiry-based teaching. Kathy's classroom had moved somewhat from lecture to student-centered learning as evidenced by the students' behavior when she was out.

She also described questioning as an important aspect of inquiry in that she stated that:

An inquiry activity is listed as research and I don't know that I consider that inquiry but I guess it's how deep you get into asking questions where it's inquiry instead of research. I'm still working on that.

At the end of the semester she talked about her definition of inquiry:

I think I have the general idea of inquiry as more long-range stuff than what I used to think. It's more, instead of me. It's letting the kids observe things and giving me some challenging questions, not just ask this, this and it leads to the end product. That's what I think it is anyway.

Earlier in the semester she asked each group when working on a problem to come up with only one intelligent question for the teacher to help them find the answers they needed. She was trying to encourage critical thinking skills. So, her definition became more refined as she continued through the semester and aligned with the reform-based definition which stated that questioning would be vital to the inquiry process. She became a little more detailed as the semester progressed in how she described inquiry in her classroom.

Kathy felt misled by workshops promoting "inquiry-based science" in her definition of inquiry-based science and was often confused because of misinformation and miscommunication of the concept given at these workshops. At first, she felt she did not understand inquiry because she described workshops about inquiry as a place where the definition was unclear or wrong. The teachers at the workshops would say that inquiry was a 15-minute activity in which the student engaged in hands-on activities but not necessarily with inquiry learning taking place. She said that often activities introduced as inquiry were five-minute vocabulary activities. She said the first time she heard of inquiry the lady introducing it described it as taking your labs that you did at the end of your class and doing them first. Also, when Kathy looked on the Internet for lesson plans and ideas she often found simple activities that she now does not identify as inquiry. Missing were the authentic problems, grappling with data, students connected with the real world problems that are evidence of inquiry teaching and communicating findings (Crawford, 2000; Keys and Bryan, 2000).

Implementation of Inquiry-based Science

The vignette describing the observation of egg osmosis illustrated that Kathy was attempting to move toward a student-centered classroom and beginning to use inquiry teaching. Aspects of inquiry teaching that were present were the set up of understanding osmosis through observation and gathering data. She began the assignment with the question, "Does water move into or out of your eggs." The students also were asked to relay their findings in writing fulfilling the inquiry teaching requirement of having the students be able to communicate their findings. The students were beginning to own their own learning as evidenced by watching them enter the classroom, begin work and stay on task with little teacher prodding. As the semester progressed Kathy's room continued toward successful implementation more closely aligned with the reform-based definition of inquiry. She began using student-centered activities and inquiry was evident within this lesson and others by her use of questioning and creating authentic problems. She had the students grapple with data in many lessons such as this lesson where osmosis of the water through the egg membrane was observed and recorded, the class also took measurements of bottle environments where they discovered what effect runoff had on water supplies and they formulated what was occurring during meiosis and mitosis based on observation. Even though she had poor training in inquiry-based science she overcame this and her implementation became more aligned with the reform definition of successful inquiry implementation as time progressed and she thought through the implementation process. She did a lot of reading on the Internet concerning inquiry-based science teaching and she spoke with colleagues about it. This helped her to develop a clearer definition of inquiry teaching.

Fostering ownership of the classroom assignments was important to Kathy in that she constantly asked them questions that allowed them to think deeper and set up the learning environment so if they had questions about something they would look them up, ask others or investigate to find the answers. She was out for a few days with another class on a field trip and when she returned she was astounded to realize that class continued very well without her. The students had studied meiosis and mitosis and had a good understanding of it through assignments she had left. She even found out that a substitute did not show one day and class continued as normal. Crawford (2000) outlined that students beginning to feel a sense of ownership in the classroom is key to being effective in implementing inquiry-based teaching. Kathy's classroom had moved somewhat from lecture to student-centered learning as evidenced by the students' behavior when she was out.

Other references to questioning mentioned were in a follow-up interview when I asked Kathy about questions she asked students on genetics about how could you create a red-haired child or produce a green pea. Kathy replied that they had done those activities while out for snow and she was asking more questions about the topic that would make them think beyond just the assignment. She asked questions that caused deeper thinking that were not on the worksheet assigned but had to use the information gathered through the assignment. She spoke of open-ended questions leading them in the right direction. She said the way it was set up by the students coming into the classroom and working on projects such as the bottle environment project where the students took measurements of how fertilizer added to an environment effected the water in that environment. They talked among each other to discuss what was occurring and if they were getting similar answers and what kind of effect they were discovering. They often asked each other instead of her what kinds of chemicals were now present in the bottle environment. She would ask them to only look up answers, ask someone in the class or figure them out on their own and then at times she would allow them to come up with one question for her if they were unable to find out what they needed to know. She felt finding answers on their own enabled them to become better learners since they had to discover answers for themselves

Kathy also questioned students to help them make realistic connections with what they learned in the classroom and the outside world. In one of the classroom projects she called the bottle experiment that was described earlier was set up to observe how nitrogen run-off affected the water cycle. The students had pond water in the bottom of a bottle and identified things in the water such as microbes, amoebas and such and then added fertilizer to the environment and observed what happened.

> *Like I had one little girl that said, 'My dad says don't add fertilizer to a plant when it's next to a stream.' Kathy replied, "Good thinking, but it doesn't matter if it's next to a stream it's going to end up there eventually.' This way they make the connection between the water itself and the fertilizer, and then when we uh…that has led us into alternatives. Beans, and they brought some beans seeds and one little boy brought some bean seeds in and they want to see how the beans re-fertilize the soil. They knew that farmers around here plant things in the off season when they alternate crops but they didn't know why. One thing will just lead into the other. That it starts as the fertilizer run-off.*

Kathy felt that the discussion had generated a connection between what they were discovering in the classroom and what was actually going on out in the world. She was receptive to their curiosity and allowed them to explore their train of thought drawing the connection between what she was trying to teach of the effect of the fertilizer on the water and what they already understood in their day-to-day lives. The student wanting to bring the bean seeds in really helped generate more interest, ownership of their learning, as well as being able to explore a whole new area of revitalizing the soil.

Perceived Successes in Implementation

Another aspect of reform-based inquiry that Kathy saw taking place with her students was that they began to see connections in science. She said:

> *"With the old way of lecturing they might remember it to take a test. But with inquiry-based science they may forget the vocabulary but they don't forget the processes. And they can think and apply it to other things. That's a big thing for me in science is that you can teach two different processes and they can never make a connection between them and now they can make connections or they can apply what they have learned to other things."*

Later she restated this by saying: "…my biology classes are low level and I can see they are learning a lot more than even my honors kids did through lecture. And they understand processes

She referred to students understanding processes and making connections between things being studied such as understanding the cell of a plant and the cells of animals because learning activities were set up for the students to explore what made up a plant cell and then the students were to create an animal cell. Students had to figure out what was each part of the cell's function. This allowed the students to see the connections between plant and animal cells better and they were retaining the knowledge better because of these connections.

She said that her kids that had biology last year are going on and taking AP Biology and remembering much more than they used to with her old method of teaching. She noticed more retention in other classes. Not only did she feel the students were retaining more according to her they were learning more because of the excitement and motivation this process brought out in her students.

Motivation was one of the main reasons that Kathy felt this process of inquiry teaching was so successful in her classroom. She said students who were usually unmotivated to do schoolwork really enjoy exploring and discovering in the way that inquiry was established in this classroom. Kathy talked about the AP Biology teacher who said that the kids that have had inquiry before tend to just jump right in and do their own work. They do the whole lab write up without teacher direction. They seemed motivated to be active learners.

The students' excitement level was something Kathy referred to time and again as a byproduct of the inquiry process. Kathy said that kids were not afraid to take a chance. They have to come up with their own steps and work the entire class on developing their own way to solve the problems or set up the experiments. Kathy summed up her students' motivation by saying:

> *The success comes from the kind of students that we have. They enjoy being active in things and they enjoy being challenged. Umm, they sort of get a kick out of, you know, showing up each other or coming up with ideas. So far it's worked well. I haven't had a class that didn't like it. Once they have gotten used to things working this way in this class then they enjoy it and they know that's what you expect them to do. They quit asking so many questions until they try things first and then you have one or two that don't want to let go.*

One or two of the students did not want to explore on their own but be told step-by-step what to do to make sure they did not make any mistakes. Kathy felt that just a couple wanted to be spoon-fed and told exactly step by step the process they should use to get the "right" answers. But, she felt most of the students really enjoyed coming up with their own process and discovering answers to their own questions.

<u>Perceived Challenges to Implementation</u>

Kathy grappled with her own feelings of inadequacy because of little professional development. She struggled with the several challenges: She felt unprepared to teach the method because she did not feel professionally informed as to how to implement this method. This feeling of inadequacy began easing off throughout the semester when she experienced success in the students' motivation level and the increase in their abilities to understand science. She struggled with guiding the students too often instead of doing true inquiry and allowing them to find out on their own. She felt pulled between allowing them to discover and telling them every step of process. She also had difficulty finding enough inquiry activities to do with all of the topics in the amount of time she had available. She felt that she needed to do inquiry with every topic, which is not always necessary for good teaching. She worried that there would not be enough time in the semester to cover the expected curriculum. These were all challenges to her implementation process.

Challenge 1: Feeling unprepared to teach the process

One of the most common concerns from teachers trying to enact inquiry-based instruction is the problem of inadequate professional development. Fostering a culture of inquiry demands that teachers be coaches, diagnosticians, innovators, researchers and learners (Crawford, 2000). These are difficult roles, especially for teachers who are accustomed to giving out information and dictating to students what specific steps are in experiments. Teachers need critical, ongoing and consistent support to help learn these roles when using innovative teaching such as inquiry.

Although a challenge to implementation, her struggle with feeling unprepared did not keep her from continuing to access knowledge on the inquiry-based process by searching the internet and asking others for more information. She stated that she went to one workshop presented by the North Carolina Science Teachers Association and picked up inquiry projects that were ten-minute assignments she said that she did not believe those projects to be inquiry because they were more of restating information or learning new vocabulary terms.   This informed me that Kathy tried to get professional development to understand inquiry better but felt that a lot of professional development was inadequate or uninformed about true inquiry teaching. She also said in her final interview that more professional development was available in workshops and on the Internet now and that was more helpful. She said a challenge to her was getting the money to be able to attend these workshops or take classes online. She actually signed up to take an inquiry teaching course online which cost $150.00 and had asked the school system to fund this but they did not so she had to drop the course.

When asked if there was any staff development available for her at her system level she talked about how the teachers share ideas. She felt that she was not getting adequate professional development so she sought out teachers in her teaching area throughout her system and asked them about inquiry projects or lesson plans in which they had had success with. She also shared some of her inquiry projects with them

In Kathy's school system the science teachers met periodically and shared activities. The teachers were encouraged by their curriculum director to bring hands-on, student-centered activities. Kathy felt that many of the teachers brought activities that were ineffective activities and the teachers praised each of the lessons regardless of their qualities. She felt there was little criticism of activities. They all seemed to be accepted in the same way so that teachers' feelings would not be hurt. She felt new teachers were often led astray by this to use ineffective strategies. Blumenfeld, Krajcik, Marx and Soloway (1994) found teachers in similar situations reflecting on lessons in which they had tried to implement project-based instruction. These teachers "rarely critiqued each other or related their practice to the features of project-based science. Instead, they tended to congratulate each other on any attempt at innovation rather than to evaluate whether the practice illustrated … was congruent with constructivist theory." She said that was a challenge because she wanted good inquiry projects but often just got hands-on assignments. She was incredibly reflective in that she was thinking about the lessons and wanting more information and help to do inquiry correctly. Teachers implementing reform-based instruction in their class are going to need to be reflective about what they are doing and constantly evaluating their instruction. Spillane, Reiser and Reimer (2002) when studying how teachers make sense out of reform-based implementation wrote that teachers often see new ideas as familiar and this was an obstacle to implementation of new teaching ideas such as inquiry-based science. For example, teachers may just put inquiry into the category of hands-on science since they are familiar with that term and this was what Kathy was seeing here. Although feeling inadequate to teach this process she felt that what she was doing this semester was effective.

Challenge 2: Inadequate amount of lesson plans or activities available

She struggled with coming up with enough activities to do inquiry with every lesson.

> *Kathy: The struggles have been finding the activities. It has taken a lot of time for `me to sit down and do some research myself.*
> *(Later on)*
> *Interviewer: Is there anything else you want to talk about?*
> *Kathy: I wish there was something you know every time we fill out forms we put on there we want inquiry activities if somebody could find some things for us to do. Cause I spend so much time sitting right there looking for things.*
> *Interviewer: That seems to be your only resource right now (Internet)?*
> *Kathy: It's in our curriculum-science is inquiry.*

She was constantly on the Internet looking for lesson plans and asking others in her department for lesson plans that would work with all of the different lessons she wanted to teach. She verbalized frustration regularly that there were not enough examples of inquiry activities that she could be doing. She often asked for lessons through her curriculum person in her system but was not provided with any lessons.

Challenge 3: Not wanting to guide the students too much

Kathy continued in another interviewing saying that she wanted to give the kids the same information that she was giving in a whole group discussion of genetics but present it through inquiry. She felt like she was feeding facts to the students but did not have any idea how to convey facts about genetics to the students through inquiry. She stated that " …drawbacks, just coming up with ideas. There's not you know I use the internet a lot and it's getting better but there's not a lot of ideas but you sort of have to give yourself a chance to try something even if it doesn't work." Many teachers use a guided inquiry to help the students frame what they are looking for in their answers but does not spell out specifically everything. This guided inquiry versus allowing the students total freedom was one challenge Kathy faced. In current research some teachers use a structured method of guided inquiry (Igelsrud & Leonard, 1988) while others provide students with very few instructions (Teinnesand & Chan, 1987). Haury (1993) outlined how different teachers view inquiry-oriented science differently and wrote that inquiry teaching could be done either way if it met the criteria of engaging students in investigations to satisfy curiosities and constructing mental frameworks that explain their experiences.

In one discussion, she allowed the class to decide what they wanted to do when looking at transpiration and how important plants were to the water cycle. They, as a class, decided what they wanted to measure and they decided the size of the leaves. She felt like she led them somewhat to this conclusion of choosing to look at the size of the leaves to see if the leaves had received little or a lot of water. She involved the students in designing this experiment and felt like she guided them to come to this but expressed that she did not lecture. She felt like students came up with too many variables to measure.

Some of the kids wanted to look at the effect temperature played on the leaves and others aspects of the environment. She felt that setting up the experiment to study the size of leaves was the most practical but felt she might have aided them too much in determining this. She stated that some of the students expect the teacher to hold their hand through the process and lead them through it. She said it is hard for some of them to let go and make decisions on their own. She did not want to spoon feed the students but wanted to temper freedom of choice with enough guidance to keep the kids on the right track.

She found it difficult not to stand over the kids and say "This is what you need to know," and even at the end of lessons she tended to summarize what they should have gotten out of the lesson and if they missed something vital go back and cover it. Later she stated that she wanted to summarize everything. Although, this is not inconsistent with inquiry in her understanding of inquiry teaching she felt it was inconsistent.

In a follow-up interview after an observation Kathy said, "I still get the feeling sometimes that I need to be standing right in front of them even though it's inquiry I need to be there" telling them exactly what to do. In her final interview she spoke of struggling to let go and let the students figure out things. She felt it took a lot of time to be able to do that. She stated that she discovered they actually came up with what she was going to say anyway and so she felt better letting them explore ideas. She said the students had to be willing to be wrong sometimes and it was hard for her not to correct them right away but let them stray a little bit and come back to a workable answer. Her feelings were shown when asked:

> *Interviewer: So, you let them try a little bit?*
> *Kathy: Yeah, Sometimes too much but if they are interested in something and they're coming up with some intelligent ideas.*

During the observation on October 22nd Kathy was struggling with not guiding her students. They were doing a lesson where they were to make a shoebox of items that resembled plant and animal cells. The students were coming up with different items that represented different parts of the plant and animal cells. Sometimes when students asked questions such as "Are pennies all right for the mitochondria?" and Kathy confirmed that it was ok or Kathy would ask a question such as, "Why did you choose that for the nucleus (ping pong ball)?" and the student said, "Because it's round." She seemed to be taking a more inquiry-based approach and then Kathy might tell another student to use a balloon or to cut a skittle in half. So, she would sometimes get the student to think about what and why they were doing something and other times I observed her she would give the students the answers she expected.

In another interview she said that open-ended questions were to lead them in the right direction because she didn't want them to waste a lot of time going off. So, she seemed to be fighting with allowing the students to discover what to use and telling them what to use. As Kathy struggled with allowing the students to explore their own thought processes and come up with ideas and procedures she continued to keep time and curriculum in the back of her mind.

Challenge 4: Kathy struggled with trying to cover the expected curriculum in the time allowed.

Time and curriculum would often come up in discussion as to what would hold her back from always doing inquiry. She mentioned that it was difficult to let the students go with their own thought processes and take much time away from covering curriculum to allow them to explore. When asked in an interview this is what she said:

> *Interviewer: So, you feel like you have time to try things even if they don't work sometimes?*
>
> *Kathy: No, there's not enough time.*
>
> *Interviewer: Is that one of your drawbacks too?*
>
> *Kathy: But, this doesn't take up a lot of time either. They come in, we set this up a week ago and they come in and usually by the time the tardy bell has rung, they've looked at their stuff and gotten their observations for the day. And so it doesn't*

Take a lot of time.

(Later on)

Kathy: And some of it can be time-consuming. If the biology curriculum left out the goal on anatomy, which is … you can spend a year on it. If they would completely leave that out then you could do anything else with inquiry. But, it does take some time. Especially if you do research activities.

In one observation Kathy's class met back after many snow days out which also played in her perceived barrier of time. She felt that since the students had missed so many classes that she had to do some whole class discussion to catch them up and make sure they had gotten pertinent information. She spoke about 80% of the class on the topic of genetics. She put some punnett squares on the overhead and handed out worksheets. She made the comment that if they were not behind they would be able to do inquiry activities. So, time played a factor in her implementation of the process. She even mentioned to the students that "If we would have had time we would do a lab with a crosspring." So, it was in the back of her mind. At the end of the class she chose to do an activity where the class did some hands-on, student-centered work so that this class would not be completely lecture and discussion. This was evidence of Kathy continuing to try to move to a student-centered classroom.

Although Kathy grappled with a lot of barriers to implementing an inquiry-based teaching environment in her classroom she stated many times that this was the best way to teach science in her opinion. She summarized her beliefs in the final interview:

> *Kathy: I could not go back to lecture and the old way.*
> *Kathy: …I'm going to make it work with oceanography. I'm going to do all of it inquiry.*
> *I: Are you? I'm not coming back [to watch] but I think that would be interesting.*
> *Kathy: Cause, I don't think I could do it any other way.*

Jeb/The Innovator

Background and Classroom Environment

As you entered Jeb's classroom you saw plants placed randomly around the room. Some plants were enclosed in environments, some sitting in the window, and others in dark spaces in his storage area. Student's work was displayed prominently throughout the room with posters and booklets hanging on the walls.

Jeb, who is thirty-nine, and has sandy blond hair and usually wears jeans or khakis with a casual shirt. He often wears boots or casual shoes, and when I observed him, he had on goggles and had his shirtsleeves rolled up, becoming part of the experiment that took place in the room by taking water samples and testing the chemical content. I had a difficult time figuring out which person was Jeb and which were his students, because Jeb was dressed similar to them and was always surrounded by students. I could easily have seen him knee deep in one of the ponds the students had made around campus for gathering plant and animal life. He usually experiments along side the kids and finds his own results to compare with theirs.

As a kid, Jeb spent numerous hours in the outdoors. He loved activities that connected him to nature, such as camping and fishing, and grew up engrossed in 4H projects. 4H is a national organization devoted to young people and offers hands-on experiences with nature, and when Jeb turned nineteen 4H was so impressed with his leadership abilities they asked him to be one of their leaders and work with children interested in science.

Jeb actively sought science throughout high school by completing extra work in addition to his science classes. His high school teachers gave him suggestions of extra assignments in school because he was so interested in discovering new things and loved experimentation. He was a camp director for a summer camp in which the students conducted experiential scientific education experiences, such as night hikes and working in a marine lab. His camp was located at the coast, and he stated that this camp was one of the great experiences of his life. This experience later influenced his classroom strategies by encouraging him to teach his students in an experiential manner. Jeb feels that studying nature by using a textbook is contrary to everything he believes and that students should experience science in nature and natural settings. He has always soaked up knowledge and believes his students should also.

His colleagues describe him as “high strung”, “energetic”, and “busy”. He continually tries to do something new and finds creative exercises to do with his classes. His colleagues said he is like the canary that was lowered into the coal mines to check for carbon monoxide, in that if the canary was alive when pulled out, the mine was safe. Jeb’s colleagues have him test new lessons and strategies to see if they are successful before they attempt them in their classes. His peers have great faith in him and his opinion about methodology.

Jeb devotes his time and energy largely to his classes and students. He constantly reads journals about inquiry teaching and how to use it in his AP environmental science class. The science teacher next door often comes in his room through the open door between the rooms sharing research articles and talking about their lessons. Jeb is very caring according to his fellow teachers and according to them he sometimes worries about his students to the point that he loses sleep.

During classroom discussions, I observed Jeb leaning on his college experience in science classes when he spoke of environmental issues. In one class period, he spoke about the Valdez oil spill and how some scientists came up with various ways to clean it up. He spoke of a student he knew who wrote about the use of panti-hose material in cleaning up the spill and entered that idea in a national contest. Students were excited to hear Jeb's stories about what he experienced in college science classes. Jeb described his teaching as a type that changes based on the type of students he has. He wanted to "try to be hands-on as much as the class will allow."

During my first observation of Jeb's classroom, I knew his class was different than most. My field notes told why.

It was not so much in the organization of the facilities itself. They were similar to the other rooms in the department, however his room contained several lab tables for the students as well as sinks and cabinets around the side of the room. But as I entered his AP Environmental Science Class for the first time, the biggest difference was that students were studying various plants, looking through microscopes, and others seeking information on the computer and in textbooks throughout the classroom. There were numerous student activities, and the room seemed alive and busy. Some students looked at water in tubes at the back of the room, some completed written assignments, while others put on goggles. There were bottles created by the students to represent mini-

environments, and the students were adding chemical water to represent acid rain to their environment in order to check the effect on the plant and animal life in their mini-environments. Students used two-liter bottles cut with the upper half of the bottle upside down resting on the lower half. There were three bottles similar to these stacked on top of each other with holes leading to the next layer. The top portion of the bottles contained dirt and grass, and the next one contained dirt and plants. The bottom contained rocks, fish, and water. The room was bursting with energy while everyone did something different, but all students seemed to know what was happening. I found it difficult to sit in Jeb's room and not become involved myself. On this my first observation of his room, I found myself becoming engrossed in all the student activities as they occurred.

Student 1: Is our grass growing anymore?

[Researcher's note] (As students looked in the back of the room at an environment they had created.)

Teacher: How would you know?

Student 2: Ours has stopped.

Teacher: I don't think it is growing up.

[Researcher's note](Conversations are buzzing all about.)

Teacher: How do you get grass in your yard?

Student 2: Seeds.

Teacher: You've seen wheat. That's a grass.

Student 4: That makes sense.

[Researcher's note](Everyone seems to be coming toward an experiment in the front.)

Teacher: You're not going to get finished if you're all up here. Who's doing dissolved oxygen. OK. Three people doing that. If you're testing oxygen, you're blowing oxygen in there. Squeeze it before you put it in there.

Student to another student: This goes by to the 5 milliliter line right?

Student: Right, yeah.

Teacher: See how it's gooey. Yours is the only one doing that.

Student: Is that bad?

Teacher: There's not bad or good. If you're testing for oxygen or carbon dioxide don't add these gases to your water. It will throw your results off.

Student: How many weeks are we doing this?

Teacher: I hope 10, but we're missing two Fridays this month.

Student: You could test it for us.

Student 2: It was yellow to begin with.

Student 3: This was dissolving some oxygen.

Student 4: There's a black thing in it.

Teacher: Probably a piece of leaf. Don't worry about it. Usually you're ankle deep in the creek anyway. After you've seen and tested the differences in here, we'll go out and test the ponds we have outside.

[Researcher's note](The teacher sent two students out to look at ponds.)

Student 4: How long after school are you staying today?

Teacher: Why?

Student 4: I've got a meeting.

Teacher: I'll wait.

[Researcher's note](Students wear goggles and test water samples throughout the room.)

Student 2: I'm going to take out another 45.

Student 3: Don't take out that much, we only have one test.

Student 2: I need at least 20 for this.

Student 3: OK. Well, we can put it back in.

[Researcher's note](The teacher is moving around the room with goggles and gloves and answering questions, sometimes with questions. He looked like a student himself.)

Student 5: Do plants take up ammonia? We have two plants now.

Teacher: We've not checked the pH. It might show how quickly it dissolved.

Student 5: It won't explain the nitrogen.

Teacher: I've got tablet tests.

Student 5: I'd do it again. That shouldn't be that yellow.

Teacher: OK. What test is that one? Phosphate?

[Researcher's note](A new student enters and brings a late slip.)

New student: Justin, have we done the phosphate.

Justin: No, that's the only one left.

New student: Which test do we use for phosphate?

Teacher: There's two. One for diluted…

New Student: OK. I see it… Oh, dear, it's so dark. It looks like tea.

Student to student: We can go ahead and start.

Student 7: Nicky, do you have your sheet out.

Teacher: What do you think might have happened to that water?

Student: Mine is turning yellow, also.

Student 5: More settled… a little bit of condensation?

Student 6: Yeah.

Student 2: If it's turning blue, why did you put more stuff in it?

Student 3: It's got to turn clear.

Teacher: …class field trip.

Student: I'm hearing that. Where?

Student: We're gonna make it rain. (The student turned to me and said, "This is my favorite part" and poured water into the bottle environment.)

Student: Our water is lighter than everyone else's because of those plants.

Student: What did we have for dissolved oxygen?

Student: Nothing. It don't turn blue. He did it too. (Referring to the teacher)

Teacher: We can't say it has to do with the fish or indicator because they're the same. Did you guys run into this before?

Students: No.

Teachers: I'm not sure I've seen this before. Jessie, please try and see what you come up with.

[Researcher's note](All the students gathered around. The teacher set up the samples and students tried it again. There's much discussion among the students about why the results are occurring.)

Student: Would the plant get CO2 in there?

Teacher: The environment would. It's not sealed.

Student: If they were anaerobic would they be given that off?

Teacher: No one is sabotaging the equipment.

Student: Maybe you made it too yellow when you put too much in there.

Teacher: All that's doing is indicating if it's there. That's easy. I've got a potato back here.

[Researcher's note](The teacher gets the potato from a storage room in the back and begins testing.)

Teacher: All this is a starch indicator.

[Researcher's note](One student writes. Other students close equipment. Some still watch.)

Student: Did you test all of them?

Teacher: None of them work.

Student: The plants are not healthy.

Teacher: What causes your plant…

Student: Sunlight.

Teacher: What about sunlight? Right. It's blocking the sunlight. The plant you have produces bubbles. It's producing a lot of oxygen. OK. Oxygen changed. What else changed?

Student: Our carbon dioxide went up.

Teacher: What else changed?

Student: Our phosphate changed slightly.

Teacher: Are the water plants growing at all?

Student: Not a lot.

Teacher: How about the grass?

Student: Taller but not a lot.

Teacher: Why?

Student: This one did not turn.

Student: Did you use the same.

Student: I used one of these and one of these.

Teacher: Now we don't know which worked. Remember control. I want to test this starch indicator. Use the water she used. Then, we've got to see what's going wrong.

Student: Is this single displacement, double displacement or synthesis?

Teacher: Read at the bottom of this.

Student: Oh, OK. Can I play with this to see if it will turn blue?

Student: Maybe there's a bond, covalent bond, not an ionic bond. Have they been exposed to heat or cold?

Student: No, it's closed tightly.

Student: I'm guessing somebody didn't close it tightly.

[Researcher's note] (The bell rang and everyone packed up and left.)

Jeb stated that he had never tried inquiry-based teaching before, yet on my first observation, his classroom contained many of the elements of an inquiry classroom. There was a curiosity aroused in the students, and they were already grappling with data and discussing it on their own. They were being encouraged to decide how to test what they needed to know and to decide possible conclusions, as well as to express what they discovered and record it for later use. After the 10 week bottle project assignment, students asked to keep the projects going throughout the semester.

Jeb stated that he wanted to move to an inquiry-based teaching classroom this semester, and that he felt this would be an effective method with this AP environmental science class. He had conducted numerous experiential assignments before where students worked with the earth and water, but they lacked an overriding question and much of the student ownership that inquiry teaching fosters. Later in the semester, he began using inquiry teaching in interesting and creative ways as the following vignette described. Jeb took his basic understanding of what inquiry teaching looked like and applied it to a class in which videos were used:

Students came in, and one carried a poster. I observed various assignments on the board as the teacher distributed study guide questions. These were general questions to fill in while students watched a video on the Valdez Oil Spill and clean up. (The teacher informed me that he is showing two separate videos in separate rooms. One of *the videos is produced by an animal rights group, The Cousteau Society, and the other is produced by EXXON.) Half of the students are moved to another teacher's room to view one of the videos. The room in which I remained watched the video produced by the animal rights group. Jeb periodically went out and checked on the other group. The video I watched probed the idea that EXXON was not ready for the spillwhen it occurred and did little to clean it up. Marine biologists were interviewed and beach areas were shown after the EXXON cleanup.*

Jeb had bottles still in the back of the room from the earlier bottle projects filled with water, plant life, and soil. There were various live plants spread throughout the room, and the walls were colorful with student posters and projects. Jeb fast-forwarded the VCR to the last segment of the video. He moved the students that remained in the room I was observing to the right side and brought in the second group. Each student took a seat on the left side of the room.

Teacher: Before we begin questions, I want to ask you about wildlife. Tell me what happened to sea otters?

<u>Group 2</u>

Otters got oil on their coats; they couldn't keep them warm. Rescuers came and cleaned the otters with dishwashing detergent until they got natural oil back. They found about 1,000 carcasses.

<u>Group 1</u>

The otters were dying. The fish were killed. They didn't have a reserved place for them.

Group 2

The fish population boomed and eagles were affected little.

Group 1

It said it killed one million birds. The land wasn't cleaned up, and the water wasn't cleaned; nothing underneath.

Group 2

The cleaning was good. Send in hydrocarbons to help bacteria eat the oil. They tested water and land, and it was fine. EXXON cleaned it up.

Group 1

They used EXXON and scientists. 1989. EXXON caused it.

[Researcher's note](There was heated discussion between the groups, and Jeb periodically asked questions to spur the discussion.)

Group 1

They talked about bird deaths and other deaths.

Teacher: What visual images did they show?

Group 2

Stuff being cleaned up.

Group 1

Junk lying there. They would say, "Yeah, right, that's clean, and they picked up puddles of oil.

Teacher: [There are] two ends of the spectrum; One by Cousteau Society and one by EXXON.

The [one by EXXON] was after the incident, and they were required to do [this for] community service. They made this video to educate people. They sent it to every school in the country. So, this is the viewpoint most people got. How do you decide?

Student 1: Watch both?

Teacher: But do most do that?

Student 2: No, they should go there.

Teacher: How do the citizens of Surry County find out about stuff?

Student 1: News.

Teacher: How do you make wise decisions?

Student 3: Maybe understand as much as you can.

Student 4: One video said that by 1992 everything was ok.

[Researcher's note](His class evokes people to want to get involved in the discussion.)

Student 4: What they were saying was true.

Student 5: But the phrase might be true, but they didn't say anything about anything else.

[Researcher's note](Discussion took place among all students, and the teacher about the discrepancies in the videos.)

Student 2: I never thought about when it was talking about seals coming to the surface, but it breathed oil fumes. I never considered the oil fumes going in.

Student 7: It didn't lie. It just didn't talk about…

Teacher: Some oil not refined can sink into pockets.

[Researcher's note](Discussion died down about 30 minutes later.)

Student: We've heard the two extremes. What really happened?

Teacher: That's the evidence we have. You need to find journals not working with either side to…(interruption by announcement over the intercom.)

Teacher: Think about cleaning oil off. Do you think that would be as easy as our video made it?

Student: Wouldn't dishwashing detergent in the ocean be bad for the ocean?

Teacher: Yes.

Teacher: There were a lot of methods of cleanup put out there. One method I read about… they said to strike a match. One of the best methods, which was a student experiment, was to pack pantyhose in and soak up the oil.

Student: That would take a lot of pantyhose.

Student 3: Couldn't they make it and use a net?

Teacher: It said let's produce a material similar to pantyhose.

Student: How, if they collect it could they [dispose of it?].What can they do?

Teacher: Send it back to a refinery. It dissipates over time.

I watched this video six years ago. This makes the oilspill look like a weekend cleanup. Another teacher explained the history of the video to me. So, I thought it would be neat to show both videos.

Student 5: The scientist talked about nesting habits and they were coming back and laying eggs. It's easy to believe scientists who have worked on this for 20 years.

Teacher: They could have put her on TV, and she would have wanted that.

How many are finished with posters? OK. I'll give you a few minutes to finish them and give me the answers to your questions on Monday. Read the first four sections of Chapter 19 and the other stuff on the board.

[Researcher's note](The posters are about lab findings of radiation's effect on radishes. They are to present posters in a couple of days.)

Teacher: You probably need to put stuff in your water bottles.

[Researcher's note](Some kids add water or remove water from their bottle environments.)

This vignette illustrated that Jeb continued to use inquiry throughout the semester in this course but in different ways than previously observed. He would later realize that this was an exciting discovery for him when he spoke about this class in his final interview:

> *Interviewer: What are some of the ways that you have… and we've talked about some of these, implemented inquiry-based activities into this semester? You talked about the way you set up the bottle projects. What are other ways you have set up the class?*
> *Jeb: I think what I did with the videotapes. The students didn't know what was going on. I raised the question, I hope it raised the question in their minds when they first started discussing it- What was the source of the information? And I think they were able to bring into their own minds questioning of sources because inquiry is not just an activity, it is a skill that you should have throughout life so that you can always question and always be a life-long learner.*
> *Interviewer: Had you set that specific lesson up as inquiry or did that just kind of evolve or…?*
> *Jeb: I made an attempt on my part to make that an inquiry activity by showing each video. You know the alternative was to just show the one video. I think they went for it to have two opposing viewpoints, and they could discuss that. They had an open forum to discuss that.*

These vignettes and interview illustrated what Jeb perceived as a definition of inquiry teaching which he said was informed mainly by:

…Professional journals…And some good articles from several staff members and myself. We share articles. Several staff members and I, we read different journals and share ideas that come through. And with such a big push in the country to do inquiry, there's lots of stuff being written about it. And you have your own research. As a science teacher to do things like that… right now it appears you would have to take the initiative to learn to teach yourself.

Definition of Inquiry

Jeb's classroom had the elements of reform-based inquiry teaching in that he began with a question or questions that the students were to think about throughout the class; he aroused their curiosity in many ways. He also gave them tools to develop a method to answer the question, allowed them to collect data, describe what they found, and explain how it answered their questions. In the bottle projects, he showed students how to set up environments and allowed them to test for different elements being present. They introduced acid rain to the environment and then tested for the effect. They were to collect data presented in the videos to answer the question, "What really happened?" In his initial interview, Jeb verbalized inquiry teaching as:

There's what I call inquiry and guided inquiry. With an inquiry approach, you would give the students a task to perform and the equipment to perform it with, but that would be all. They would have to come up with an entire method on how to do that. In a guided inquiry type activity, you would give them clues or hints as to what direction they would go in. A lot of times, at least my experience has been, to start with one and move towards the other. Students have a hard time thinking and [a hard time] jumping right into inquiry most of the time; look at what you give them and they don't know what to do…. They have to be taught how to think their way through an approach. Give them one approach and let them develop a better approach as another possibility…. Real world situations…Hands-on. Definitely immerse themselves in it. Don't show it to me.

Put them there as an active participant, fully active participant. So, you basically set it up and let them do it. If my students are coming up with the activity and designing the way to find the answers to those questions, then, it provides ownership, and any time they take ownership, they tend to be more focused.

Jeb spoke about "guided inquiry" and "inquiry" being separate. Igelsrud and Leonard (1998) also discussed guided inquiry as giving prodding questions during investigations leading students to discover answers. Tinnesand and Chan (1987) wrote of teachers giving very little instruction as they provided an inquiry-based classroom.

A book Jeb referred to the book, Environmental Science: A Collection of Activities for the Middle School Classroom, in his classroom and said that he understood inquiry teaching as it was defined in this book. Science as inquiry was defined as:

- Ability to do scientific inquiry
- Understanding about scientific inquiry
- Ability to perform safe and appropriate manipulation of materials, scientific equipment and technology
- Mastery of integrated process skills
  - acquiring, processing and interpreting data
  - identifying variables and relationships
  - designing investigations
  - experimenting
  - analyzing investigations
  - constructing hypothesis
  - formulating models

Since this book was published by the National Science Foundation and the Science and Technology Center at North Carolina State University, it had a working definition of inquiry teaching that aligned with previous definitions published during the reform movement.

Implementation of Inquiry-based Science

Jeb's implementation of inquiry teaching aligned with his beliefs about how students learn science. When asked what he felt would be the perfect way to construct a class to teach science, he stated:

> *Jeb: Well, I would well… it would depend on what level I'm dealing with, too. I've often thought it would be interesting too if it was possible at high school to offer a mini-course and revolve it around a tree on campus. Where you've got a small group of students, so there's a lot of teacher/student interaction. And you bring the students outside cause I'm a natural science person. All of my stuff is biology and college-related. So, I would want to maybe take them out and let's do a program on all the stuff we can learn about, come up with, about that tree. They come up with the questions and have them come up with ideas of how they would find the answers to those questions. Just from what we have on the tree, no Internet, no looking it up in the book. I want you to use your brains to come up with ways to find out the answers to your questions…measurements and observations…real world and hands-on.*

This belief about how students learn science was evident in his bottle projects, where the students decided what part of the environment they wanted to test, such as oxygen or carbon dioxide levels, and then conduct experiments. Later in the semester, Jeb gave them beads to wear that changed color based on the environment. They were to find out "why" they had changed color. This illustrated trying to answer unknowns. He also had the students look at ponds on campus to see the effect the environment had been having on them. This went back to his belief about looking at nature to answer questions. He constantly had his class to try new ideas and ways of learning concepts. His belief system aligned with the definition of inquiry teaching that he understood and was expressed in the lessons he taught.

Perceived Successes in Implementation

Jeb felt that inquiry teaching fostered ownership by the students.

Jeb stated several times that if the students had a vested interest in the classwork, they would be motivated to do their best work. He stated,

> *They have a vested interest in seeing it through, and they pay more attention to the procedures and…instead of just going through the motions. Their brain has come up with the questions, and their brain has wondered what the answer is and catch it and retain it.*

He said in his initial interview that,

> *…it provides ownership, and any time they take ownership, they tend to be more focused on it and more willing to work harder to come up with a solution. More involved, they learn more because they feel like they have a bigger stake in it. That's probably one of the biggest [successes].*

His classroom showed student ownership in every observation that I made. Even at the end of the semester when students had been out of school for a week for snow days, they were finishing up projects, taking tests, and completing assignments. They were on task and busy working around the room with little instruction. The following vignette illustrates that students were engaged and active in projects as well as felt they owned the assignment:

Three students look at slides in microscopes, five students complete bookwork, worksheets and paperwork. The students using microscopes catch up on an assignment, in which they laid dust particle collectors in their rooms the night before and were looking at what was in their room's environment, mainly dust particles floating in the air. They try to identify particles since they had previously discussed air pollution. Some students began to move to the microscopes to draw items and label lung tissues. The use of microscopes assists students and enables them to draw what they see.

On the board the following was written:

Exploration of Air and Air Pollution

Acid Deposition Lab

- ***Pre-lab questions***
- ***Classroom investigations***

  -with notes recorded in lab notebook and labeled

  -examination of lung tissue

  -drawings in lab notebooks and labeled

- ***Dust particle collection (Fig. 17-8)***

  -Note particle size and particles per unit area

  -Can you identify any? (Lab notebook)

Jeb looks up bronchitis on a computer for a student, and there is discussion about what to do with the bottles in the back of the room. Two students look at them and ask about a cockroach decomposing; Jeb said it was probably the shell.

Even as the class approached the end of the semester, students were engaged and worked on projects. The class I observed that day was unstructured in that Jeb encouraged the students to finish anything incomplete, and the students were motivated and on task.

Every observation made in Jeb's class showed the students motivated and interested in the class. They were always busy with one project or another, and even when observing the video class where they were not up and moving, their minds were engaged, one could tell by the conversations they were having with each other and the teacher. Every student was involved in the discussion and asked questions about the videos. The US Department of Education and the National Science Foundation (1992) endorsed inquiry-based science to motivate students, and student motivation is encouraged in inquiry classrooms. One of the goals of inquiry teaching, according to the National Science Foundation, was to engage each student in thoughtful activities to learn about science. Jeb described motivation as the biggest success in this inquiry teaching process. He felt the kids owned the assignments by conducting them as if they had actually developed them and wanted to know everything about the investigations. Jeb felt this motivated them to participate, ask questions, and engage in activities to find answers to their questions. He said, *As the teacher, I want to learn, and I like to see my students learn, and I can tell my students are learning. And if there is a student interested in something, if they are interested, I know they are learning something.*

Jeb felt that it was difficult for some students to complete assignments with little direction at the beginning and not be given step-by-step approaches to the assignment. He said that lower level students that were not hampered by needing to know step-by-step directions were more successful with this method. He felt upper level students were afraid of any kind of failure, and wanted to know exactly how to do an assignment, and were less able to develop a plan of research on their own.

The low level learners, who are more creative and don't fit into the normal scheme of the classroom… because they are so creative and they are not focused on the step-by-step, they do very well with these things, and they can take off with that [inquiry assignment] and not need much help at all…

Jeb felt grades were more reflective of actual learning.

It seems like when it's time to get grades in I feel a whole lot more comfortable because I am not snowed under with a bunch of papers to grade. The activities take longer, but I think they get more out of it because they are spending more time on them and having to think as they work through them…You might have ten grades as opposed to 25 grades in the end.

Jeb felt the activities often take more time, but he also felt they were worth the time invested since this taught them much about science. He believed the grades he recorded were accurate and required less work on his part because before he often graded lengthy written assignments. Now he has students think through assignments but actually write fewer assignments on paper.

One area he felt was a success for him personally during inquiry teaching was the "light bulb moment". It was at this moment that he discovered he could use inquiry teaching in other settings than just labs. He used inquiry teaching creatively as we saw in the video class. Another class he used inquiry creatively was in a class in which the students drew and colored posters:

On this particular day in Jeb's class, students worked on a Dragonfly Pond assignment. The previous day they were asked to build a collage of human land-use activities around a pond, arranging items such as housing complexes, factories, the city, etc. Each group was asked to consider a different perspective, such as one group was businessmen, one was farmers, one was gas station owners, and so on. Then the groups were asked to present the collage to the class and explain why they had built and arranged it this way.

Teacher: Tell me what you guys are representing.

Student 1: OK… our interest was the highway (showing poster)

The resort was around the water and the highway near houses. The feedlot was away from houses so you don't smell it, run-off goes downstream, use the river for irrigation.

Teacher: What's across the street from the grocery store?

Student: The dry cleaners. It's near the highway.

[Researcher's note](This group continued discussing where they placed things and where the pollution from their factory went.)

[Researcher's note](Another group began presenting their project:)

Student 2: We're ordinary citizens who want a nice place to live.

Student 3: Let's talk about housing where the common people live, easy access to the business, the highway and for seclusion. We put grocery stores near the houses, and we put restaurants so people on their lunch hour can eat. We put gas stations on the highway. We put the farm feedlot really far away so there will be no smell.

[Researcher's note](Jeb displays maps from both groups on the board with masking tape. He places each city map one directly above the other connecting them. Each group continued to discuss the perspective they were coming from, and Jeb continued putting the posters one above the other connecting all of the cities.)

Teacher: Most of you put the bleach factory on the bottom corner of your paper. What did you not consider?

Students: The next town.

Teacher: Now that you see the big picture or the water as a larger ecosystem, what should you consider?

Student: They're all going to settle on the lakes below it.

Teacher: Are there any big areas of concern.

Students: Yeah, the third one.

Teacher: Would this (bottom poster) one be a good place to be with all this moving into this water? I think you can see the bad things. There are good points on this. Something else you're missing?

Student: Maybe the marsh, the marsh takes out the bad stuff.

Teacher: The marsh acts as a natural buffer. Is there enough to handle all that everyone is putting in there? That's something to consider.

Student: The first two doesn't have the bleach factory near the lakes.

Teacher: Boy, look at this third one. The bleach factory is near the production of food for human consumption.

[Researcher's note](There is much discussion.)

Student: Which one is more realistic to towns today.

Teacher: This one. It's always been putting houses close together. Now they're looking at giving houses larger lots and preserving more trees.

Students: Our water is going to be really clear and clean.(Referring to the bleach factories)

Student 5: It might burn your skin.

Student 2: And all of your fish will be white.

[Researcher's note]The class continued discussing the placement of the buildings and water in each town and its effect on the other towns.

Jeb illustrated in this class that he did not have to apply inquiry teaching only to labs, but he could also use collage projects where the students answered questions and saw an overall picture in different ways.

Perceived Challenges to Implementation

Challenge 1. It was difficult for students to think in this way.

Even though most students appeared motivated to be part of the inquiry classroom and actively engaged in the classroom discussions, that had not always been the case. Jeb described that early in the semester kids had a difficult time coming up with ideas when given an inquiry assignment. In one interview he explained:

> *Students have a hard time thinking so to jump right into inquiry… most of the time they look at what you give them, and they don't know what to do. They have been taught so much, that everything is either do this step, do this step, do this step or multiple choice. They want to break everything into what are my options. I can ask a student a question and it's a three-part question. If I write the question so that it reads statement "a", part "b" and part "c", my students will automatically choose a part, they don't try to answer the three parts, they just pick one.*

On one assignment, students were asked to design a model of Mount Ranier based on a description Jeb had given them. The students were not given much direction other than they must describe the topography of the mountain. The topography was different at various elevations, and the students were encouraged to use cardboard, straw, scissors and a variety of items to illustrate the different topography. The overall package was to design the model and sell it in a gift shop at the mountain.

> *And then I had a large number of students that looked at it and then looked at me, and they looked back down like, "What do I do." "What do I do first?" They put both hands in their lap and said, "What do I do first? OK. I've done that. Now what do I do?*

Jeb later described the students who were challenged by this assignment. He said that eventually he gave 4 or 5 students the option of doing a five page report requiring three pictures because the kids had struggled for days and rather than have them fail at the assignment, he had to make an alternate assignment.

Challenge 2. When in a time crunch, inquiry teaching is difficult to do.

Jeb felt that the 90-minute block scheduling gave him ample time to teach his class using inquiry-based teaching. He felt that schools with 45-minute blocks would be unable to use inquiry because once a teacher begins an experiment or lesson, he/she would not have ample time to complete it. But, with block scheduling, if students are out a day, it is like missing two days, which would put students behind quite a bit.

Near the end of the semester, Jeb had inquiry projects planned, but due to inclement weather, he had to assign short-term projects requiring more written work, such as fill-in-the blank or matching. Students completed projects and turned in final paperwork. He realized inquiry teaching required time to complete the assignments and decided to cut the inquiry projects due to time constraints. Researchers Marx, Blumenfeld, et. al (1994) also found that all of the teachers they studied implementing inquiry teaching had a dilemma with respect to balancing their use of time and content coverage with granting students' autonomy.

Challenge 3. Teachers must have planning time and knowledge of the content area

Jeb believed a knowledge of the subject area to be imperative as he attempted to implement inquiry teaching. He felt that he must know his subject area well because otherwise students may get involved in discussion and discovery that took them places they were not familiar with or places in which he could not answer their questions.

> *In this situation you have to be very knowledgeable in the subject because you don't know which direction it's going to take when you start. Sometimes you may have a plan… different than what you originally thought, but it may still be a good subject to explore, and you may have to jump back after it gets started on your own and try to find more information.*

Not only preparation by knowing your subject was imperative to Jeb, but he expressed a preparation with producing the lessons as being a key part to successful implementation of inquiry teaching. He described this in these terms:

> *It's difficult, especially, well, you go to workshops and you hear everything and think I'm going to go back and do this in my classroom, and you realize this is hard. It takes a lot of time. The time factor is the thing. You can do a lot before and after. With this activity, you have to do a lot before the activity whereas other classroom structures…after.*

And in another interview he stated:

> *Planning time…. If you do an inquiry activity the way it should be done, and for yourself the background knowledge you need…. I kind of teach two ways of teaching. If you do inquiry you spend a lot of time before the activity planning, as opposed to other styles of teaching where you spend all of your time grading papers or checking worksheets. There's a trade off before and after. I find it very difficult to do very well the first few weeks of school because I spend the summer planning, but once things gets rolling, it's hard to find time to plan in advance.*

Challenge 4. Jeb had little preparation in teaching inquiry teaching.

In an interview, Jeb described his lack of professional preparation to teach inquiry-based science.

> *Interviewer: How have you prepared to use inquiry by your system or by yourself. Have you attended workshops, have they provided professional development or did you pretty much do it on your own, or have you been talking to colleagues? What do you feel has helped prepare you to teach using inquiry?*
> *Jeb: It started [when I was] working with the summer camp.*
> *Interviewer: You were familiar with it[inquiry-based science method] from there?*
> *Jeb: Yes, from there, some coursework in school. There was a mini-assignment in my methods class. However, I found my methods class to be set in one reality and people work in another one. The school, as far as offering [professional development]… I have not had any type of training in inquiry. We spend our time in writing across the curriculum, in thinking maps, which…they are good to use within a lesson, even if it's an inquiry lesson, but,*
> *Interviewer: But not specifically inquiry-oriented?*
> *Jeb: Not specifically.*
> *(Later in the interview)*
> *Jeb: I went from high school and other jobs [into teaching]. The only teaching examples I could think of were what you get at college. Of course, most of the time is spent in a lecture hall. So, that was a big drawback or not having the bag of tricks and a bag of activities… What to do?…they can't listen to that [lecture] for long.*

Challenge 5. Standardized testing was in direct conflict to this style of teaching

Many studies about inquiry teaching find teachers try to cover curriculum to prepare students for standardized tests and are unable to do as many inquiry-based assignments as they would like. Marx, Blumfeld (1994) Ladewski, Krajcik, and Harvey (1994) all described teachers trying to cover their required curriculum and incorporating project-based science into the curriculum guidelines.

Jeb verbalized this concern when he said, *With standardized testing and standard course of study, especially in science, I know there is so much information. You've got five days to spend on this topic, and you cannot spend any more time than that or you'll have to take it away from something else….I know I can't do a whole class for the whole semester, but you can do inquiry lessons[with] some things. Instead of three activities, I would go more in depth… It's very difficult in this course in one semester because…there's your whole semester.*

Jeb felt that standardized testing was in direct conflict with inquiry-based teaching. He said, "Life is a process which takes time."

Table 3 Cross-Case Comparison

	Kurt	Kathy	Jeb
How do teachers define inquiry-based teaching?	• Hands-on *"It's kind of like life…hands-on is the best way [to learn science] and this is hands-on."*	• Hands-on • Open-ended assignments with challenging questions *"I think I have the general idea of inquiry as more long-range stuff than what I used to think. It's more, instead of me, it's letting the kids observe things and giving me some challenging questions, not just ask this, this and it leads to the end product."*	• Reform-based definition of inquiry *"With an inquiry approach, you would give the students a task to perform and the equipment to perform it with, but that would be all. They would have to come up with an entire method on how to do that."*
How are these definitions impacted by their beliefs about how students learn?	• Stated that active strategies were the best way but did not use them consistently.	*"Now, when I took Biology, that was the thing, memorize photosynthesis…that's not what I want my kids to do. I want them to be able to think their way through anything."*	*"I've often thought it would be interesting too if it was possible…to offer a mini-course and revolve it around a tree on campus…do a program on all the stuff we can learn about, come up with, about that tree. They come up with the questions and have them come up with ideas of how they would find the answers to those questions."*
How do teachers who are transforming their practice from traditional methods of teaching enact inquiry-based teaching?	• Hands-on *"They make a poster, and we talk about it…we did it with the booklets with liquids."*	• Moving toward a student-centered classroom. • Fostering ownership of the assignments • Using questioning to facilitate learning	• Implemented many inquiry activities throughout the semester using open-ended format, guiding questions, investigations and articulating findings.

What are factors that enable teachers to enact inquiry-based teaching?	• Students that were motivated received vital information. "*…the benefit is that when you put a kid that has the ability, it puts them in a spot where they have to find the information.*" • Students' motivation increased as inquiry was enacted. • Students retain knowledge	• Students learn science by connecting aspects of science together • Student motivation level "They enjoy being active in things, and they enjoy being challenged." • Students understand processes and retain science knowledge	• Fostering ownership by the students of the assignments "They have a vested interest in seeing it through, and they pay more attention to the procedures…instead of just going through the motions." • Student motivation increased with the use of inquiry "And if there is a student interested in something, if they are interested, I know they are learning something." • *Low level learners became involved in the lessons* "The low level learners, who are more creative and don't fit into the normal scheme of the classroom…because they are so creative, and they are not focused on the step-by step, they do very well with these things." • *Jeb felt grades were more reflective of actual learning* • "…I think they get more out of it [inquiry], because they are spending more time on them and having to think as they work through them…" • *Using inquiry teaching in settings other than lab* • *Students understanding scientific concepts*
What are factors that hinder the teachers from enacting inquiry-based teaching?	• Kurt did not want to lose control of his class. "*I need some kind of order in the classroom.*" • Kurt felt some students did all the work for	• Kathy felt unprepared to teach the process. • There was an inadequate amount of lesson plans or activities available "The struggles have been finding the activities."	• Jeb felt it was difficult for students to process this way "Students have hard time thinking so to jump right into inquiry….most of the time they look at what you give them, and they don't know what to do." • When in a time crunch, inquiry teaching was difficult to do • Teachers must have planning

	the group. "For the kid that's not motivated, they're gonna wait for someone else to do it for them, and they're just not gonna do it." • Kurt was not sure how to implement inquiry-based science.	• Kathy did not want to guide the students too much. "[Kathy felt compelled to say]…this is what you need to know." • Kathy struggled with trying to cover the curriculum in the time allowed	time and knowledge of the content area "In this situation you have to be very knowledgeable in the subject, because you don't know which direction it's going to take when you start." • Jeb felt unprepared to teach inquiry • Standardized testing was in direct conflict to this style of teaching

Summary

Patterns emerged in several of the categories. Two patterns seemed to characterize the "definitions" category; two patterns emerged from beliefs statements, two from the "practices" category, two from the "enablers" category, five from the "barriers". In most cases, Kathy and Jeb were far closer in their understanding and practice than was Kurt.

Pattern 1: ***This is like life…hands on.*** All three teachers referred to "hands-on" activities being part of inquiry-based teaching. Kurt's definition stopped there. In his mind and in his understanding, apparently "hands-on" was the same as "inquiry." He saw inquiry as anything that is "hands-on" in which the students gain knowledge through discovering it on their own rather than the teacher lecturing to the students. His conception of teaching had been so teacher-centered that any change to a higher level of active engagement on the parts of students was a dramatic shift, with the activity structure (hands-on) encompassing the task structure (inquiry learning).

<u>Pattern 2:</u> ***Instead of me, it's the kids…-*** On the other hand, Kathy referred to inquiry-based teaching as "hands-on" plus some other factors such as the teacher using challenging questions to encourage the students to think for themselves, as well as using challenging questioning among the students, or allowing students to ask each other and the teacher questions as they investigated.

Jeb only referred to "hands-on" as being an ***aspect*** of what the students do as part of their investigations into questions. He stated that inquiry involved real world and "hands-on" activities. His definition was more in the way of saying that the teacher sets up the learning environment by piquing the students' curiosities, providing equipment to help the students develop a method of exploration and helping them carry out those explorations. In Jeb's understanding, inquiry involved setting the task and providing equipment (resources), but the learning came from having the students structure their learning (their questions, their procedures, their analyses) on their own.

<u>Pattern 3:</u> ***Foundational knowledge and beliefs.*** Concerning the teachers' belief systems all three stated that inquiry-based teaching was the best way the students could learn science because the students were involved in actively learning, through hands-on activities and being vested in the investigations. The teachers stated that students that felt in control of their learning environment learned better. However, Kathy and Kurt talked about inquiry in terms of foundational knowledge. Kurt again focused on active engagement (hands-on) as the best way to learn. But he seldom practiced it. Thus he seemed to say that the best way to learn science content was in a "hands-on" manner. Kathy wanted her students to be able to "think" but her conception of inquiry was one that was opposed to memorization. So for Kathy, too, science content knowledge seemed to be paramount.

Pattern 4. ***Transformational learning "They come up with the questions…".***

Jeb, on the other hand, had broader beliefs about inquiry. For Jeb, the important thing was for students to take a situation (a tree, for example) and to come up with the questions. For Jeb, the important knowledge was process knowledge, and apparently inquiry was process.

Pattern 5. ***Student motivation "Biggest [success] by far is the motivation of the students…".***

Student motivation was the main reason each teacher said inquiry-based teaching was successful in their classrooms. The teachers felt that the students were actively engaged in the process when using this method, and the students felt they were part of the learning process and not just recipients of information. Kathy and Jeb said if they could foster ownership among the students the lessons being taught were well received. If the students believed they could develop what they were to investigate, they would pursue those investigations with vigor.

Pattern 6. ***Students retain more information when teachers use inquiry-based teaching***

Each teacher agreed that students retain science knowledge by participating in an inquiry classroom. Kathy said some of her lower level students had learned more with this method than had her higher level students learned with lecture. Kurt, when talking about students learning the periodic through inquiry, felt instead of memorizing facts students were actually learning, and Jeb felt that the students understood that you cannot just accept facts when given, as in the oil spill videos, that one must investigate to discover the truth.

Pattern 7: ***Inquiry is found effective for lower level students. Enablers of successful implementation.***

Kathy and Jeb felt the lower level students were successful with inquiry because they were freer to take risks than upper level students. The upper level students were concerned with doing the assignments exactly right, but the lower level students really enjoyed the creativity and excitement of controlling their own learning.

Pattern 8. ***Student risk taking is a barrier, "Getting them to let go and try it on their own is the hardest part…".***

Each teacher stated it was difficult for students to take risks with inquiry-based teaching that students had been told step-by-step what to do and that asking them to develop their own method and investigation was a barrier to teaching inquiry. Jeb stated, "They [students] are not trained to think outside the box." The teachers felt getting the students to begin thinking in this creative way was difficult. Kathy and Jeb felt it was more difficult for upper level students to take risks with this method, because they were more afraid of failure than the average or low level students.

<u>Pattern 9.</u> ***Not maintaining total control of the classroom was a barrier. "…kids are up walking around, and people who don't understand that walk by and think, 'she has no control over her class, they're wild.".***

Kurt and Kathy both felt losing control was a negative factor in implementing inquiry, because they felt they needed to maintain behaviors and make sure other teachers and administrators in their school did not think their class was out of control.

<u>Pattern 10.</u> ***Upper level students had difficulty participating in inquiry. "The low level learners who are more creative…do very well with these things."***

Jeb discussed four students he actually had to give the option of writing a five page report with three pictures, five pages, double spaced, because he felt they were afraid to take a chance on an inquiry project. Each teacher discussed students being told step by step all that they were required to do and felt this method was a new way of thinking for most kids. Kathy said, "They're used to you holding their hand and leading them through it so it's hard for them to let go."

<u>Pattern 11.</u> ***"With standardized testing and standard course of study…you've got five days to spend on this topic and you cannot spend any more time than that…" Time and curriculum constraints are barriers to implementation.***

The teachers found it difficult to incorporate inquiry into an already tight schedule. Kathy and Jeb both stated that there was too much curriculum to cover with little time to stop and have week long investigations. They felt the state's standard course of study and national goals for science education were not aligned with using inquiry-based teaching. When the semester was shortened due to snow both Kathy and

Jeb withdrew lessons of inquiry and substituted hands-on activities and some question and answer time.

Pattern 12. ***"It appears you would have to take the initiative to learn to teach yourself." The teachers felt unprepared to teach using inquiry-based teaching.***

The central office and administration of this school provided workshops with hands-on activities as well as staff development concerning thinking maps. Each of these teachers felt inquiry was a method they should begin in their classroom but had little staff development available to prepare them to teach this method. Kathy requested staff development money for a class teaching the inquiry method but was denied the funds. Jeb and Kurt stated that they had no preparation to teach this method.

CHAPTER V

DISCUSSION

Summary of Results

This study investigated three cases of individual teachers at one school in various stages of enacting inquiry-based science instruction. The study used qualitative methodology (Merriam, 1998) to investigate the teachers as three separate cases. Data was collected by means of interviews, observations, and artifact or document analysis. Open coding (Strauss and Corbin, 1990) was used to analyze the data.

The focus of my study was to specifically look at how these teachers defined inquiry-based science instruction and what effect that definition and their beliefs had on implementation of this instruction. Kurt was a novice concerning inquiry-based science instruction, having never taught in this way before. Kathy began implementation of inquiry-based science instruction the year before, and Jeb had used a similar style of teaching for many years. Jeb referred to his previous style of teaching as experiential science but could draw many similarities between the two styles.

This focus led to the following research questions:

1. How do teachers define inquiry-based teaching?
   a. How do these definitions change over time?
   b. How are these definitions impacted by their beliefs about how students learn?

2. How do teachers who are transforming their practice from traditional instructions of teaching enact inquiry-based teaching?

3. What are the factors that enable the teachers and factors that hinder the teachers from enacting inquiry-based teaching?
   a. How do these factors change over time?

4. What are similarities and differences between the teachers' definitions of and factors with inquiry-based teaching?
   a. What might explain these similarities and differences?

5. How do the hindering factors and enabling factors of the three teachers inform other researchers?

In the following section, I provided brief answers to the research questions grounded in the data. I then provided discussion and interpretation of the findings, inferred patterns that were common across cases, and finally suggested implications for policy, practice, and further research.

1. How do teachers define inquiry-based teaching?

Kurt's definition of inquiry was characterized by using the term hands-on activities. Kathy also used the description of "hands-on" to define inquiry but continued by stating that teachers also must be a facilitator, provide materials and ideas, and that inquiry allows students to teach themselves and others. Both of these definitions remained constant throughout the semester. When asked again in December, these teachers responded similarly.

Jeb's definition began the same as the reform movement definition of inquiry-based science instruction. Jeb mentioned guided inquiry and stated that students have a task to perform and the teacher provides the equipment with which to perform it. Jeb defined guided inquiry as encouraging the students to explore but giving them options so that they were exploring certain areas. He mentioned that the students were asked to organize a instruction, to work on problems, and that they must immerse themselves in the data. His definition also stayed similar from the beginning to the final interviews.

The three teachers' definitions correlated with the time that each teacher was involved in conducting inquiry in their classroom. Kurt, being the novice, had the surface definition and aligned it with his current understanding of hands-on activities. Being involved in her second year of implementation, Kathy correlated her understanding to be somewhat closer to the reform's definition because she added a dimension to hands-on which allowed the students to develop their own instruction to conduct experiments, working with data and articulate explanations. Being considered an expert teacher in inquiry activities, Jeb had the definition closest to that of reform which covered the aspects that engaged the students, gave priority to evidence, allowed students to formulate explanations and communicated their explanations.

1.b. How are these definitions impacted by their beliefs about how students learn?

Throughout implementation, the belief systems of the teachers were affected. Being skeptical at first, Kurt stated several times that he felt this was the best way for students to learn, but he felt inquiry was most effective with middle grade science students, and the young benefited from it more than a high school science student.

As I began conducting interviews with Kurt, it was apparent that he was not happy to be conducting inquiry, and he felt inquiry belonged in the middle school science classroom. He stated that inquiry worked with middle grades, and sometimes students involved in inquiry allowed others to do their work for them. But in his final interview, he stated the benefits of inquiry were that the students did more work, they were able to choose the way they learned, and the responsibility to learn was on their shoulder.

Kathy felt that science could not be taught any other way than using inquiry although she had always used lecture and lab. She had a genuine belief that her students were learning better this way. She stated that she could never return to her old way of teaching.

Jeb stated that his eyes were opened while watching the students' reactions seeing that inquiry could be used in numerous effective settings and also could be used in other subject areas.

2. How do teachers who are transforming their practice from traditional instructions of teaching enact inquiry-based teaching?

Each teacher's definition impacted how they implemented inquiry-based science instruction in their classrooms. Kurt and Kathy's classrooms were characterized by hands-on activities, where Kurt's and Kathy's students made posters, charts and booklets. Kurt's classroom implementation began changing in early December when he introduced the submarine projects, which illustrated more characteristics of reform- based inquiry because the students created submarines and entered an imaginary ocean. The students took measurements with an imaginary set of data and made judgments based on what they found. The students also spoke with real scientists and made “real world” connections.

Kathy’s implementation used hands-on projects and some inquiry lessons. Her implementation included hands-on projects, but she also used lessons that were not only hands-on but also asked questions for investigation. Kathy asked students to develop questions to investigate and to develop instructions to answer those questions. As when she conducted lab activities, she asked the students to develop a instruction, use it, and record it on a lab report. Many times she asked students to develop questions before investigations, and then asked them to communicate findings, written and verbal, after investigations informed those questions.

Jeb’s implementation was closer to reform-based definition of inquiry. He had students’ curiosities aroused with authentic questions, and he provided students with material and equipment to begin answering these questions. Students grappled with the data and compared their findings with others. Jeb became immersed in the investigations with them and asked the students to reflect a scientific understanding of what they found. Jeb asked students to communicate their findings and justify these findings. He even felt comfortable enough with inquiry to use this process in other settings besides just lab settings, as illustrated in the video class.

3. What are the factors that enable the teachers to enact inquiry-based teaching?

All teachers felt there were factors that enabled the ability to conduct inquiry and encouraged their implementatin to be successful. All three teachers found the motivation of the students to be one of the main reasons that inquiry worked in their classrooms. The three teachers stated there was excitement among the students when doing inquiry that they had not seen with other instructions. Excitement was evident in the teachers when they saw their students participate in activities and become involved in the classroom activities.

Kathy and Jeb both alluded to students showing ownership in the activities and claiming a stake in what was going on in the classroom. They cited this as being a successful byproduct of inquiry and kept the students active in the learning process. All three teachers mentioned that students received science information they needed using this process because they must dig for themselves.

Kathy mentioned that students actually saw processes of science and how they connected together. Kathy and Kurt both mentioned that instead of memorizing information, students were actually learning about conducting scientific experiments and how to process knowledge. Jeb spoke of students being lifelong learners as a reason for using inquiry, and Kathy mentioned that her students needed to learn to think for themselves which inquiry-based teaching encouraged.

Jeb also mentioned enabling factors or successful factors which allowed low level learners to be successful. Jeb and Kathy spoke of how upper level students sometimes had difficulty with conducting investigations without step by step instructions, but that lower level kids learned really well with this instruction.

Jeb felt that grades were more reflective of what the students actually know. Jeb cited that as being a positive attribute of this instruction, because the students spend more time using scientific information and investigating questions.

3. What are the factors that hinder the teachers from enacting inquiry-based teaching?

Chaos in the classroom was a concern of both Kathy and Kurt. Kurt felt like he needed a little order in the classroom and found it difficult since students were in different aspects of investigation. Kathy stated that administrators passing her classroom might see activities as chaotic.

Kathy and Jeb felt students had difficulty thinking about science in this way. The students were accustomed to being told Step 1, Step 2 instead of being given a question and asked to develop their own steps. Both Jeb and Kathy stated that upper level students needed to be told what to do and were afraid to take risks needed in inquiry. Jeb created alternate assignments for upper level students who had difficulty thinking creatively in the fashion inquiry-based science instruction asked.

Other factors seemed to be barriers for Kurt and Kathy. Kurt felt some students did the work for others in the groups, and Kathy did not want to guide the students too much by telling them exactly what to do. Kathy and Jeb felt that time was a factor because often they were not able to conduct inquiry due to limited time. Kathy and Jeb also mentioned that they were concerned with having enough time when trying to cover the curriculum. Many times they correlated a lack of time with the ability to cover the required curriculum using inquiry activities.

Plenty of planning time and knowledge of the content area was important to Jeb because he felt the students may ask numerous questions, and he would need to be able to help them. Kurt disagreed, saying that it was easier in a subject he was not as familiar with because the students discovered knowledge on their own and learned things he would not have covered in lecture.

All three teachers agreed that they were unprepared to teach inquiry-based science instruction. They felt that effective workshops were not offered; they were not given accurate information, and no one was available to aid their implementation of inquiry. Another barrier to all three teachers was a feeling of having to discover on their own a working definition of inquiry and how to effectively implement it.

Conceptual Framework in Relation to Patterns

The socio-cultural aspect of the framework used in this study outlines that teachers are affected by their surroundings, and that they are situated, as they make sense and implement inquiry. This socio-cultural portion of the framework illustrates how participants are making sense of the reform initiative of inquiry through their social interaction with students, other teachers, and administrators. This socio-cultural aspect may be affected by social patterns and the physical make-up of the environment. As the individual participant is constructing knowledge, they are also teaching in social settings.

Constructing knowledge and teaching practices are not exclusive, but interplay with each other. In this study, patterns are heavily influenced through this “situative” lens.

In Kathy’s case, she was influenced by a workshop she attended and came back to her school excited about using inquiry. She convinced others in the science department to also begin looking at inquiry as a possible mode of instruction. As Kurt began implementing inquiry, other teachers would share inquiry lessons with him that he could use. As shown in his case, Kathy was in his classroom one observation day finding internet sites for Kurt that contained lesson plans that he could use.

Jeb was the canary in the mine because the other teachers gave him lessons to try out before they used them. He would deem them successful or not before others tried them. Another teacher not in the study but in this science department also shared research articles with Jeb about inquiry. He showed those to the researcher and spoke of the articles being influential in his understanding of inquiry.

The social patterns of this department in which inquiry information was shared was informal. It was observed usually before or during class when the teachers were in other teachers’ classrooms. The doors between the classrooms were often left open and teachers were frequently in and out of others’ rooms sharing information. Each teacher spoke of other teachers in the department freely sharing the success of lesson plans sometimes even as they were conducting them. When the researcher was observing the classrooms other teachers would be in and out of the rooms.

Two of the teachers had common planning times and they all had common lunch. Many exchanges of information occurred during these times informally. The teachers had strong relationships with each other and felt free to share information. These interactive frames impacted teacher learning and provided a lens for interpretation.

Patterns, Implications for Practice and Policy, and Further Research

In this section, I described emerging patterns in the data between the three cases. I explained the patterns by comparing them to literature of research in this area. I also provided implications, based on these patters for practice and policy as well as give areas that need further research. These patterns are clustered around the research questions.

1. How do teachers define inquiry-based teaching?

Pattern 1: *This is like life…hands on* (Teacher Definition)

Pattern 2: *Instead of me, it's the kids…(*Teacher Definition)

Many educators, when implementing new methodology assimilate the new instructions with something they already understand (Klaymon and Ha, 1987; Flavell, 1963) losing the difference between old methodology and new. In Kurt's and Kathy's case, definition of inquiry aligned with their understanding of "hands-on" activities. Although Jeb mentioned "hands-on" activities, he understood that those activities were part of the investigation phase of inquiry.

Hall and Hord (2001) explained the first step to moving toward change is to "develop, articulate, and communicate a shared vision of the intended change." Teachers must have a similar and accurate understanding of inquiry if it is to be effectively implemented. Hall and Hord continued by saying that the definition must be clearly defined by all that are informing others about the innovations. Everyone should agree on the specific definition of the instruction. Fullan (2001) identified this step as "clarity" and advised principals or innovators to encourage change by clarifying the definition of change instruction.

Practice and Policy

In practice, teachers who have a better understanding of inquiry can implement inquiry more effectively than teachers who do not have a clear understanding will. if teachers are working to implement this instruction without the support of central offices or administration, teachers must have a basic understanding of inquiry, as agreed upon by experts in the field of science to effectively implement inquiry.

If districts implement inquiry-based science teaching, they must provide ways of communication to make clear inquiry-based teaching before trying to implement it in the classrooms. An expert teacher should be available to teachers implementing change that can help teachers understand the definition as it is used in the day-to-day activities of their specific classroom. Written and verbal explanations of an accurate and usable definition of inquiry are critical for the successful implementation of inquiry.

Further Research

Further research needs to be conducted to investigate what definition teachers at other schools, who implement inquiry have and how that definition affects their implementation. Also, entire departments working to implement inquiry-based teaching need to be observed for their definition of inquiry-based teaching, how it is communicated and if it is effectively communicated to the teachers. Investigations must observe what the definition looks like prior to implementation, if the teachers understand it, and what effect this understanding has on implementation.

1a. How are these definitions impacted by their beliefs about how students learn?

Patterns 3: *Foundational knowledge and beliefs*

Pattern 4: Transformational learning "They come up with the questions…"

Many researchers agree that teacher beliefs about how students learn are an important aspect of teacher change (Kracjik, Blumenfeld, Marx and Soloway, 1994; Anderson, 1998, Fullan, 2001). Although there is some discussion as to whether beliefs must be addressed prior to implementation of new strategies or if implementation will change beliefs, each teacher in these cases had his/her beliefs about inquiry strengthened throughout the semester. Kathy even stated, "…I could not go back to lecture and the old way."

Each teacher's prior beliefs about learning affected the way they implemented inquiry. Kurt and Kathy both believed science knowledge to be paramount and saw science more of a body of knowledge to be learned. This had an effect on how they both implemented inquiry. They taught science as if disseminating information about science through inquiry-based lessons. Jeb, on the other hand, believed students should learn processes of how to think and explore for answers. He believed that acquiring scientific understanding is more of a process than an understanding of a body of knowledge about science. This was evidentin how he structured his classes providing opportunities for the students to have their curiosities aroused, explore those curiosities and develop interesting explanations of those quandaries.

Kurt's beliefs about inquiry changed as he saw students learned and became motivated to participate in his class. In his initial interview, he spoke of inquiry being the best way for students to learn science, but as previous research tells us, he fell back on the teaching style he was most familiar with when confronted with using a new strategy (Flavell, 1963). He had reservations about inquiry in his initial interview and stated that inquiry was more effective for middle school students or younger students, however, as he approached the end of the semester, his practice had changed to include inquiry as being one of the most effective instructions for students preparing to enter college, based on his observation of inquiry being implemented in his classroom. The students' motivation level and knowledge they were acquiring through inquiry changed his mind about the benefits of inquiry. He saw inquiry as more effective for all students.

Practice and Policy

In practice, administrators implementing change must recognize that beliefs have a direct impact on how teacher's implement change. They need to be aware of teacher's prior beliefs, but not necessarily feel they must change those beliefs prior to implementation practices beginning. Teacher's attitudes about how students learn may change as inquiry is enacted, as did these three teachers. Changing teacher beliefs may, in fact, occur after implementation. Enactment proved crucial in prior studies concerning changing teacher beliefs (Blumenfeld, Krajcik, Marx and Soloway, 1994).

Further Research

Further research on a broader base of teachers about their specific beliefs about inquiry informed these findings. As teachers implement inquiry, it is essential to observe their prior beliefs about inquiry and beliefs after inquiry is enacted in their classroom to observe if similar findings are found. Correlation studies between how teachers believe students learn and how effectively they implement inquiry is another avenue of research needed.

3.What are the factors that enable the teachers to enact inquiry-based teaching?

Pattern 5: *Student motivation. "Biggest [success] by far is the motivation of the students…"*

Little is known about how teachers implement inquiry-based teaching on a day-to-day basis. This study informed that question by outlining that each teacher saw student motivation as an important factor for the success of inquiry in his or her classroom. Observations of the students also reported more student motivation when they were involved in inquiry-based lessons. The students were active and excited in each of the classrooms during inquiry lessons. The motivation of the students proved to strengthen each of these teachers' resolves to continue to use inquiry in the semesters to come.

Practice and Policy

In practice, teachers may be made aware that positive student motivation was a byproduct of inquiry-based teaching in these cases, and may be in their own case. Teachers may use this positive student motivation to allow inquiry to work for them. Motivation will provide the energy needed to have the students conduct investigations and find knowledge on their own.

Further Research

Further research must be done on a much broader base of teachers and classrooms to see if student motivation is a byproduct in other schools and in other educational settings. Further research in these three cases after more time of implementation is needed to observe if this student motivation is sustained. It would benefit research to examine under what conditions student success could be sustained while implementing inquiry-based science instruction.

Pattern 6: *Students retain more information when teachers use inquiry-based teaching.*

Much of the research about positive aspects of inquiry-based science instruction outlines that students retain science knowledge, and inquiry has a positive effect on cognitive achievements of students (Shymansky et. al., 1983; Mechling and Oliver, 1983; Lloyd and Contreras, 1985, 1987). Each teacher in these cases stated that retention of scientific knowledge was an aspect of using inquiry.

Kathy discovered that other teachers found her students from last year better equipped than previous students to be successful in higher level courses. She felt they retained more information than previous years when she had used lecture.

Practice and Policy

In practice, teachers may find that students retain more knowledge using inquiry because of the active student involvement in the knowledge. The students are learning to develop questions, produce investigations, and answer questions. They are learning the process of learning as well as acquiring knowledge. Teachers may find that students use the information rather than just memorize the information.

Further Research

Further investigation into classrooms such as Kathy's that focused on student retention of knowledge could inform this question. Following students in an inquiry-based science classroom compared to a traditional lecture or a "hands-on" activities classroom could provide insight into whether the instruction is a factor in student retention of scientific knowledge.

<u>Pattern 7: Inquiry is found effective for lower level students.</u>

Research also finds that inquiry works well for the disadvantaged or low level student (Carpenter, 1963; Bredderman, 1982). This study helps promote this finding. Kathy and Jeb both spoke in interviews of average and lower level students performing well with inquiry. They felt students that were not hindered by having to know exactly what was expected of them were successful with this instruction. Both Kathy and Jeb found these lower level learners more of the creative mindset and willing to take a chance by developing their own instruction of investigations and pursuing those. These students felt less threatened about taking a chance and making a poor grade than perhaps higher achieving students.

Practice and Policy

In practice, teachers may see that lower level students do well with inquiry and use that to their advantage to reach students that are difficult to teach otherwise. Inquiry may help students to think "outside the box" as Jeb said, so that they may discover ways of learning and knowing the students have failed to get through traditional classrooms.

Further Research

Further research is needed to specifically look at the students of all levels and observe their performance in an inquiry-based classroom. Interviews with these students would help paint a better picture of the thought processes these students go through when first introduced to inquiry and throughout an inquiry-based science course.

3**. What are the factors that hinder the teachers from enacting inquiry-based teaching?**

Pattern 8. ***Control of the classroom*****.**

Teachers having difficulty releasing classroom control, wanting to control their lessons and maintaining order with little talking have been discovered in other classrooms as barriers to implementation, in which inquiry was being enacted (Marx, Blumenfeld, Karajcik, Blunk, Crawford, Kelly, Meyer, 1994; Anderson, 1998). Kathy and Kurt both expressed difficulty in accepting this aspect of teaching inquiry.

Practice and Policy

In practice, teachers can expect to grapple with this as well. Administrators must support teachers as they may encounter these feelings when moving from a teacher-centered classroom to a student-centered classroom. The administrators must produce a school climate that is accepting of a student-centered classroom with all of its characteristics such as students moving throughout the classroom and carrying on discussions with other students and the teacher.

Pattern 9. ***Upper level students having difficulty with inquiry.***

Pattern 10. Time and curriculum a factor

Upper level students having difficulty using inquiry was observed in both Kathy's and Jeb's classes. Kathy and Jeb both found students having difficulty processing information the way inquiry requires. Often, Kathy and Jeb discovered it was higher level students that were struggling to begin developing instructions and conducting investigations without specific instructions from their teacher. The barrier to these children was the creative way in which they were asked to think and that it was so far removed from the way they were usually exposed in other classes. Usually, as Kathy stated, they were used to, "Step 1, Step 2, Step 3" or as Jeb stated, they were used to being given "multiple choices" to choose from instead of creating their own.

In this study, I discovered other barriers these teachers faced that are not common in the previous literature. Kathy and Jeb spoke about preparation of an inquiry lesson and how much time it takes. Kathy also spoke of needing more usable activities.

Practice and Policy

In practice, administrators need to create a learning environment in which many classes, if not all, use student-centered learning where students are exposed to processing information this way.

Administrators and central offices need to train teachers to use inquiry by training them in a hands-on way to teach inquiry. Creating an inquiry classroom for the teachers to participate to gain experience with the instruction is a start. Teachers should be provided with adequate planning time that allows for this style of teaching and provided with usable lesson plan examples that can be used in their classroom. Kathy and Jeb had asked multiple times for help with practical lessons as well as information about inquiry, but received little help from their central office.

<u>Pattern 11. Teachers unprepared.</u>

Each of the teachers felt they were unprepared to teach inquiry and had little information to help them enact inquiry-based science instruction. These teachers were able to successfully use inquiry at some level despite the lack of support from their central office and administrators. These teachers were determined to continue using inquiry because of the positive effect it had on their students.

We have little research that investigates the day to day implementation practice of teachers enacting inquiry in a "real world" classroom (Spillane, Reiser, Reimer, 2002). It would be informative to have more qualitative studies, which observe day to day implementation of inquiry to see if there are barriers in other classrooms. Identifying barriers would help researchers in developing ways to overcome barriers.

Each of the teachers in these cases began a change in practice because their district encouraged student-centered learning. These teachers chose to use inquiry-based science instruction as their student-centered learning instruction. In practice, districts hoping to incorporate inquiry into their science classrooms must tie this into their teacher accountability requirements, as well as follow up with support and observation.

Practice and Policy

Policy changes that could help eliminate barriers must take place at the state level in curriculum and standardized testing. Curriculum goals need to allow for investigations and time to cover curriculum goals as well as align with the use of inquiry. State required tests need to reflect a "problem-based" approach, which would require "problem-based" activities in order to be prepared.

Further Research

If inquiry-based science is being shown as a instruction that is central to teaching science and can help reach all students, then further investigation into barriers to other teachers would better inform this discussion. More hands-on, qualitative research is needed into the everyday workings of the classroom in which teachers implement inquiry-based science instruction. With barriers being studied, it would be possible to address these barriers and make implementation of inquiry-based science instruction more effective for a larger group of science teachers.

Summary and Conclusion

This study investigated the definition, beliefs and practices of three teachers who implemented inquiry-based science instruction, even though each of the three teachers were in different stages of implementation. Kurt was a novice. Kathy was in her second year of implementation, and Jeb was an expert. Data was collected through observation, interviews, and artifacts, such as lesson plans and student work.

Major findings in this study were discussed according to the following patterns.

Pattern 1: *This is like life…hands on*

This was a statement from Kurt about life and inquiry both being a "hands-on" process and illustrated his and Kathy's comparison of inquiry with "hands-on" activities.

Pattern 2: *Instead of me, it's the kids…*

Kathy and Jeb both expanded their definition from just “hands-on” activities to the students being the center of the learning process, and that instead of the teacher being the center, the students learned by exploration through inquiry.

Patterns 3: *Foundational knowledge and beliefs*

All three teachers felt that inquiry was the best way to learn. Although Kurt felt reluctant to implement this process based on no experience with the process.

Pattern 4: Transformational learning “They come up with the questions…”

Jeb felt that the students learn best when they have a natural curiosity and investigate that curiosity.

Pattern 5: *Student motivation. “Biggest [success] by far is the motivation of the students…”*

Each teacher spoke frequently of how motivating the process of inquiry was for their students. The teachers saw the students engaged and excited in their investigations and discussions.

Pattern 6: *Students retain more information when teachers use inquiry-based teaching.*

The teachers were also pleased with how much information the students retained throughout the semester. Kathy had students in subsequent courses and found them to be better prepared than students she had taught using lecture.

Pattern 7: Inquiry is found effective for lower level students.

Jeb and Kathy spoke of lower level students, who responded well to inquiry-based teaching practices.

Pattern 8. ***Control of the classroom*.**

One of the barriers for Kurt and Kathy was a feeling of lost control of the classroom. They began to feel more comfortable as they saw their students remain on task and retain knowledge.

Pattern 9. ***Upper level students having difficulty with inquiry.***

One pattern not seen in previous literature was a difficulty for upper level students to complete inquiry activities. Investigation into why this remains a problem for these students is needed.

Pattern 10. Time and curriculum a factor

As other teachers have found when implementing inquiry, time and covering the entire curriculum in the standard course of study were barriers for Jeb and Kathy. Although they wanted to use inquiry, they used traditional teaching techniques when faced with time crunches.

Pattern 11. Teachers unprepared.

Based on the teachers having little preparation for teaching inquiry, the teachers felt isolated and unprepared to teach this instruction. They asked for information but received none.

These patterns illustrate what these teachers experienced and inform what other teachers and districts can do to help produce more effective implementation of inquiry-based science instruction. As these three cases began implementing inquiry in their specific classrooms, they met with success even though their definitions were varied, they had little training, and they had little support from their administration or district. In each of the three cases, the teachers planned to continue using inquiry in their classroom and were excited about the success they witnessed with the inquiry-based instruction.

Districts seeking to implement inquiry in their schools must communicate a clear definition of inquiry-based science instruction with practical examples of how to use it within the classroom setting. Teachers' belief systems must be recognized as part of the change process and addressed in conversation, but may develop as inquiry is enacted.

Staff development should provide "hands-on" opportunities for teachers to practice enacting inquiry, and teachers must continue to be supported throughout the change process. As teachers face barriers to enactment, an informed support person would be beneficial to overcome barriers. Teachers must be provided adequate planning time and practical lesson plans applicable to the curriculums they are asked to teach. With a clear understanding of inquiry, support and resources from their district, teachers can be expected to be successful at enacting inquiry in their classrooms and help the educational community reach its national goal of inquiry in every science classroom.

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