COLLEGE SCIENCE TEACHERS' INQUIRY BELIEFS AND PRACTICES IN THE SCIENCE CLASSROOM

by

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ABSTRACT

The purpose of the study was to examine college science professors' beliefs regarding the use of inquiry in the college science classroom, how these beliefs impacted their instructional choices and how these beliefs were enacted in the classroom. Additional questions were how teachers' beliefs vary across institution types (community college, private, four year college, and large research institution), and how beliefs vary across disciplines (life sciences and physical sciences). A case study design was required for this study due to the complexity of the topic and different data sources needed to answer the fore stated research questions. These data sources included surveys, interviews, classroom and laboratory observations and written records such as laboratory activities and syllabi. Twelve college professors at three different institutions; large research institution, small, private four year college and community college were interviewed. In addition to interviews, classes and labs were observed, a questionnaire on the five essential features of inquiry was given and samples of labs and syllabi were obtained. A laboratory coordinator was also interviewed as she was responsible for the laboratory section for two of the professors at the research institution. All schools were located in the southeast United States. The perception of inquiry by college science professors has been found to be a barrier to the inclusion of inquiry in college classrooms and was supported in the current study. While the professors described constraints to inquiry such as large class size, lack of time, disinterest of students, and lack of equipment, these limitations were due, in part, to the professors' incomplete view of inquiry as what researchers do. This view was most pronounced with the professors at the large, research institution. At the research institution, observations in the classroom mirrored the beliefs of inquiry. Lecture was the primary instruction in the science classroom, and the labs were scripted and shown to be "cookbook" with little or no evidence of inquiry noted in the labs

obtained. There was more evidence of inquiry at the private four-year college and community college than at the large research institution; what was observed in the classroom mirrored what the professors believed about inquiry. There was a difference in the beliefs between institutions with the professors at the research institution holding an incomplete view of inquiry while the professors at the private college and community college included many aspects of the inquiry continuum in their view of inquiry. There were no differences noted between disciplines.

Dedicated to my family who supported me the last six years as I pursued my dream –Chuck, Perrin and Tyler. You are my rock!

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LIST OF ACRONYMS/ABBREVIATIONS/DEFINITIONS

Belief (Rokeach, 1976) – A belief is any simple proposition, conscious or unconscious, inferred from what a person says or does, capable of being preceded by the phrase "I believe that…." The content of a belief may describe the object of belief as true or false, correct or incorrect; evaluate it as good or bad; or advocate a certain course of action or a certain state of existence as desirable or undesirable (p. 113).

Constructivism (Driscoll 2005; Gredler, 2005) – Constructivism is several related perspectives that view knowledge as a human construction. Radical constructivism, derived from Piaget's perspective of learning, views the learner's knowledge as adaptive. The teacher's role is to challenge the child's way of thinking (Gredler, p. 428). The goals are problem-solving, critical thinking and the active and reflective use of knowledge (Driscoll, p. 393).

Inquiry (NRC, 1996) – Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as understanding of how scientists study the natural world (p. 23).

Case Study Approach to Research (Bell, 2005)- "All organizations and individuals have their common and unique features. Case study researchers aim to identify such features, to identify the various interactive processes at work, to show how they affect the implementation of systems and influence the way an organization functions" (p. 10).

Science education reform (AAAS, 1990: NRC, 1996) - The current science education reform was initiated by the launch of the Soviet rocket, Sputnik. America's economic decline and the decreasing educational performance of American students has kept alive science education reform. The goal of the current science education reform is to create a scientific literate society for all.

Social constructivism (Gredler, 2005) – Social constructivists, in contrast to constructivism, view knowledge as a social product (p. 428). Social constructivists view the classroom as a community charged with the task of developing knowledge. Furthermore, they view knowledge as inseparable from the activities that produced it. Therefore, knowledge is transactional; learning is socially constructed and is distributed among the co-participants (p. 85).

CHAPTER ONE: INTRODUCTION

> *Public opinion overwhelmingly favors "ensuring a well-qualified teacher in every classroom" as the top education priority. Indeed, teachers- once viewed as central to the problem of underachievement – are now being recognized as the solution. In teacher preparation, there is a "multiplier effect" that can span generations. While a sound undergraduate science education is essential for producing the next generation of scientists, it is equally critical for future teachers of science. The refrain, "You can't teach what you don't know," surely applies (National Science Board, 1999).*

Teaching and learning to teach is daunting. Research at the primary and secondary levels have documented the struggle of learning to teach well (Kane, Sandretto, & Heath, 2002). From the body of research on the process of teaching has come an understanding of the importance of beliefs and how they impact teachers' instructional choices. Current science education reform recommends moving toward instruction that incorporates more inquiry. While efforts in science reform have concentrated on elementary, middle and high schools, the way science is taught at the college level must also be examined. Studies on the beliefs of both K-12 and preservice teachers with respect to inquiry instruction is extensive (Beck, Czerniak, & Lumpe, 2000; Haney, Czerniak, & Lumpe, 1996; Lumpe, Haney, & Czerniak, 2000; Zint, 2002); however, there is modest documentation regarding the role of beliefs with respect to inquiry instruction of teachers of higher education. (Brown, Abell, Demir, & Schmidt, 2006; Kane, et al.). Since teachers' beliefs affect how they view curriculum and its implementation, these beliefs are critical components of any examination of educational reform (Kane, et al.; Pajares, 1992; Tobin, Tippins, & Gallard, 1994). The study of college science teachers' beliefs is significant due to the current science reform efforts, which emphasize the use of inquiry as a key instructional strategy (Kane, et al.). Additionally, college science teachers' beliefs may influence how they view inquiry, and whether or not they teach future science teachers how to use inquiry in their classrooms. Since college science teachers are often responsible for providing science content instruction to beginning teachers, understanding their beliefs about inquiry as an instructional method is central to facilitating its use in the K-12 setting. According to Pajares (1992), "understanding the belief structures of teachers and teacher candidates is essential to improving their professional preparation and teaching practices" (p.307). This study examined college science teachers' beliefs regarding inquiry in the college classroom as an essential link to understanding the use of inquiry in the K-12 setting.

Many researchers have suggested that by understanding why teachers make the instructional choices they do, professional development programs can be planned to address issues that hinder necessary change (Crawley, 1988, 1990; Haney & Lumpe, 1995; Haney, Czerniak, & Lumpe, 1996; Koballa, 1986, 1989; Lumpe, Haney, & Czerniak, 1998a, 1998b). Many colleges are not providing preservice teachers with the types of inquiry experiences necessary for them to incorporate inquiry into their own classroom (McKinnon & Renner, 1971). Examination of why inquiry experiences are not being utilized in the college science classroom is important if the reform effort in science education is to continue to move forward (Apedoe, 2008; NSF, 1996). Shulman (1990) states, “how you learn a subject in college affects how you teach it” (p. 406).

The National Research Council (NRC) (2001) has identified improvement in teacher education as a priority in the next decade. If improvement in teacher education is to be realized, the college faculty responsible for educating teachers must be included when exploring ways to advance science instruction. Although the focus of the NRC is primarily on science and mathematics teachers of K-12, there are several areas that affect teachers of science at the college level. The NRC has advocated the responsibility for teacher education in science and mathematics to involve, not only school districts and schools of education, but also institutions of higher education. Because future teachers of science and mathematics are enrolled in college courses in science, college faculty must be cognizant of how their teaching influences these prospective teachers (NRC). Currently, many college science teachers have been unable to provide the necessary education in order for prospective science and mathematics teachers to be successful in their classroom (NRC). According to the NRC, “The preparation of beginning teachers by many colleges and universities (preservice education) does not meet the needs of the modern classroom” (p. 31). The professors at colleges and universities may be uninformed as to what is expected to assist beginning teachers in acquiring the subject matter and theory necessary to become effective teachers of science. In addition, many science professors at universities and colleges do not engage in professional development designed to assist them in modeling effective teaching (NRC).

Teachers, as learners, have their own experiences regarding how to teach and how to learn. These situations help develop views of teaching and learning that will have personal meaning when in their own classrooms. Teachers teach how they learn (Tobin, et al., 1994). The Interstate New Teacher Assessment and Support Consortium (INTASC) have stated:

> Teachers of K-12 science and mathematics need to meet the National Research Council's standards for science and the National Council of Teachers of Mathematics' standards for mathematics. INTASC has emphasized further that teacher education should focus understanding of content in subject areas and knowing how to apply that understanding in problem-solving and inquiry-based situations in the classroom. (NRC, 2001, p. 5)

As science reform continues in the K-12 arena, more students will enter college having been taught science using inquiry and with the expectation of continued inquiry learning (Apedoe, 2008). College science teachers will need to adapt their own teaching styles to meet this need. The emphasis on inquiry teaching and learning that is being placed on K-12 is now being placed on colleges and universities (Apedo). If reform is to continue, institutions of higher education, especially those involved in teacher education, will have to make changes in order to keep the reform effort alive (NSF, 1996). The National Science Foundation (1996) report states, "All students have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology, and all students learn these subjects by direct experience with the methods and processes of inquiry" (p. 12). The Committee on Science and Mathematics Teacher Preparation (CSMTP) has called for two and four-year colleges and universities to assume greater responsibility and accountability in the improvement of science and mathematics teachers' education (NRC, 2001).

Southerland, Gess-Newsome and Johnston (2003) identify two components in the science education reform effort. The first component is that if reform is to be effective and change to science instruction is to occur, then this change must occur at all levels of science education. Not only must change occur in elementary, middle and high schools, but also college level science instruction must change as well. It is at the college level that future science teachers are taught science content. Research supports that instructional choices and how one teaches is influenced by how a teacher was taught (Gess-Newsome & Lederman, 1999). The second component in the reform effort is that science teaching must be embedded in the understanding of the nature of science.

Many teachers have never been involved in practicing the type of learning they are now expected to teach (Singer, Marx, Krajcik, & Chambers, 2000). They have not participated in an inquiry-based lesson and are unsure how to develop research questions, design and implement a controlled experiment, and use data to interpret their findings. This is the essence of inquiry-based learning which the *NSES* have deemed necessary in ensuring science literacy (NRC, 2002). Understanding the beliefs of college science teachers with respect to change in teaching practices is important and can possibly lead to adjustments in how teachers teach science in the classrooms (Tobin, Tippins, & Gallard, 1994).

Calls for reform in science education have been heard since the launch of Sputnik in 1957 (DeBoer, 2004). Several national organizations such as the National Science Teacher

Association (NSTA), the American Association for the Advancement of Science (AAAS) Project 2061 and the National Research Council's (NRC) National Standards for Science Education (NRC, 1996) recommend education reform. Although the need for reform and what that reform should look like is not questioned, there has not been significant change in science education (Tobin, Tippins, & Gillard, 1994). This push for science education reform demands that teachers utilize a social constructivist view of learning that engages students in inquiry learning (Hoy, Davis, & Pape, 2006). Traditional methods in teaching science do not promote student thinking and learning in ways necessary for the understanding of science as it is now advocated (Schneider, Krajcik, & Blumenfld, 2005). How the teacher designs and implements the information to be taught is how students are instructed, therefore, the teacher design and implementation directly affects student achievement. Teachers frequently teach how they were taught (Zint, 2002), and so an understanding of instruction at the college level is necessary. Attainment of the goals of the current reform effort relies heavily upon teachers and their practice (Bybee & Ben-Zvi, 1998), and while major revisions in current teaching practices are necessary, these changes will be complex (Zint). People are resistant to change, and science teachers, both at the K-12 level and those in higher education are not exempt from this fact (Lumpe, Haney, & Czerniak, 2000).

Problem

This study focused on the beliefs held by college science teachers with regards to inquiry in the classroom, how these beliefs impact their instructional choices, and how these beliefs are enacted in the classroom. Additional questions examined included how teacher beliefs vary across institution types (community college, private four-year college and research institutions), and also, how beliefs vary across disciplines (life sciences and physical sciences) to explore the differences, if any, in inquiry in those disciplines. Understanding the beliefs of college science teachers with respect to inquiry teaching is one step in moving the current K-12 focused science reform effort upward to the college level as the current science reform emphasizes the use of inquiry as a key instructional strategy. Identifying and understanding barriers to the implementation of inquiry at the college and university level may assist in development of professional development opportunities focusing on supporting university and college professors in integrating inquiry strategies in their courses (Crawley, 1988, 1990; Haney & Lumpe, 1995; Haney, Czerniak, & Lumpe, 1996; Koballa, 1986, 1989; Lumpe, Haney, & Czerniak, 1998a, 1998b). How college science teachers teach science may influence how future science teachers will teach science in their own classrooms. Many times the emphasis in introductory science classrooms is on a body of facts and not as “a way of knowing the natural world through inquiry” (Coble & Koballa, 1996).

The preparation of the vast majority of science teachers depends upon colleges and universities where teachers study science and learn to teach. Science professors in science departments at the university level are involved in teaching basic and advance science content to beginning teachers. According to Yager (2005), many of these professors are not experts in the science of teaching or on the current research about how learning occurs. Too many times teachers teach as they were taught (Yager, Lutz, & Craven, 1996). If teachers are to teach inquiry-based lessons according to the *NSES*, these standards should apply to science teacher education as well (Yager, et al.). It may be that science teachers at the college level are unaware of the National Science Education Standards or do not see the relevance to their practice.

Tobin, Tippins, and Gallard (1994) state that teacher beliefs are vital factors in change and those beliefs cannot be ignored. If we are to expect a shift in science teaching from the positivist to the constructivist view at the college level, understanding the beliefs of college science teachers with respect to inquiry and understanding the obstacles those teachers view to implementation of inquiry is one step towards the goal of realizing inclusion of inquiry in the college classroom.

If we expect K-12 teachers to incorporate inquiry learning in their classrooms, then their college teachers must have an understanding of exactly what inquiry is and what it looks like. They must also provide K-12 teachers with experiences to learn about and use inquiry methods. This has not been the case in many undergraduate science classes; prior experiences in inquiry are mostly lacking for prospective teachers (NRC, 2001). As state and national standards demand the shift to more inquiry teaching, it appears that changes need to be made within science content courses to accommodate this instructional change. It is through learner-centered and inquiry-oriented environments that students learn best (Adamson, Banks, Burtch, Cox, Judson, Turley, Benford & Lawson, 2003) and so restructuring college science classrooms to better align with reform recommendations is essential.

Identification of barriers to the reform effort is vital if the reform is to be effective. Implementation of reform and adoption of constructivist teaching is not an easy task as studies have demonstrated (Tsai, 2002; Windschitl, 2002). Teachers have difficulties with implementation of inquiry teaching and continue to maintain a positivist view (Tsai; Windschitl). As teachers are the key to any reform effort in education, understanding why teachers are resistant to inquiry teaching is vital. Teachers' beliefs influence what happens in the classroom and understanding those beliefs is the first step in change (Yang, Chang, & Hsu, 2008).

Teacher beliefs will affect how they view curriculum and its implementation (Ball & Cohen, 1996, Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000, Collopy, 2003). Therefore, in order to implement reform in science classrooms, teacher beliefs at the college level must be considered along with reform efforts aimed at change in K-12 science education.

Conceptual Framework

Four major elements make up the conceptual framework for this study, 1) inquiry, 2) teacher beliefs, 3) science education reform, and 4) higher education. While each can stand alone, this study investigated the relationship between and among the four elements by examining college science teachers' beliefs about inquiry in the college classroom. The Venn diagram is used to demonstrate the overlap and integration of the four elements and illustrated in Figure 1.

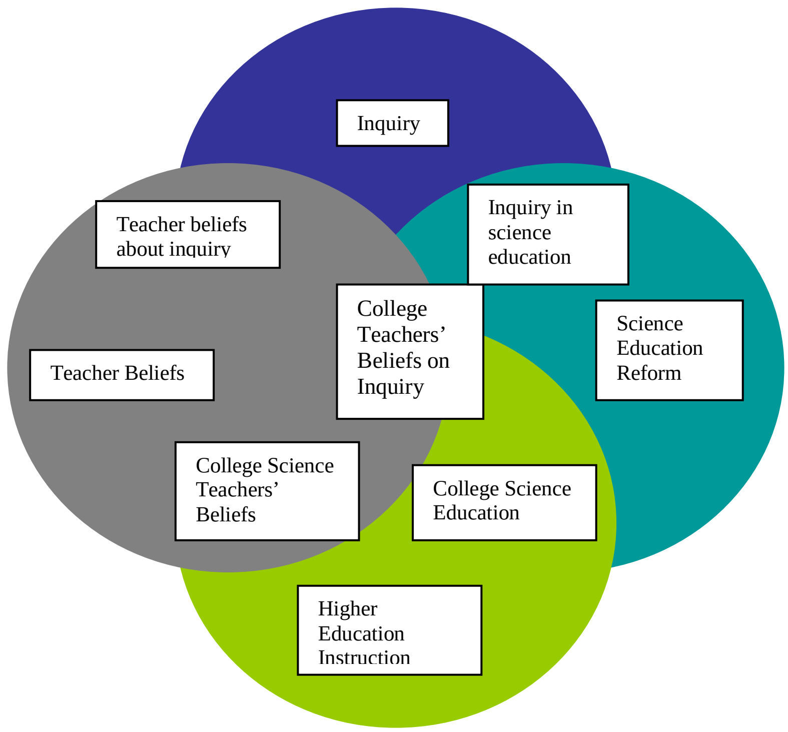

Figure 1: Conceptual Framework

Inquiry-based science is embedded in the social constructivist theory of learning and can be traced back to Dewey (Crawford, 2000) as he advocated that students learn by becoming involved in experiences in real-world activities that promote problem solving as well as interaction and discussion with others (Crawford). Students need to be engaged in finding answers to questions, developing explanations, and sharing ideas with peers and teachers; these activities foster deep understanding of science (Schneider, Krajcik, & Blumenfeld, 2005). While student involvement in real world activities is the basis for inquiry learning, reformers must realize that the importance of how a teacher teaches is essential as well; it is possibly more important than the curriculum (Yager, Lutz, & Craven, 1996).

Teachers come to the classroom with a set of beliefs that impact how they teach as well as what they choose to teach. Formed around situations, these beliefs can form attitudes (Pajares, 1992). Teachers' attitudes become important in determining behavior and these behaviors can become connected to form values (Ajzen, 1985). Beliefs, according to Bandura (1986), will determine decisions people make. When applied to education, teacher beliefs about teaching, students and the subject matter become an important factor in the development of inquiry-based learning in their classrooms. The work by Zacharia (2003) supported the research of others that "beliefs affect attitudes, and these attitudes then affect intentions and behaviors" (p. 812). Research on teacher beliefs in the K-12 arena and preservice teachers is extensive (Beck, Czerniak, & Lumpe, 2000; Haney, Czerniak, & Lumpe, 1996; Hoy, Davis, & Pape, 2006; Lumpe, Haney, & Czerniak, 2000; Pajares, 1992; Zint, 2002), but research on beliefs of college science teachers is lacking. According to Pajares (1992), "understanding the belief structures of teachers and teacher candidates is essential to improving their professional preparation and teaching practices" (p.307). It can be argued that if college science teachers are expected to play a role in the science education reform effort, then an understanding of their beliefs on inquiry teaching is necessary to effect change in K-12 teachers' beliefs and practices. College science teachers' beliefs with respect to inquiry are an essential piece of the science education reform puzzle.

Design of the Study

The research questions in this study were twofold. First, what were college science teachers' beliefs on inquiry teaching in the entry-level college science classroom and second, how were these beliefs enacted in the classroom? Supporting questions addressed if there was a difference in college science teachers' beliefs between institutions, (community college, private four year college and large, research university), and if there was a difference between the disciplines of life science and physical science.

A case study design was required for this study due to the complexity of the topic and different data sources needed to answer the fore-stated research questions. A case study approach enabled the researcher to better explicate the beliefs and practices of college science teachers regarding the use of inquiry in the science classroom and allowed the use of multiple data sources. These data sources include surveys, interviews, classroom and laboratory observations and written records such as laboratory activities, syllabi, and lesson plans.

A modified snowball sampling technique was utilized to select participants. Emails were sent to department chairs of science departments at a community college, a small, private college, and a research institution, asking for names of professors who may be willing to participate in the study. Those professors were then sent emails asking for their permission as well as for names of others that might be willing to become involved in the study. Twelve professors of science were chosen, as well as one laboratory coordinator. Interviews, questionnaires, classroom and laboratory observations as well as collection of labs and class syllabi were done. Interviews were transcribed verbatim and member checking was employed to determine accuracy of the interviews. The questionnaire and observation protocol were based on the five essential features of inquiry as defined by the National Research Council (2000). The use of the five essential features of inquiry, in both the questionnaire and observation protocol, was an attempt to standardize what the professors believed they did in the classroom and laboratory with what the researcher observed. Communication with a well-known science education researcher prompted the inclusion of these features in the current study, as it was felt that previous studies on inquiry in the science classroom had not incorporated these essential features of inquiry.

Organization of Dissertation

A review of the current science education reform and the importance of inquiry in that reform were introduced in Chapter One. Chapter Two provided a review of the literature with respect to the four parts of the conceptual framework used for this study; inquiry, teacher beliefs, science education reform and higher education. While each of these factors is able to stand alone, it is the relationship between and among them that is the focus of the literature review. By examining the four aspects, science education reform, college science education, beliefs of college science teachers and inquiry, and their connection, an understanding of how these factors affect change in the college science classroom becomes apparent. Chapter Three was a discussion of the methodology, sampling techniques as well as data collection and analysis methods. Chapter Four included the results, identifying the differences and similarities between the three institutions and the professors participating in the study with respect to the research questions of this study. The final Chapter, Five, presented the conclusions and the suggestions for future research.

CHAPTER TWO: LITERATURE REVIEW

> *Not long ago, a college chemistry professor grew angry with the way her daughter's high school chemistry class was being taught. She made an appointment to meet with the teacher and marched with righteous indignation into the classroom – only to discover that the teacher was one of her own former students (Yates, 1995, p. 8b).*

Research has demonstrated the benefits of inquiry learning and inquiry teaching in the science classrooms (Ertepimar & Geban, 1996; Freedman, 1997; Glasson, 1989; Lord & Orkwiszewski, 2006; Odubunmi & Belogyn, 1991; Stohr-Hunt, 1996; Von Secker, 2002). Organizations such as the National Research Council have advocated the use of inquiry in the reform of science education. In spite of the overwhelming evidence of the benefits of inquiry, the majority of teachers continue to teach in the traditional way. One reason for this may be that science teachers have not had the inquiry experiences in their college courses (Taylor, 2002). How one teaches and the instructional choices they make are impacted by how they were taught (Gess-Newsome & Lederman, 1999). Hence, the relevance and need for this research study, which aims to explicate the beliefs and practices of college science teachers, is supported.

The National Research Council (2000) supports programs that clearly focus on inquiry as both an end product for teachers and as the way for teachers to learn the content of what they are to teach. A key component of any course taken by prospective science teachers should be "learning through inquiry and active engagement with subject matter" (NRC, 2001, p.119).

In this chapter, the conceptual framework that guided this study includes four elements: 1) Science Education Reform, 2) Inquiry, 3) Higher Education, and 4) Teacher Beliefs. While the study investigated the relationship between the four elements with respect to college science teachers' beliefs on the use of inquiry in the college science classroom, the next section discusses each element independently.

Science Education Reform

The United States has undergone many educational reforms. According to Hurd (1991, 1994) there have been at least 40 reform efforts in the last 150 years and over 400 published reports during the 1980s and 1990s advocating reform in the teaching of science, especially as it relates to prospective science teachers. The major themes of these reforms have been to make education such that it is "more immediately practical and useful by reflecting the culture of the time" (Yager, 2000, p. 51).

The launch of the Soviet Sputnik in 1957 also launched the current reform effort in science education. This one event spurned 20 years of federal funding in science education focusing on student learning and knowing the science that scientists know as well as learning the skills that scientists used to study the natural universe (DeBoer, 1991; Yager, 2000). Bybee and DeBoer (1994) identified three major changes in the goals of science education during this time. They included (1) a weakening of the personal-social development goal; (2) the importance of understanding the structure of scientific disciplines; and (3) the prominence of scientific methods such as inquiry, discovery, and problem solving. Jerome Bruner, from Harvard, was a psychologist who had a tremendous impact on science education (Bybee & Deboer; DeBoer).

Bruner (1960) stated, “The curriculum of a subject should be determined by the most fundamental understanding that can be achieved of the underlying principles that give structure to that subject” (p. 31).

Scientists in their fields worked to infuse the curriculum with ideas for new courses while school leaders removed technology from the classroom (Yager, 2000). Inquiry as a way to teach science and as a way to learn science became the focal point with emphasis on laboratory activities. Curriculum programs such as the Physical Science Study Committee (PSSC), Biological Sciences Curriculum Study (BSCS), Chemical Bond Approach (CBA), Chemical Education Material Study (CHEM), Science- A Process Approach (SAPA), Elementary Science Study (ESS), and Science Curriculum Improvement Study (SCIS) were developed and implemented in public schools across the country. These programs were primarily developed by college science professors and teachers with very little input, if any, by education specialists (DeBoer, 1991).

By the mid-1970s, support for these reforms was fading. The exclusion of the personal and social aspects of curriculum earlier as well as the absence of technology in the curriculum was now seen as a concern. In 1971 Bruner (1971) modified his earlier view on education stating:

> A decade later, we realize that *The Process of Education* was the beginning of a revolution, and one cannot know how far it will go. Reform of curriculum is not enough. Reform of the school is probably not enough. The issue is one of man’s

> capacity for creating a culture, society, and technology that not only feed him but keeps him caring and belonging. (p. 30)

The interest in education shifted from concerns about the Soviets to improving education so that it was an unbiased and humanitarian surrounding for all students. The war in Vietnam, poverty, and racial prejudice fueled feelings of dissatisfaction and turmoil in the United States. The attention to academic excellence and rigid study was relaxed. The call was for science education to be relevant to all students, not just those who were entering science, including each student's ability and interest (DeBoer, 1991).

Project Synthesis was funded in 1978 and identified four goals for modern science education (Yager, 2000). These goals were (1) Personal Needs; (2) Societal Issues; (3) Career Awareness; and (4) Academic Preparation. Harms and Yager (1981) reviewed Project Synthesis stating:

> Not only is there an increased need to understand large national issues, there is also an increasing need to understand the way science and technology affect us as individuals. Thus, a new challenge for science education emerges. The question is this: "Can we shift our goals, programs and practices from the current overwhelming emphasis on academic preparation for science careers for a few students to an emphasis on preparing all students to grapple successfully with science and technology in their own, everyday lives, as well as to participate knowledgeably in the important science-related decisions our country will have to make in the future? (p. 119).

The goals of Project Synthesis came under scrutiny in 1983 when education again experienced a crisis. It was no longer the Soviets that influenced American education but rather the perceived superiority of Japan over the United States (Yager, 2000). The National Commission for Excellence in Education (1983) sounded the alarm with the report, *A Nation at Risk* stating that the "once unchallenged [U.S.] preeminence in commerce, industry, science, and technological innovation" (p. 5) was no longer. Japan and other industrialized countries had overtaken the United States in areas of education, technology and industry. The education system of the United States was placed squarely in the center of the crisis as the Commission acknowledged that the United States' schools had "lost sight of the high expectations and disciplined effort needed to attain" what was required to keep America at the top (National Commission for Excellence in Education, 1983, p. 5). The National Science Foundation began to fund research in cognitive science, studying the process by which humans learn. Research from studies on human learning became the foundation for reform efforts (Yager, 2000).

From this renewal in science education reform came the American Association for the Advancement of Science's (1993), *Benchmarks for Science Literacy* and the National Research Council's (1996), *National Science Education Standards.* These became the guidelines for individual states to develop curriculum that aligned with national and/or state standards and they assured students would gain knowledge of content that would appear in mandated assessments (National Research Council, 2007). Administrators reintroduced technology in science, and teachers were encouraged to change how they taught. The move towards an inquiry-based classroom was advocated (National Research Council, 1999; Yager, 2000). Table 1 illustrates these changes.

Table 1: Change in Emphasis in Teaching Advocated by the National Research Council's National Science Education Standards

Change in Emphasis in Teaching Advocated by
The National Research Council's National Science Education Standards

LESS EMPHASIS ON	MORE EMPHASIS ON
Treating all students alike and responding to the group as a whole	Understanding and responding to individual students' interests, strengths, experiences, and needs.
Rigidly following curriculum	Selecting and adapting curriculum
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

Source: National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press (p. 52).

There are many roles for educators to play in the science reform effort. One role of educators, as advocated by the National Research Council (2000,) is to move toward an inquiry-based classroom in attempts to improve science education.

While these documents illuminate the path science education should take with respect to how and what should be taught, the transfer from research into practical application has not happened (Yore, 2001). This transfer pertains to college science classrooms since it has been shown that professors of science infrequently teach in ways that foster student construction of knowledge (Walczyk, Ramsey, & Zha, 2007).

Inquiry

The NRC (1996) advocates inquiry and collaboration in science courses at all levels as a means of attaining the goal of science literacy for all students. The term science literacy was defined in the 1970s as having a wide and functional understanding of science allowing people to use science in their world to answer questions. The National Science Teachers Association (2004) published their position statement regarding scientific inquiry recommending "all K-16 teachers embrace scientific inquiry" (p. 1). Inquiry is a form of learning and teaching that engages the student in active learning and discovery, and it has been shown to improve science learning (Crawford, 2007).

The reform effort in science education continues today, but in spite of the long history of the benefits of inquiry, little has changed (Walczyk, Ramsey, & Zha, 2007). There may be several reasons to explain the lack of movement towards more inquiry in the classroom. The first may be a lack of a clear and concise definition of inquiry. Many different people have defined inquiry in many different ways. The word inquiry is used in the literature two ways, both as a way to teach and a way to conduct research (Buck, Bretz, & Towns, 2008). Teachers in the K-12 arena and professors in undergraduate programs have different interpretations of inquiry. (Colburn, 2000; Mohrig, Hammond, & Colby, 2007; Windschitl & Buttemer, 2000). Both K-12 teachers and undergraduate professors use their own definitions and concepts as to what inquiry is and there is very little in common between them (Brown, Abell, Demir, & Schmidt, 2006; Buck, Bretz, & Towns). In order to clarify the meaning, one must make a distinction between inquiry learning and inquiry teaching. Inquiry teaching is what teachers do to promote inquiry learning by their students. There is also the use of inquiry to identify what scientists do to study the natural world. The definition of inquiry for this research comes from the National Science Education Standards (NRC, 1996). Inquiry is the cornerstone of these standards and is a vital component of the science reform movement. The NRC (1996) defines inquiry as:

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (p. 23).

The *NSES* distinguishes between full and partial inquiry depending upon the inclusion of the five essential features of inquiry (NRC, 2000). Full inquiry is defined as inclusion of all five essential features and is student directed while partial inquiry is defined as more involvement by the teacher in one or more of the five essential features

(NRC). Full inquiry is viewed as that which scientists do when studying the natural world.

The second challenge for science teachers is the confusion over exactly what inquiry is and what it looks like. It is important that inquiry not be so narrowly defined as to include only those activities that mirror scientists but rather can range from activities that are highly structured with students reaching known answers to activities that are totally student driven. Brown, Abell, Demir and Schmidt (2006) developed a continuum to represent the range of inquiry from full to none and from teacher-directed to student-directed. This continuum is represented in Figure 2. The y-axis is labeled Degree of Inquiry, ranging from none to full and represents the quantity of essential features of inquiry as defined by the NRC (2000). The x-axis is labeled Degree of Guidance, ranging from guided to open and represents the continuum of teacher involvement (Brown, et al). Many science teachers define inquiry as only “open” and are not aware of the many facets of inquiry (Brown, et al). This narrow view can be a limiting factor in implementation of inquiry in the classroom.

Teachers could plan inquiry lessons that fall anywhere on the continuum. Although the activity may be teacher directed, features of inquiry such as questions, evidence, explanations and justifications could be included (Brown, et al., 2004).

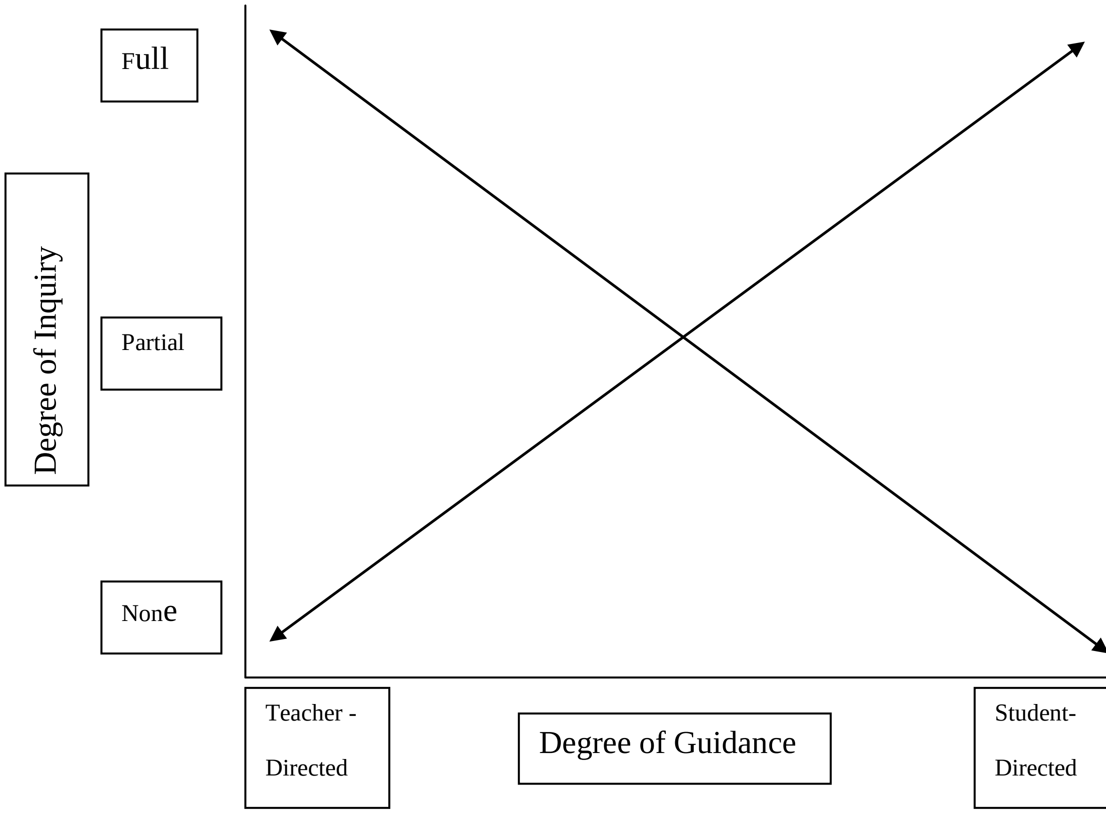

Figure 2: Inquiry Continuum

Buck, Bretz, and Towns (2008) describe how the two faces of inquiry, as a style of teaching and as a method of research, can cause confusion. Anderson (2002) uses the terms "relatively non-specific and vague" (p. 4) when describing the definition of inquiry in educational literature. There are many words used to describe inquiry including guided inquiry, traditional inquiry, directed inquiry, inquiry learning, inquiry teaching, full inquiry, and scientific inquiry (Chinn & Malhotra, 2002; Colburn, 2000; Eick & Reed, 2002; Gaddis & Schoffstall, 2007; Martin-Hansen, 2002; Mohrig, Hammond & Colby, 2007; Schwartz, Lederman and Crawford, 2004; Windschitl, 2004).

These challenges to the implementation of inquiry in science classes are not limited to the K-12 arena but extend into the college and university settings. Improvement of science education at the undergraduate level is a vital step in the improvement of science teaching in the elementary, middle and high schools because undergraduate professors instruct future teachers of science in the K-12 area.

There are many studies to support the use of inquiry in improving science achievement of students (Ertepinar & Geban, 1996; Freedman, 1997; Glasson, 1989; Lord, & Orkwiszewski, 2006; Odubunmi & Belogun, 1991; Stohr-Hunt, 1996; Von Secker, 2002). Von Secker's (2002) study examined the effect of inquiry-based instruction on academic excellence of students of all socioeconomic statuses. Findings demonstrated that for every one standard deviation increase in the amount of emphasis teachers placed on inquiry teaching, students showed a 0.58 standard deviation increase in science achievement. While there is research to support inquiry teaching at the K-12 level, empirical evidence with respect to inquiry teaching is lacking at the college level.

One study by Lord and Orkwiszewski (2006) demonstrated how inquiry labs in an introductory, non-majors biology class improved science learning. One hundred college students participated in the study. All students attended the same lecture but were separated into four different laboratory classes. Two of the laboratory classes served as the control while the other two labs were the experimental groups. The control group followed prewritten directions and procedures and answered questions. Researchers considered these labs to be "cookbook" where students were told how to perform the lab with all students reaching the "correct" answer. The experimental laboratory group utilized inquiry. Students were placed into small, cooperative groups and given a problem to solve. While no groups followed the same procedure, all reached similar conclusions. Results of Lord and Orkwiszewiski's study demonstrated an increase in test scores for the experimental group, as well as a better attitude about science accompanied by an increase in attendance, enthusiasm and interest. As Yager (1991) stated, "…inquiry teaching helps kindle the embers of science in students; if it is done carefully, inquiry will flame a passion for science in the participant for the rest of his life" (p. 57).

The use of inquiry in the science classroom as a means to improve science education has been a major emphasis in the science reform effort of today. While the focus of this reform, in the past, has been primarily in the K-12 arena, current efforts are demanding that inquiry be used in higher education. Richard Riley, U.S. Secretary of Education stated in his Seventh Annual State of American Education Address:

> Our efforts to improve education will rise and fall on the quality of our teaching force, and higher education has the defining role in preparing the next generation of teachers. I ask leaders in higher education across the nation to please make this their mission. (Riley, 2000).

This statement emphasizes the importance of why college science teachers must be included in science education reform.

Higher Education: Science Teaching Reform and Inquiry

Examination of undergraduate classes in science over the last decade has shown that these classes have not been taught in ways that encourage student construction of knowledge (Walczyk, Ramsey, & Zha, 2007). Teachers at research institutions are frequently researchers, a role they are well trained to do. These teachers are often called upon to teach, a role for which they may have little or no formal education (Kane, Sandretto, & Heath, 2002).

The call for science education reform is not limited to elementary and high schools but includes the university and college setting as well. Science education can be viewed on a continuum, and those who will teach at the elementary, middle and high school levels graduate from programs at the university level. Teachers of science at the K-12 level learn to teach in their undergraduate courses. There is a cycle in that the students in undergraduate science courses come from the K-12 system where they were taught by teachers educated in the undergraduate science courses (Kyle, 1997). College science professors, who teach prospective science teachers, utilize the transmission model where teachers impart or transmit knowledge to students. Because of use of this model, prospective teachers learn to teach science in an atmosphere where memorization is stressed and there is little importance given to understanding (Abbas, Goldsby, & Gilmer, 2002). Science at the undergraduate level is usually taught as a body of knowledge that the student must learn; there is no engagement in higher-level thinking and inquiry (Geddis and Roberts, 1998). It is understandable that these prospective science teachers then create a similar atmosphere in their own classrooms. It is imperative that universities and colleges that educate science teachers examine their role and responsibility in science education.

There has been a movement of students withdrawing from science majors. Exiting students cite the number one reason for leaving as poor teaching (Seymour & Hewitt, 1994). Students stated that science courses were void of student-teacher dialogue, stressed memorization and did not provide application of information taught (Brown, et al, 2006). Science college classes have been deemed boring, dull and uninviting (NSF, 1996).

The National Research Council (NRC, 1996) and the National Science Foundation (NSF, 1996) have called for undergraduate education to broaden the view of science, mathematics, engineering and technology (SME&T) education to include all students, not just those who will become scientists. The NSF (1996) states:

> Too many students leave SME&T courses because they find them dull and unwelcoming. Too many new teachers enter school systems unprepared, without really understanding what science and mathematics are, and lacking the excitement of discovery and the confidence and ability to help children *engage* SME&T knowledge. Too many graduates go out into the workforce ill-prepared to solve real-world problems in a cooperative way, lacking the skills and motivation to continue learning. (p. iii).

Many explanations as to why science education reform and the use of inquiry in the classroom have not reached the college and university level have been proposed by researchers. These reasons include the dual role of university professors (Boyer, 1995; Hattie and Marsh, 1996), a disconnect between what professors view as effective teaching and what students believe about professor effectiveness due to lack of preparation in how to teach (Hativa 1998; 2000 Hativa, Barak and Simhi 2001), and finally, resistance to change due to the culture of the college setting (Lord, 2008; Taylor, 2002).

Research universities have a dual role, to teach and to research. According to the Boyer Report (1995), undergraduate education by research universities has been dismal. With instructors poorly trained to teach, an emphasis on research instead of teaching, and a merit system that rewards research money brought to the university instead of effective teaching, universities have left undergraduates behind. As the role of research in large universities has increased, many feel the role of teaching has diminished (Boyer, 1995; Hattie and Marsh, 1996).

Many university professors are involved in research as their primary responsibility leaving teaching to a secondary role. When examining promotion requirements at research institutes, more emphasis is given to research production than to effective teaching (Boyer Commission, 1995). The National Research Council (2003) advocates the inclusion of evidence of student learning as an important component of college faculty evaluation and promotion. Teaching undergraduates and involvement in academic research do not exist at the same level. The Boyer Commission stated, "Advanced research and undergraduate teaching have existed on two quite different planes, the first a source of pleasure, recognition, and reward, and the latter a burden shouldered more or less reluctantly to maintain the viability of the institution (p. 7)."

Hattie and Marsh (1996), in their synthesis of research studies on the relationship between research and teaching, discuss three reasons why there may be a negative relationship between professors involved in research and teaching. The first deals with time, energy, and commitment. As one increases time spent with research, time spent teaching is decreased and the opposite is true as well. The authors do make note that increased time spent on teaching does not necessarily mean the teaching is quality teaching. Jauch (1976), in examining views of academics, found that the majority (91%) believed that professors actively involved in research were more effective teachers but the opposite did not hold true. Only 29% of academics felt that effective teachers should do research. There are those who advocate a separation between teaching and research at the university level (Scott, 1991; Weisner, 1992; Westergard, 1991).

A second reason for poor teaching at the college level is that the majority of faculty teaching science, technology, engineering and mathematics have had little formal education or training in effective educational processes, student assessment, and evaluation of effective teaching practices (NRC, 2003). University teachers do not usually receive preparation for how to teach. Hativa, Barak and Simhi (2001) state that beliefs of university teachers about teaching develop over time through their teaching experiences and student and personal assessments. As this road to pedagogical knowledge is unintentional and incomplete, the knowledge acquired may be disjointed.

Hativa (1998) evaluated a physics professor teaching an introductory physics class to nonphysics majors. The study revealed a great disconnect between the veteran physics professor and his students. While the students felt the professor taught in an unclear manner and this contributed to their lack of understanding, the professor felt the problem was with the students and their lack of motivation. When evaluating the professor with respect to the three categories of teacher knowledge used in the study, general pedagogical knowledge, knowledge of students and knowledge of self, the researcher found much lacking. The professor was familiar with just a few teaching techniques and did not use them in his classroom. While the physics professor was well aware of his goals for the class, he was unaware of his weaknesses and how these weaknesses affected student learning. He realized there were many problems with the class but placed the blame on the shoulders of the students. The results of this study are not specific to this one case study but evidence of such disconnect can be found in many college science classes (Hativa).

In a later study, Hativa (2000) again found evidence to support earlier findings on the disconnect between what university professors believe about their effectiveness with respect to teaching and what students believe about professor effectiveness. It was found that the majority of students felt their university professors did not reach goals of effective teaching and students viewed the teaching as dull, futile, and vague. This result was in stark contrast to the beliefs of the university professors who felt they were successful in reaching their goal of effective teaching.

Many college science courses are taught in lecture format with students unable to understand the scientists' role and the nature of science (Brown, Abell, Demir, & Schmidt, 2006; Shipman, 2004). Over 95% of science professors in the United States use the lecture as the primary way to teach (Bligh, 2000). The lecture format is not an effective method for learning science (Shipman, 2004). Large lecture college classes encourage the student to be passive learners who memorize information to pass the test and then promptly forget it (Ebert-May, Brewer & Allred, 1997). Science is best learned by a constructive process which encourages students to become active learners (Ebert-May, et al.). This is not to say that lecture does not have its place in the college classroom, but professors must begin to include forms of inquiry-based techniques in their classrooms. This change will not occur because national organizations advocate change to inquiry teaching, but the change must come from other sources including evidence of the superiority of inquiry teaching and a push at the local levels (Shipman, 2004).

The third explanation is resistance to change due to the culture of the college setting (Taylor, 2002). This culture includes factors such as beliefs and values of teachers, unwritten protocols and codes of behavior. Lord (2008) interviewed over 50 college science professors inquiring as to why they persisted with the lecture format and had not adopted better teaching strategies. The most frequent response indicated a lack of faith in educational research. Others indicated that they did not intend to abandon the lecture format as lecture has been the way they have taught for years (Lord). Many of the professors in Lord's study felt that group learning and peer teaching were poor examples of how to teach, while others felt that the time commitment to non-lecture formats was too constraining.

In another study by Walczyk, Ramsey and Zha (2007) obstacles to reform in undergraduate science and mathematics was examined. Their results indicate that colleges place little weight on teaching effectiveness and faculty have little formal training in educational practices. Those teachers who did have training in pedagogy were more apt to view teaching as important and consult outside sources in an effort to improve teaching.

Although there have been many calls for reform in science education, little has changed in the way teachers currently teach (Bybee, 2000). Bybee states, "Most evidence indicates that science teaching is not now, and never has been, in any significant way, centered in inquiry whether as content or as a technique" (p. 42). Ebert-May, Brewer and Allred (1997) advocate a need to change the focus of science education to what is it that educators want students to know regarding science and what is it educators want the students to be able to do with that knowledge. Change is difficult to implement and even more difficult to sustain which is why college teachers in education and science have been encouraged to become a part of the reform (Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; NRC, 2001). With regards to college science teachers, the NRC (1996), states:

> University and college professors of science are an integral part of this educational system because it is, in very large part, from our courses that society will learn its science…. The responsibility of science faculty members is to develop not only the science knowledge of our students, but also their understanding of the nature of science, their ability to understand and use scientific ways of thinking, and their ability to make connections and apply what they know to the world outside the classroom. (p.ix).

The NRC (1999) made several recommendations with regards to American colleges and universities in attempts to encourage undergraduate education to move toward a more student centered environment. One of these recommendations advocates that teachers use a learner-centered format with students actively involved in collaborative learning.

The Boyer Commission (1995) also made several recommendations in attempts to improve science education at the university level. One recommendation was teaching, not via "transmission of knowledge" (p. 12) but by more involvement of undergraduates in inquiry learning. Teaching using the inquiry based approach would entail major restructuring of undergraduate education from what is the current norm.

The lack of movement toward inquiry at the college level does not mean that interest and research at the college level is absent. The literature reveals many studies examining attempts to institute inquiry in the undergraduate setting, in both classrooms and laboratories (Apedoe, 2008; Buck, Bretz, & Towns, 2008; Crandall, 1997; Ebert-May, Brewer, & Allred, 1997; Gaddis & Schoffstall, 2007; Kyle, 1997), but little practical work is available (Brown, et al.). A study by Lord and Orkwiszewski (2006) involved 100 students in a non-major, introductory Biology course. All the students attended the same lecture but were separated into four laboratory sections. Two of the groups were the control and performed labs that were considered “cook book” with known procedures and results. The other two groups were the experimental groups and performed inquiry-based labs. Results showed that students in the inquiry labs had better attitudes about science, were better able to solve problems at a higher level and had more enthusiasm and interest in the laboratory activities.

Research by Ash, Brown, Kluger-Bell and Hunter (2009) demonstrated that college science professors can maintain an effective dual role of researcher and teacher. In their study, 120 scientists participated in a five year program consisting of a five-day workshop where participants were involved in “inquiry immersions” (p. 69). The average was 25 scientists participating each year with approximately 25% returning for each year. Participants were graduate students and postdoctoral scientists who wished to improve how they taught. Results were positive with scientists becoming involved in inquiry teaching. The authors state, “Physical scientists became deeply immersed in practicing new teaching; they began to adopt identities as both research scientist and as inquiry science teachers” (p. 73).

The goal of science education should be to teach science concepts and to excite and motivate students. As Yager states (1991), " inquiry teaching helps kindle the embers of science in students; if it is done carefully, inquiry will flame a passion for science in the participant for the rest of his life" (pg. 57).

Teacher Beliefs

In spite of the push for reform in science education and major expenditures of time and money, there has been little change in teacher practices. Gess-Newsome, Southerland, Johnston, and Woodbury (2003) describe a possible explanation for why change has not occurred. The effect of teachers' knowledge and beliefs are vital in any reform within the classroom. Research is abundant with regards to the effect teachers' beliefs have on teaching (Ball & Cohen, 1996; Beck, Czerniak, & Lumpe, 2000; Haney, Czerniak, & Lumpe, 1996; Prawat, Remillard, Putnam & Heaton, 1992), but this research has been centered on the beliefs of K-12 and preservice teachers. Research on beliefs of science teachers in the college setting is insufficient (Brown. Abell, Demir, & Schmidt, 2006). Kane, Sandretto, and Heath (2002) feel that research into preservice teachers' beliefs as well as primary and secondary teachers' beliefs have allowed us to reach an agreement on several matters such as: (1) Preservice teachers come to the classroom with beliefs based on their experiences as students, (2) Beliefs are resilient and difficult to change, (3) Beliefs are difficult to convey. It is logical to assume that these findings could be applied to college science teachers. Entwistle and Walker (2000) state, " while teaching in higher education is bound to have distinctive characteristics, it also has elements in common with more general ways of describing teaching. Consequently, we can draw on research on school teaching" (p. 343). Teacher beliefs are critical aspects in reform (Tobin, Tippins, & Gallard, 1994) and if reform at the college level is to be realized, beliefs of college professors cannot be overlooked.

Research on the relationship between beliefs of teachers and how these beliefs impact decision making in the classroom is scant and the relationship between the two is implied in many studies (Speer, 2008). Speer (2008) argues that research design may limit attempts to understand the connection between beliefs held by teachers and decisions made in the classroom. Schoenfeld (2000) describes a lack of powerful explanations in how beliefs mold practice and more is needed than just a description of what teachers are able to do or what they are willing to do; the questions of how and why beliefs affect practice are needed. Speer (2008) states that, "very little is known about the influence of beliefs on teaching practices *at the very level of detail where it appears development most productively occurs*" (p. 219).

Teachers come to the classroom with a set of beliefs that impact instructional choices. These beliefs can form attitudes when they are formed around situations. These attitudes then influence actions (Pajares, 1992). Teachers' attitudes become important in determining behavior and these behaviors can become connected to form values (Ajzen, 1985). Cuban (1982) and Sykes (1990) have stated that many times teachers will adapt ideas of reform to match their beliefs about teaching. Haney, Czerniak and Lumpe (1996) utilized Ajzen's Theory of Planned Behavior. This theory predicts intent and likelihood of engaging in a behavior. Their findings illuminate several issues regarding reform. One is the importance of teacher attitude towards change and another is the teacher's belief in his ability to implement the change. Haney, et al.

found that teachers believed barriers such as lack of administrative support, lack of resources, and lack of staff development opportunities hindered their ability to implement educational change.

There are many factors that affect how teachers teach, such as knowledge, curriculum, social factors and teachers' goals (Borko & Putnum, 1996; Clark and Peterson, 1986). One factor that has a considerable impact on teacher practice is beliefs (Calderhead, 1996; Pajares, 1992). Teacher beliefs have a substantial impact on how teachers view student learning, curriculum materials as well as adaptation of those materials for use within their classrooms (Ball & Cohen, 1996; Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Collopy, 2003). Failed science reform efforts of the 1950s and 1970s ignored teacher beliefs, developing curriculum and materials viewed as "teacher proof" (Duschl, 1990). Tobin, Tippins and Gallard (1994) state:

> Future research should seek to enhance our understanding of the relationships between teacher beliefs and science education reform. Many of the reform attempts of the past have ignored the role of teacher beliefs in sustaining the status quo. The studies reviewed in this section suggest that teacher beliefs are a critical ingredient in the factors that determine what happens in the classrooms. (p. 64).

Teacher beliefs are developed from their own personal experiences as students, as well as personal experiences as teachers. Research has shown that these beliefs are not necessarily in alignment with what research informs as the most effective way to teach, and these beliefs are resistant to change (Gill, Ashton, & Algina, 2004; Lumpe, Haney, &

Czerniak, 2000; Southerland, Sinatra, & Matthews, 2001). Beliefs are one of the most important factors in determining how decisions are made (Bandura, 1977), and "the beliefs that teachers hold influence their perceptions and judgments, which, in turn, affect their behavior in the classroom" (Pajares, 1992, p. 307). Dole and Sinatra (1998) maintain that beliefs and prior knowledge are vital aspects in influencing change.

In a study of secondary science teachers' beliefs about inquiry, Wallace and Kang (2004) found two opposing belief strands influencing implementation of inquiry in the classroom. The first strand was developed from the climate within the school and detailed those issues that restrict inquiry. Some of these restricting issues include teacher beliefs about students and standardized test preparation. The second strand was one that promoted inquiry and arose from the teacher's belief that inquiry was beneficial for student learning. While the first belief strand hampering inquiry implementation was public, the second belief strand supporting inquiry implementation was private. The teachers in this study acknowledged the benefit of inquiry with respect to learning goals the teachers held for their students, such as higher level thinking skills, creativity, understanding the language of science, but these goals were not specified in the mandated curriculum. This disconnect between a teacher's personal learning goals and mandated curriculum goals caused tension. The results of the study by Wallace and Kang were similar to results of other researchers (Gregoire, 1999; Munby, Cunningham, & Lock, 2000; Yerrick, Parke, & Nugent, 1997).

There is no question that teachers' beliefs play a vital role in determining the effectiveness of reform in science education (Lumpe, et al), therefore these beliefs must be addressed if true reform is to occur. A hindrance in addressing teacher beliefs and reform is the lack of a standardized definition of what is belief and what is knowledge. In an attempt to differentiate belief from knowledge, it is easy to become entangled in a list of what is considered knowledge and what is considered belief (Cobern, 2000). Attempting to define "belief" can cause more confusion than clarity. Add to that confusion the attempt to distinguish belief from knowledge and the uncertainty increases. There is much disparity in the literature with respect to defining these two constructs (Southerland, Sinatra & Matthews, 2001).

Researchers continue to grapple with defining the terms belief and knowledge. Many times these terms are used interchangeably and vague definitions are offered. Hofer and Pintrich (1997) state that with respect to beliefs, it is a "particularly slippery term in the psychological literature" (p. 112) while Alexander and Dochy (1995) agree stating that "explicit definitions of these terms are rarely offered" (p. 414). Alexander and Dochy reinforce the lack of clarity between belief and knowledge with the statement, "it is unclear where the boundaries of these two fundamental concepts lie. Are knowledge and beliefs, in actuality, synonyms marking the same semantic territory, or are they antonyms denoting orthogonal dimensions of human understanding?" (p. 415).

A distinct separation of beliefs and knowledge may not exist. Alexander, Schallert, and Hare (1991) state that, "knowledge encompasses all that a person knows or believes to be true, whether or not it is verified as true in some sort of objective or external way" (p. 317). It does not matter if the belief is true. A person's view confirms truth, making it true for them (Lumpe, Haney, and Czerniak, 2000). Dewey (1910) viewed beliefs as an element of knowledge. In contrast, Alexander and Dochy (1995) discovered that educational psychologists viewed knowledge as developing from school or formal learning. Beliefs came from informal experiences; knowledge is based on fact or is objective while beliefs are subjective and have an affective component. Pintrich, Marx and Boyle (1993) disagree with this distinction as the affective piece of knowledge cannot be ignored.

Goodenough (1963) defined beliefs as propositions thought to be true and "accepted as guides for assessing the future, are cited in support of decisions, or are referred to in passing judgment on the behavior of others" (p. 151). Pajares (1992) describes the confusion which surrounds the term beliefs stating:

> Beliefs travel in disguise and often under alias – attitudes, values, judgments, axioms, opinions, ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practical principles, perspectives, repertories of understanding, and social strategy (p. 309).

According to Southerland, Sinatra and Matthews (2001):

> That is, there can be true beliefs and false beliefs – or more accurately the propositional content of beliefs can be true or false. In turn, true beliefs can be divided into two categories, justified true beliefs- those for which the individual has adequate reasons for holding- and accidental true beliefs – those for which the individual has inadequate reasons for holding (p. 332).

The issue in this is what one considers “justification” as what justifies one person’s belief may not justify another person’s belief.

Examining disciplines such as educational psychology, social psychology, philosophy and anthropology, one can find research that has supplied an awareness of beliefs and the effect beliefs have on actions (Hoy, Davis, & Pape, 2006; Kane, Sandretto, & Heath, 2002; Nespor, 1987). How beliefs and knowledge are defined, how they develop, as well as their impact on learning are of interest to those in education, especially educational psychologists (Southerland, et al., 2001).

The question now becomes, with respect to education, should we be concerned with this distinction between knowledge and belief? Does it matter if a teacher “knows” inquiry is advantageous in student learning or “believes” it to be true? Since research has shown prior knowledge and belief to influence learning and behavior, is the distinction between the two necessary when it comes to educational research?

It is beyond the scope of this study to attempt to differentiate between the two and so the definition of beliefs for the purpose of this study is from Rokeach (1976):

> A belief is any simple proposition, conscious or unconscious, inferred from what a person says or does, capable of being preceded by the phrase “I believe that….” The content of a belief may describe the object of belief as true or false, correct or incorrect; evaluate it as good or bad; or advocate a certain course of action or a certain state of existence as desirable or undesirable (p. 113).

In examination of the literature, it becomes apparent that understanding the beliefs of college science teachers become an important aspect in moving science education reform and aspects of inquiry into the college level science classrooms. In the next chapter, an explanation of the research method, participant selection, instruments, data collection and analysis outline the methodology.

CHAPTER THREE: METHODOLOGY

The purpose of this study was to examine the beliefs held by twelve college science teachers and one laboratory coordinator with respect to inquiry in the science classroom. Professors at three colleges and universities in central Florida participated. The research questions of this study were as follows: (1) What were college science teachers' beliefs on inquiry teaching in the entry level college science classroom? (2) How are these beliefs enacted in the classroom? Supporting questions addressed if there was a difference in college science teachers' beliefs between institutions, (community college, private four year college and large, research university) and if there was a difference between the disciplines of life science and physical science. This chapter outlined the research design, participant selection, description of participants, validity, data collection, instruments, and data analysis.

Research Design: Choosing the Research Methodology

A case study design was required for this study due to the complexity of the topic and different data sources needed to answer the fore stated research questions. A case study approach enabled the researcher to better explicate the beliefs and practices of college science teachers regarding the use of inquiry in the science classroom and allowed the use of multiple data sources. These data sources included questionnaires, interviews, classroom and laboratory observations and written records such as laboratory activities and syllabi. According to Yin (1994) case studies are distinctive kinds of qualitative work that researches a phenomenon within specific boundaries. Merriam (1999) identifies some examples as "a program, an event, a person, a process, an institution, or a social group" (p. 13).

Ary, Jacobs, and Razavieh (1990) suggest a reason for undertaking a case study approach as being able to gain knowledge about an individual and their behavior. This can also be a weakness as the behavior of one individual may have little or no relationship to another individual. A case study approach may allow for connections and relationships being discovered that were not expected (Ary, et al.). Best and Kahn (2003) discuss case study as a way to "view social reality" (p. 249) by examining a person, a family, a social group, institution or community. In a case study, data can be obtained by many methods including observations, interviews, questionnaires, and data from written sources. The use of a case study method in this study was necessary to provide an extensive analysis of the beliefs held by college science professors with regards to inquiry teaching. By examining questionnaires, observations, demographics and review of written sources, as well as interviews, both stated and enacted beliefs were able to be recognized. Observing classrooms and laboratory situations allowed the researcher to visualize if what professors believed about inquiry was being implemented in the classroom.

Participant Selection

This study took place at three colleges and universities in central Florida. Twelve college science teachers and one laboratory coordinator from three different institutions: two-year community college, research university, and private four-year college, participated in this study. Science department heads at these institutions were contacted for a list of teachers who teach introductory science classes with laboratory components and who have taught the same class at least three times. This was to ensure that the teachers were familiar with the course being taught. As such, the sampling technique for this study was purposive. Purposive sampling or nonprobability sampling was used to ensure that participants met the requirements of teachers who teach introductory science classes with laboratory components and who had taught the class at least three times. Every attempt was made to include science professors who taught introductory classes with a laboratory component, but several professors, who volunteered to participate, while teaching introductory classes, did not have a laboratory component. To maintain an adequate sample size, these professors who taught introductory science classes but did not have a laboratory component were included in the study. Use of purposive sampling allowed for selection of participants who would provide sufficient information to answer the research question (Kemper, Stringfield, & Teddlie, 2003).

There are several types of purposive sampling techniques. The one used for this study was Snowball sampling which involves using participants to identify other participants who may be eligible to participate in the study (Kemper et al.). Emails were sent to those teachers meeting the criteria, and meetings were set up to discuss participation. Participants who agreed to be in the study were then asked for names of other professors who met the requirements and would possibly be interested in participating. Those professors were then sent an email explaining the study and asking for participation in the study. This process continued until 12 professors had agreed to participate. IRB approval was obtained prior to the study (Appendix A) and anonymity of each participant was protected. An attempt was made to insure an equal number of participants teaching the life sciences and physical sciences. There were six professors who taught physical science, including physics, astronomy, and chemistry, and six professors who taught life science, including biology and anatomy and physiology. The laboratory coordinator was included in this study as she was in charge of the laboratory experience for some of the biology courses at the research university. Table 2 illustrates the division of participants and schools.

Table 2: Distribution of Participants across Disciplines and Institutions
***Includes Laboratory Director**

	Large Four Year Research University	Small Four Year Liberal Arts College	Community College
Life Sciences	4*	1	2
Physical Sciences	3	2	1

Description of Participants

Community College

Mrs. Davis

Mrs. Davis taught anatomy and physiology and had been teaching at the community college since 1980. Education included a double major in chemistry and education with a minor in biology. She received a Masters in the art of teaching with a specialization in biology. Education courses included 18 hours at the graduate level. Prior to teaching at the community college, Mrs. Davis taught middle and high school. When asked what she felt was most important to teach, her focus in teaching was to meet the needs of the community by providing nurses for that community. She wanted the students to be critical thinkers and apply critical thinking skills to problems they will encounter when they enter the health care field. She viewed her primary responsibility as teaching.

Mr. Greer

Mr. Greer began his teaching career as a teaching assistant in college. He has his bachelor's and master's degree in Biology and began teaching at the community college in 1991. He has taken a few education courses in Curriculum Design. When asked what was most important about what he teachers, he replied that he wanted the students to have better lives than they currently have. He wants them to be critical thinkers and to be able to think their way through problems. This skill is more important than content. He designs his classes around those principles that the content does not matter as much as the thinking skills they develop or the value they can derive from being able to think critically. His primary responsibility at the college was teaching.

Dr. Barrett

Dr. Barrett has a bachelor's degree in chemistry, a master's degree in inorganic chemistry and a PhD in bio-inorganic chemistry. While working on her PhD she realized that while she enjoyed research, the time commitment was not what she wanted. She began teaching and found she enjoyed it and has been at the community college for 13 years. She has taken no education courses, but she has taken several courses offered by the college such as *Action Learning and Authentic Assessment*. What Dr. Barrett feels is most important about what she teaches is to help students find their passion in life and to give them skills to be successful in achieving their dreams. Her primary responsibility is teaching.

Private Four Year College

Dr. Griffith

Dr. Griffith received her bachelor's degree, master's degree and PhD in microbiology. She has been teaching at the college for 31 years. When asked how she got her start teaching college science she replied that she had really started as a teaching assistant as an undergraduate. She enjoyed teaching and felt that teaching was her talent. She realized while working on her PhD that research was not her main interest.

She has never taken an education course but was involved in summer inservice workshops for elementary education teachers. Dr. Griffith and an education professor co-taught a class for elementary teachers. The education professor would teach science methods while Dr. Griffith would teach the science content. She feels that this experience helped improve her teaching.

Dr. Griffith does not feel that content is what is most important for her to teach but rather skill development is most important. She wants her students to have analytical skills along with the ability to distinguish between fact and fiction and be able to support ideas with facts. She views her primary responsibility as teaching.

Dr. Fenton

Dr. Fenton has a bachelor's, master's and PhD in physics. He begain teaching as a teaching assistant when an undergraduate and really enjoyed the experience. After receiving his master's degree, he taught high school and worked as a college instructor. He enjoyed the small environment and interaction with the students, and so after receiving his PhD, he looked for small, undergraduate schools that do research. He took no education courses while working on his degrees.

He feels strongly that a major problem with our society is that our population is not science literate. With that in mind, he feels that it is important for students to learn how to attack a difficult problem. He wants his students to be able to evaluate statements made in the news and to be able to make informed decisions. His primary responsibility is teaching.

Dr. Matthews

Dr. Matthews teaches in the physics department at the college. He began teaching while in the Army. The Army sent him to get his PhD and then assigned him to West Point to teach. He has taken no education courses. When asked what was most important about what he teaches Dr. Matthews responded that he teaches the process of solving problems. He feels that students need to learn how to approach problems and this skill is more important than content. Dr. Matthews views teaching as his primary role at the college.

Large, Research Institution

Dr. Fleming

Dr. Fleming came from a purely research position in the western United States. He came to the university to teach because in his research position, it was difficult to obtain funding for his research. Dr. Fleming knew that teaching would be part of his job at the university; he has had no education courses.

While Dr. Fleming has not taken any education courses formally, he did acknowledge that he has been to workshops where physics and astronomy research was discussed. He specifically discussed how he learned about identifying student misconceptions in astronomy and physics and how to address them. In a semester, Dr. Fleming spends approximately half his time teaching and the other half doing research.

Dr. Branson

Dr. Branson began teaching as a graduate student as a teaching assistant. Dr. Branson taught intermittently while he was a researcher and then began teaching at the university in 2003. He received a degree in economics and worked for an aerospace company. When he was in his 30s, he went back to school and received a bachelor's, master's and PhD in geology. He has not taken any education courses. Dr. Branson feels that students need to develop ways to look at information that is presented everyday and know enough science to be able to evaluate good science from nonsense. Dr. Branson described that his time is divided three ways with 50% being research, 25% non-teaching duties and 25% teaching.

Dr. Conroy

Dr. Conroy received a bachelor's degree in physics. While pursuing a PhD in physics, he obtained a master's in teaching science (MST). He began teaching as a teaching assistant while in his PhD program and enjoyed it. Dr. Conroy took several education courses to earn his MST degree. He feels it is most important that students become literate in science as the lack of science literacy in our society is unacceptable. At the university, his job is as a lecturer, and his contract specifies that his responsibility is teaching and any research is done on his own time.

Dr. Bender

Dr. Bender has been at the university for five years but had retired from another university in another state. He teaches biology and has a bachelor's degree in biology and a master's and PhD in zoology and biology. When asked how he began teaching, he replied that he was put into the classroom as part of his duties at the university. He has taken no education courses. Dr. Bender feels it is important that students understand how pervasive biology is in their lives, and they understand the importance of evolutionary theory.

When asked how he divides his time in a week, he stated what the chair of his department assigned him which was 10% commitment to external activities, 50% to research and 40% to teaching.

Dr. Franklin

Dr. Franklin received his PhD in biology and has been teaching at the university for four years. Dr. Franklin views his role primarily as a researcher and teaches so that he is able to continue his research. Dr. Franklin wants students to develop a broad perspective of the field of biology. He has taken no education courses.

Dr. Wilson

Dr. Wilson teaches the second half of biology II while Dr. Franklin teaches the first half. He received his bachelor's degree in psychobiology, his master's degree in ecology and biodiversity, and his PhD in animal behavior. He has been teaching at the university for one year as a lecturer which is a non-tenure track position. He started teaching college science as a teaching assistant and enjoyed it. He was always interested in teaching and saw it as an opportunity to not only engage with students but also as an opportunity to improve his public speaking. Dr. Wilson wants students to learn a more conceptual perspective regarding biology and not just memorize material.

He has not taken any education classes but would like to. He wanted to take some courses as a doctoral student but the nature of his scholarship would not allow him to take other courses.

Ms. Yancey

Ms. Yancey has a bachelor's degree and master's degree in biology from the present university. Upon graduation, she was offered the job as Laboratory Coordinator and is responsible for the labs in biology I and II which are the biology courses for majors. She has taken no education courses.

Validity

Maxwell (1992) identified three types of validity for qualitative research that have implications for this study. The first is descriptive validity which refers to the collection and corroboration of the information obtained or how accurately was the account recorded. Interpretive validity is how well the researcher understands and reports the participants' views on the topic being researched. Interpretive validity attempts to understand the meaning of what is being examined from the viewpoint of the participant. The third type of validity is theoretical validity which refers to how well the data obtained fits with the theoretical framework described by the researcher. Triangulation was used to increase the validity of this study. Triangulation is defined by Teddlie and Tashakorri (2003) as the "combination and comparisons of multiple data sources, data collection and analysis procedures, research methods, and/or inferences that occur at the end of a study" (p. 717). Data for this study were obtained from four different methods in attempts to increase validity; interviews, observations, questionnaires, and written material such as lab manuals and syllabi. All participants were interviewed using a standard set of questions that allowed the researcher to ask probing questions as needed. Observations were also conducted. One class and one lab, if there was a lab component, were observed for each participant where the use of inquiry was identified. Questionnaires were given to all participants seeking to understand how they viewed the use of inquiry in their classrooms and laboratories. Lab manuals and class syllabi were collected and examined for evidence of inquiry. Data from all four sources were read multiple times looking for common themes.

One concern regarding qualitative research has been the lack of generalizability. According to Yin (1984), this need not be a problem. He makes the distinction between statistical generalizability used in quantitative studies and analytic generalizability used in qualitative studies. In analytic generalizability, existing theory is used as a comparison for the results. In this study, the five essential features of inquiry were the template used for comparison.

Data Collection

The four methods used to collect data in this study were interviews, questionnaires observations, and analysis of syllabi and lab manuals obtained from the individual professors. Three institutions in the central Florida area were used for this study. The community college in this study had an enrollment of approximately 62,000 students on 8 campuses. The private four year college had an enrollment of approximately 1700 students while the research institution had an enrollment of approximately 53,000 students. IRB approval was obtained prior to data collection. Each participant was asked prior to beginning the observation or interview if any other permission to observe their classroom or laboratory was required. At each institution, the individual professor had the power to grant permission to observers therefore no further permission was required. Verbal permission was obtained from each participant, recorded and transcribed. The researcher had no student interactions at any time during the study.

Semi-structured interviews were conducted individually with each participant at his or her institution and at times convenient for him or her. Interviews occurred between February of 2010 and April of 2010. Each interview lasted between one and two hours. While the same questions were asked of each participant, the researcher had the freedom to ask clarifying questions or additional questions depending upon the answers of the participants. The interviews were audio taped and transcribed word for word. Member checking was used to validate data. No participant requested changes to the transcripts. The questions used for the interviews are in Appendix B and the questionnaire is in Appendix C.

There are advantages and disadvantages to the use of interviews. Advantages include the ability to focus on the topic of interest, in this case, inquiry teaching, as well as the ability to make inferences. Disadvantages include bias due to response, poor questions as well as lack of specific memory by the participant and reflexivity which is defined as the participant answering questions in the way in which he or she believes the interviewer wants. These interviews were audio taped, transcribed, and reviewed by the participants.

The questionnaire included the five essential features of inquiry using the inquiry continuum. Participants placed themselves on the continuum with respect to the five essential features of inquiry, determining where on the inquiry continuum the teaching was situated. The five essential features of inquiry used in this study came from the National Research Council (1996, 2000) as does the definition of inquiry. This was to assure alignment of the questions with the definition of inquiry used for this study. According to Johnson and Turner (2003), there are three types of questionnaires: Type I is a series of unstructured and open-ended questions; Type 2 includes a combination of open- and closed-ended questions; and Type 3 which consists of structured and closed-ended questions. The questionnaire used for this study is Type 3. Participants who had a laboratory component for their class were given the questionnaire twice; once for how they viewed inquiry in the classroom and once for how they viewed inquiry in the laboratory. Five of the professors at the research institution were given only one questionnaire because they did not have a laboratory component to their class or they were not involved in the labs. None of the physical science teachers at the large, research institution (astronomy and physics) had a laboratory component. The life science professors at the large, research institution did have a laboratory component but were not involved in the design of the lab and did not teach any labs. As a result, the laboratory coordinator for the labs was given the questionnaire. One life science professor had minimal involvement with the laboratory and so was given two questionnaires.

There are several strengths and weaknesses attributed to the use of questionnaires (Johnson & Turner, 2003). Strengths include affordability, ease in administration and data analysis, anonymity, and high measurement validity while weaknesses include no responses, incomplete responses if the questionnaire is too long, low response rate, and the need for validation.

Enacted beliefs were ascertained by observation of teaching in the college classrooms. This was the third method. An inquiry check list was utilized to determine the level of inquiry present in the classroom (see appendix B). The checklist was the same as the questionnaire the participants answered and was based on the five essential features of inquiry. This checklist enabled the researcher to compare accurately what the participant said they do in the classroom with what the researcher observed in the classroom. The researcher observed each professors class one time utilizing the inquiry check list as well as observing a laboratory activity if there was a laboratory component with the class. Time did not permit additional observations.

A syllabus, handouts, and sample labs were obtained from participants who had a laboratory component for their class. These were examined for evidence of inquiry.

Instruments

Interview

The questions for this interview were developed as part of a class assignment with input from the professor. The instrument was pilot tested to ensure that the questions being asked provided responses that answer the research questions. The first six questions determined background information of the teacher, providing a description of the teacher and their educational background. The next five questions provided an understanding of the teacher's view on students and student learning. Two questions were asked to gain insight into how the teacher viewed him/herself and his/her primary role at the university or college while the last five questions determined the teacher's knowledge, use, understanding and beliefs on inquiry (See Appendix C).

Questionnaire

The questionnaire used in this study was the five essential features of inquiry, as stated by the NRC (2000), put to scale. The scale responses were developed as part of a class assignment and were evaluated by the instructor. The scale responses of the questionnaire were pilot tested and changes were made according to participant feedback. The questionnaire was then piloted a second time. Initially, only one questionnaire of the five essential features was given and participants were asked to place themselves on a continuum (low-0, high -5) for both lecture and laboratory. The initial participants in the pilot study had difficulty averaging what they did in their classroom with what they did in the lab and offered the suggestion that two questionnaires would be beneficial, one for the class and one for the lab. Changes were made to the questionnaire based on feedback from participants in the pilot study and the instrument was pilot tested a second time, giving the participants two questionnaires, one for their lab and one for their class. Both questionnaires were identical and a high inter rater reliability was obtained.

The questionnaire was the five essential features of inquiry as stated by the National Research Council (2000). Feedback from a well-known science education researcher prompted the use of the five essential features of inquiry in the current study. The five essential features included question asking, evidence, evidence to explanation, connecting evidence to theory and communication and justification of explanations. Descriptions of the essential features were included on the questionnaire. These descriptions are the variations described by the NRC (2000). The participants were asked to place themselves on a continuum from 0 to 5 with respect to inquiry in their classroom. A score of zero indicated maximum teacher direction while a score of five indicated maximum student direction. Participants were given a second, identical questionnaire for their laboratory component. (See appendix B).

The first essential feature was question asking. This was described as the learner engaging in scientifically oriented questions which are the focus in experimental investigations. Many students ask “why” questions which may not be able to be answered by science. Changing “why” questions into “how” questions allow for scientific investigation (NRC, 2000). The continuum was from zero to five representing the degree of teacher involvement and direction.

Zero corresponded to total teacher directed instruction while five represented maximum student direction. There were four descriptions for the first essential feature. The first description stated, “student engages in question provided by teacher, materials, or other sources” (NRC, 2000, p.29), and correlated to 0 and 1 on the continuum. The second description, “student sharpens or clarifies question provided by teacher, materials, or other sources” (NRC, p.29), correlated with 2 and 3 on the continuum. The third description correlated with number 4 and stated, “student selects among questions, poses new questions” (NRC, p. 29), while the fourth description correlated with number 5 and stated, “student poses the question” (NRC, p. 29).

The second essential feature dealt with evidence and was described as the learner gives priority to evidence in responding to questions. Evidence, in science, is obtained from scientific investigations using observations and measurements (NRC, 2000). Again there were four descriptions for the five numbers which included from 0 to 5, “student is given data and told how to analyze” (NRC, p. 29), “student is given data and asked to analyze” (NRC, p.29), student is directed to collect certain evidence” (NRC, p.29), and “student determines what constitutes evidence and collects it” (NRC, p. 29).

There were four descriptions for the third essential feature which represented evidence to explanation and was described as the learner formulates explanations from evidence. Essential feature three was very similar to essential feature two, the difference being that essential feature three highlights the route from evidence to explanation, while essential feature two describes criteria of evidence (NRC, 2000). The four descriptions, again from 0 to 5 included, “student is provided with evidence” (NRC, p.29), student is given possible ways to use evidence to formulate explanation" (NRC, P.29), "student is guided in process of formulating explanations from evidence" (NRC, p.29), and "student formulates explanation after summarizing evidence" (NRC, p. 29).

The fourth essential feature had only three descriptions for the continuum from 0 to 5. The fourth feature was defined as connecting evidence to theory and the learner connects explanations to scientific knowledge. This includes evaluation of explanations and consideration of other explanations (NRC, 2000). The three descriptions stated, "students are given possible connections" (NRC, p.29), "students are directed towards areas and sources of scientific knowledge" (NRC, p.29), and "students independently examine other resources and forms the links to explanation" (NRC, p. 29).

The last essential feature was communication and justification of explanations and was defined as the learner communicates and justifies explanations. All scientists share results of their investigations which allows for additional questioning, evaluation and identification of alternative explanations (NRC, 2000). There were four descriptions for the continuum ranging from 0 to 5. They included, "student is given steps and procedures for communication" (NRC, p29), "student is provided broad guidelines to sharpen communication" (NRC, p.29), student is coached in development of communication" (NRC, p.29), and "the student forms reasonable and logical arguments to communicate explanations" (NRC, p.29).

The researcher used the same questionnaire to document her observations in both the classroom and the laboratory. The scores given by the researcher were then compared to the scores the professors gave themselves. This was done to determine congruency between what the professors believed was happening in the classroom and labs and what the researcher observed with respect to the use of inquiry. Scores were also compared across institution types and disciplines.

Data Analysis

The data from this study were analyzed using the qualitative software, NVivo. Data analysis of all collected data was done to develop a set of analysis codes and their meanings. Profiles of each participant were developed and analyzed. Patterns and themes were identified, returning to the data to find evidence to support claims. Analysis of data was also done across institution types and science disciplines.

First, all qualitative data were transcribed verbatim. Member checking was utilized to ensure accurate transcription. Transcribed data was then read multiple times to identify key coding nodes. After transcription and analysis of the interviews, twenty one codes were identified. These codes were then placed into the qualitative research analysis software, NVivo. Codes were placed into larger categories for ease in analysis. The first category was Background Information and included the codes of how the professors got his or her start teaching college science, educational background, education courses taken, what the professor considered most important to teach, most important for students to learn, design of the class to assist in teaching what they think is important, and activities that help students learn. The second category was Teachers' View on Students and Learning. This category included the nodes of where learning takes place, how students learn, how has the professors teaching changed, what the professors have done to improve his or her teaching, grade distribution, tests, online support offered to students, attendance, and class size. The third category was How the Professor Views Himself and included the nodes of job responsibilities. The fourth category dealt with the Professors' Knowledge and Beliefs on Inquiry. Nodes included were descriptions of a typical lab, definition of inquiry, and limits to inquiry. Because of the open questions, there were some patterns noted in some interviews but not in all. A Miscellaneous category was added to include these. It included teaching how they were taught, teacher-student interaction, and sequencing to other classes. Table 3 lists the larger categories and subsequent nodes identified.

Placing the codes into larger categories allowed the data to be reduced. Analysis of the codes and multiple readings of the transcripts led to the emergence of several themes. The college science professors in this study either lacked an understanding of what inquiry was or held the view of inquiry as full and open (NRC, 2000); a belief that inquiry is that which researchers do. Secondary themes included what the professors believed hindered the use of inquiry and how the professors viewed their roles. This limited and incomplete understanding of the features of inquiry led to instructional choices that did not support the use of inquiry in the classroom.

Scores from the questionnaire of each participant were analyzed by correlating what was said in the interview with what the professors said they did in the classroom and lab. These scores were also compared to the scores given by the researcher during the observations. The transcripts were read again in attempts to find evidence to link the beliefs of the professors, both enacted beliefs and stated beliefs, to the themes identified. Quotes from interviews were identified to reinforce the link to the themes.

Table 3: Themes and Nodes Used for Analysis

Background Information	Teachers' View on Student Learning	How Teacher Views Himself	Knowledge and Beliefs on Inquiry	Misc.
Start teaching college science Education courses taken Most important about what you teach/what students learn How course is designed Activities to help learning	Where learning takes place How students learn How teaching has changed What they have done to improve teaching Grade distribution Tests Online support offered to students Attendance Class size	Job responsibilities	Typical Lab Definition of inquiry Limits to inquiry	Teaching how they were taught Student-Professor interaction Sequencing to other classes

Syllabi and lab manuals obtained from each professor were also examined for evidence of inquiry. Laboratory activities were read to find evidence of the five essential features of inquiry as well as evidence to support what each professor stated he or she believed occurred in the lab setting. While there were no labs for the physical science classes, one astronomy class did utilize a workbook for activities that the professor used in class. A copy of that workbook was obtained.

Summary

The case study design was utilized for this study in order to obtain multiple data sources needed to answer the research questions. Beliefs and practices of college science professors with respect to inquiry and the use of inquiry in the science classroom were identified. Data were collected from four areas: semi-structured interviews, a questionnaire of the five essential features of inquiry, observation of classes and laboratories, and analysis of syllabi and written laboratory activities. The findings, presented in Chapter Four, were divided by the themes identified and discussed above.

CHAPTER FOUR: RESULTS

The purpose of this research was to examine the beliefs held by college science teachers with regards to inquiry in the classroom, to examine how these beliefs impacted their instructional choices, and to examine how these beliefs were enacted in the classroom. Additional questions included whether the beliefs of college science teachers varied across institution type (community college, private four year college, and research institution) and also, if beliefs varied across disciplines (life sciences and physical sciences). The case study approach allowed the researcher to clarify the beliefs and practices of college science teachers regarding the use of inquiry in the science classroom.

The research questions of this study were: (1) What were college science teachers' beliefs of inquiry in the classroom? (2) How did these beliefs affect instructional choices? (3) How were these beliefs enacted in the classroom? Secondary questions were: (4) Was there a difference in college science teachers' beliefs between different institution types (community college, small, private college and research institution)? (5) Was there a difference in college science teachers' beliefs between science disciplines (life sciences and physical sciences)?

Interviews and observations were conducted at three different institutions with a total of 12 professors and one laboratory coordinator participating. Besides interviews and observations, questionnaires were given to each participant regarding his or her use of inquiry in the classroom and laboratory. Additionally, the professors provided syllabi and lab manuals and they were examined for evidence of inquiry practices. The same questionnaire given to the participants regarding their use of inquiry in the classroom was used by the researcher during the observation.

The researcher scored the questionnaires given to each participant and compared them to the scores obtained during observations. The researcher graphed these scores. Graphs of all participants were placed in Appendix D.

There were three professors at the community college, six professors and one laboratory coordinator at the large research university, and three professors at the small, private college. There were six professors from the life sciences and six professors from the physical sciences. The laboratory coordinator was included in the study as she was in charge of the biology laboratory for two of the professors from the research university.

Several themes emerged after multiple readings of the transcripts. The college science professors in this study had an incomplete view of inquiry. Either the professors lacked an understanding of the aspects of inquiry or held the view of inquiry as incomplete; a belief that inquiry is only what scientists do. Several secondary themes became apparent as a result of this incomplete view of inquiry. These secondary beliefs may have hindered the use of inquiry in the classroom. These themes included the belief that undergraduates lacked motivation and the understanding necessary to become involved in inquiry, that inquiry was time intensive, and that lack of equipment and class size prevented incorporation of inquiry in the classroom. These beliefs were supported in earlier studies (Brown, Abell, Demir, & Schmidt, 2006). This limited and incomplete understanding of the features of inquiry led to instructional choices that did not support the use of inquiry in the classroom. An additional theme as to how the professors viewed their role, as either teacher or researcher, was identified and impacted their view and use of inquiry, as well.

Presentation of findings was arranged according to the aforementioned themes. Quotes from participants were included to support the observations of the researcher and emphasize the triangulation of the collection of data. Additional information included was how the professor viewed themselves; as a teacher or researcher. This information helped to elucidate if the perceived role of the professor may have helped or hindered the use of inquiry in the classroom.

Theme One: Incomplete View of Inquiry

The use of inquiry for this study was divided into use in the classroom and use in the laboratory. The researcher gave two questionnaires, one for the classroom and one for the lab, and two observations were done, one in the classroom and one in the lab. This section was separated into views of inquiry in the classroom and views of inquiry in the laboratory. Supporting data were triangulated from the interview, the observation and the questionnaire. The classroom was presented first with the laboratory following.

Classroom Inquiry

Of the thirteen participants (12 professors and one lab coordinator) in this study, four had a view of inquiry as full and open while eight had an incomplete view of inquiry. The laboratory coordinator was not included in the discussion of classroom inquiry as she was involved only in the laboratory component for Drs. Franklin and Wilson. The four professors who held the view of inquiry as that which scientists do included Dr. Franklin, Dr. Branson, Dr. Fenton, and Dr. Fleming. When asked to define inquiry, their responses indicated a belief that inquiry was what scientists do. All of them indicated that inquiry was asking a question and attempting to answer that question through investigations. When examining the continuum of inquiry, from full to none with respect to degree of inquiry and from teacher directed to student directed with respect to degree of guidance (see Figure 2 in Chapter 2), these professors saw inquiry as student directed and full, which aligns with what researchers do.

Dr. Franklin

Dr. Franklin stated:

> Inquiry from my perspective is facilitating a student's independent journey to gain knowledge. You are there to kick them back into the playing field when they stray too far. And so you, from my perspective, you would set up a structure where the student could learn through their (sic) own experimental design, they can learn through experiments and they can learn from their own data analysis. Of course, I am speaking from a scientific perspective.

A subsequent comment, made by Dr. Franklin also enforced his view that inquiry was what scientists do, "…inquiry being that they are the ones steering their own ship and they are deciding what's important and what's not important." His belief that inquiry involved students' "independent journey to gain knowledge" and "they are the ones steering their own ship" demonstrate little, if any, teacher involvement.

It was not possible to observe Dr. Franklin's class for evidence of his belief in inquiry as he co-taught the course with Dr. Wilson, and Dr. Wilson was teaching at the time of this investigation. Dr. Franklin was included in the interview process as he taught a class that the researcher observed. Dr. Franklin was given the questionnaire (Appendix B), and he was asked to place himself on the continuum for each of the five essential features of inquiry. He gave his class a score of zero on all essential features of inquiry except for number two where he gave a score of 1. Essential feature two is the learner giving priority to evidence and the score of one correlates with students being given data and told how to analyze. Because the researcher could not observe Dr. Franklin's class, there was no researcher questionnaire to compare, but the answers to the interview questions with regard to inquiry aligned with his answers to the questionnaire.

Dr. Branson

Dr. Branson also viewed inquiry from a scientist's perspective stating:

> Well, inquiry is the systematic way of arriving at a new understanding and what teaching inquiry is all about is to look at the process of how you acquire knowledge and look at other knowledge that's out there and be able to evaluate it in a reasonable fashion.

He further commented that inquiry in the classroom was, "the way you try to teach inquiry is to make people understand how science comes together to advance knowledge." The researcher asked Dr. Branson if he looked at inquiry from how the scientists get their knowledge to which he replied, "Yes."

While Dr. Branson viewed inquiry as what scientists do, his answers on the questionnaire demonstrated his belief that he utilized all essential features of inquiry in his classroom. He gave himself scores of nearly 4 (with five being maximum student directed) for all essential features except for essential feature 4, connecting evidence to theory, where he gave himself close to three. Dr. Branson was observed on April 6, 2010, and the class had 11 students enrolled with 9 present. During the observation, there was questioning and one instance of explanations from evidence. There was one study with evidence in the Power Point but the evidence was explained from Dr. Branson's point of view; he discussed how he interpreted the data. The students were then asked for their interpretation. While in this instance the students were guided in formulating explanations from evidence, an essential feature of inquiry, Dr. Branson had given his interpretation and students' interpretations tended to agree with his. The researcher did not see evidence of inquiry in the classroom at the level Dr. Branson noted on his questionnaire. While it is difficult to evaluate the level of inquiry employed in a classroom with only one obsevation, the inconsistencies between Dr. Branson's belief on inquiry stated in the interview, what was observed in the classroom and answers to the questionnaire, reinforced that Dr. Branson's view of inquiry was incomplete. A graph comparing the scores of the researcher with the scores of Dr. Branson are shown in Figure 3, Appendix D.

<u>Dr. Fenton</u>

Dr. Fenton saw inquiry as more of what a scientist would do. His statement reflected this belief.

> Oh, wow. That's an interesting question. Um, I would say that inquiry teaching is really something, it's more like what a lab is without this, 'Here's the situation, let's start playing with it and see if we can understand what's going on.' The students posing the question, the students saying what's happening here? I think that can be kind of tough to do.

When asked why he felt that way, he responded;

> Because I don't think that students always know the question to ask? Talks I have had with other faculty and things like that, as much as we would love to think we could sit our best students down and they could figure out the laws of motion on their own, it's not going to happen. There needs to be some sort of set of basic guidelines of here's what is going on, let me give you some idea and now let's see if that actually makes sense.

The comment by Dr. Fenton that students needed guidelines in attempts to answer questions emphasizes his belief that inquiry is what scientists do and that students are unable to be involved in inquiry. Dr. Fenton believes inquiry is what scientists do and this belief is emphasized by his view that inquiry is like a lab without the teacher giving the situation.

Dr. Fenton placed himself in the middle of the continuum on the questionnaire for all essential features except for number four where he marked a 2; students are directed towards areas and sources of scientific knowledge. Dr. Fenton's class was observed on April 20, 2010. His class was held in a typical classroom with individual chairs facing a chalkboard. He began the class with a modified KWL chart on pendulums and then proceeded to discus the lab on pendulums that would be done later in the day. He put a formula for the period of a pendulum on the board and asked the students to prove that it was true. Dr. Fenton asked questions of students and made sure to ask every student a question. He made connections between what he was teaching and the use of physics in everyday life. One example he presented was discussing rotational motion and relating it to diving as there was a student who was a diver in the class. The scores given by the researcher and the scores given by Dr. Fenton were similar. Aspects of inquiry were evident in the classroom of Dr. Fenton. Students were involved in discussions of questions, they were given a formula and asked to prove it as well as looking at and interpreting data. The graph comparing the scores of the researcher and Dr. Fenton are seen in Figure 4, Appendix D.

Dr. Fleming

Dr. Fleming viewed inquiry from a scientist's perspective. When asked to define inquiry, Dr. Fleming replied;

> Umh… To me, I guess it would mean that I would try to let the students try to formulate what questions interest them and yea, well, help the student to formulate questions that are interesting to them and help them figure out how they might go about answering them.

A subsequent comment by Dr. Fleming reinforced his belief of inquiry as that which scientists do. The researcher asked if he thought it was easier for upper level students to be engaged in inquiry to which he stated:

> I guess it would be upper level because they have been more exposed to the college style. I guess I am not sure about that. There are definitely some upper level undergrads in my classes who are not in, not necessarily, a scientific frame of thinking, but they are not starting to think like scientists.

The statement that in order for students to become involved in inquiry, they must start to think like scientists supports the view of inquiry as that which scientists do; undergraduates are not able to be involved in inquiry.

Dr. Fleming was given one questionnaire for his class, as there was no laboratory component with the class. He gave himself a score of 3 for all essential features except for essential feature number 2 which he gave himself a 4. Essential feature 2 is evidence and a score of 4 is that the student is directed to collect certain evidence. Dr. Fleming was observed on March 2, 2010. The class observed was the upper division, mixed astronomy class that had 23 students with 9 graduate level students and 14 undergraduate students. Twenty students were present. Dr. Fleming reviewed an online test the students had taken. After the review, Dr. Fleming began to lecture. He wrote on the board and responded to questions from the class. There was minimal evidence of characteristics of inquiry during the three-hour class. Dr. Fleming lectured and students either had the Power Points displayed on their computers or took notes. Questions were teacher generated, and Dr. Fleming analyzed the data presented with nominal input from students. The researcher used the same questionnaire taken by Dr. Fleming as an observation tool during the class. The graph comparing the scores of the researcher with the scores of Dr. Fleming is shown in Figure 5, Appendix D.

The remaining eight participants had an incomplete understanding of inquiry. While the use of questions was the most common feature in these professors' views on inquiry, several professors included other aspects such as data analysis, investigation, justification, and teacher guidance.

<u>Mrs. Davis</u>

Mrs. Davis had the most incomplete view of inquiry. Although she included questioning in her definition, the questions did not align with the questioning described by the essential features of inquiry. Mrs. Davis questioned her students to be sure the students understood what she was teaching, or students asked questions of Mrs. Davis when the student did not understand what was being taught. She stated:

> I think it's basically critical thinking. I think that students are paying you to teach them so I think you need to first teach them, help them understand it, teaching them to help them understand it, not memorize but just to understand it so that then you could ask them questions about what you taught them.

This statement underscores her view that inquiry questioning comes from her to the student in order to clarify student understanding of material taught. The following statement supports her view that questioning in inquiry is from student to professor when students do not understand material taught. When asked to define what she thought inquiry learning is, she stated:

> Learning after the subject matter has been taught, the student to ask you questions regarding the subject matter and maybe personal situations, questions that they answered because they do have homework questions that I will give them today in lab and they have for homework for the lab. And then they will ask me questions, that's what I use more for their inquiry questions.

In clarification, the researcher attempted to restate what Mrs. Davis had defined as inquiry learning. The researcher stated, "Inquiry learning to you is when you present the material and then the students learn it and incorporate it and then come back to you with questions?" Mrs. Davis then responded, "Yes."

She was then asked to define inquiry teaching and her response was:

> How I look at it is I am giving them the foundation. I am teaching them the foundation, laying a good foundation for them so that when they ask questions, they can think about the question and ask me questions that show me that they understand it.

These statements by Mrs. Davis demonstrate an incomplete understanding of what inquiry in the classroom is and what is involved in inquiry teaching and learning. She views inquiry as questioning only, and her belief on how questioning is used does not align with the use of questioning as defined by NRC (2000) in their five essential features of inquiry.

Observations of Mrs. Davis' class further supported her incomplete view of inquiry. The researcher observed her class was on March 25, 2010. The class observed was her Anatomy and Physiology II class which had 23 students enrolled. Nineteen students were present the day of the observation. Mrs. Davis began the class by taking attendance and then answering questions from the previous class. She primarily used the overhead projector for displaying her notes. Notes were done in outline form and contained lists of possible essay questions for the test. Students had the notes that Mrs. Davis had on the overhead. She also used many overhead transparencies made from the pictures in the textbook. There was very little discussion during the class. Mrs. Davis gave information verbally, drawing on the board frequently. There were very few questions asked of the students and only one was a "why" question. When a student did not answer the question that was asked, Mrs. Davis gave hints and clues to help them get the answer. She directed students to other sources of information to assist in making possible connections twice during the class. Many of the students were not engaged. Several were talking quietly and/or texting on their phone. Those with lab top computers were on Facebook or answering mail. Very few students were taking notes.

There was no evidence of the five essential features of inquiry during the observation of Mrs. Davis except for some questions and the alternate sources of information. The class was teacher driven with very little input from students and instruction was by lecture. The graph comparing scores on the questionnaire from Mrs. Davis and the researcher is represented in Figure 6, Appendix D.

Dr. Barrett

Dr. Barrett had a more complete understanding of inquiry including both questioning and data analysis in her definition of inquiry along with making connections between them. When the researcher asked what she thought inquiry was, she made several statements supporting the questioning, data analysis and connections. She commented that as far as inquiry teaching goes, "I do not believe that you inquiry teach but rather inquiry guide" adding that, "Inquiry learning is more self-guided learning" and "Inquiry learning is really more of a development of a basis of knowledge that is self organized, like their learning style." Dr. Barrett included questions as part of her view on inquiry with the following statement. "In the lecture component, it usually starts with a question. You know, why do you think this? What do you think would happen?" This statement describes questions more in line with the five essential features of inquiry; they are higher level and asking students to make connections to previous knowledge. In addition, Dr. Barrett included data analysis as part of her definition by stating, "I start with what kind of data might we look at and how would you use that data to figure out a meaning for it, a why."

To clarify, the researcher stated, “I am getting that a big part of inquiry is this questioning and connections?” to which Dr. Barrett replied:

> Connections, yes, thank you, you said it. I am trying to see that chemistry is not a standalone subject. It’s called the Central Science which we won’t go into right now. But I try to pull things in and get them to understand the reason you have a meniscus for water , da, da, da, da, da. The reason why you die from acidosis is da, da, da, da, da, Connect those biological concepts and history, too. Why did Boyle and Avogadro do the gas laws? Why did they care? Well, there are a whole lot of economical and historical reasons for that. Because once they start having that broader base of connected information then they will be able to do a more effective job with inquiry learning.

The researcher observed Dr. Barrett’s class on March 29, 2010. Both her class and her labs are held in the same room; there is not a separate classroom or lab. The lab tables are arranged so students are in groups of 4. She starts every class and lab with a quiz; this is to ensure punctuality as well as how she takes attendance. The quiz is always on the previous class’s material. She then played spin the chalk. Dr. Barrett spun the chalk and the student to whom the chalk pointed had to come to the board and write her answer to the first question on the quiz. There was then classroom discussion about the answer. The student then would spin the chalk and a new person would come to the board to answer the second question.

After review of the quiz and previous class information, Dr. Barrett introduced new material. This class discussion was on the size of the nucleus and orbitals. She had students stand up and become the nucleus with other students becoming the orbitals. As she was explaining new material, she would ask for a thumbs up or a thumbs down display from every student to check for understanding. If all students did not display a thumbs up, she stopped and taught the material again.

Dr. Barrett moved around the room asking questions and encouraging students. She did not answer questions directly but rather asked questions back in attempts to lead the student to the correct answer. All students participated and seemed to be engaged. She would call on students randomly to answer questions or participate. Her presentation of new material was brief and she did not speak for more than 15 minutes. She referred students to other places for information and justification. One example was labspaces.net.

Several aspects of inquiry were evident in the observation of Dr. Barrett. The class, while guided by Dr. Barrett, was not totally teacher-directed. Students were involved and engaged in the learning process. Dr. Barrett stopped frequently and checked for understanding before continuing. Questioning was a large part of the class and Dr. Barrett did not give direct answers but used leading questions to allow students to discover the answer. There was discussion between groups and all students were expected to contribute. The graph comparing the scores of researcher and Dr. Barrett are seen in Figure 7, Appendix D.

Dr. Bender

Dr. Bender had a view of inquiry limited to questioning. When asked what inquiry was, he commented:

> Well, inquiry, as I understand it, is when people attempt to, they ask questions and try to solve them so, and that's a way to teach. You can give people questions and you can have

it discussed in class, you can collect the answers and you can discuss the answers and how that works. I don't use inquiry method to teach.

Dr. Bender was observed on April 5, 2010. His lecture class lasted 45 minutes and was held in a large auditorium which was approximately half full. Students came and went throughout the class with some arriving as much as 30 minutes late. There were two screens at the front of the room and Dr. Bender used a hand held microphone to speak. His lecture was on pathogens and he used a Power Point presentation interspersed with four clicker questions. There were a total of six questions asked of students verbally. Dr. Bender also had several short movie clips in his Power Point presentation. He spoke quietly and in a monotone voice. Many students were on their computers playing games, on Facebook and/ or email.

There was scant evidence of inquiry in the classroom of Dr. Bender. Dr. Bender presented content in lecture format and while there were six questions asked, they were done so by Power Point and students answered using clickers. Not all students had clickers. Questions were multiple choice; the correct answer was given after all students had answered, and then Dr. Bender proceeded with the lecture. There was no discussion about the answers. Students were not involved in any aspect of the lecture. Two students asked a question which was answered by Dr. Bender. The clickers mentioned in the above passage refer to students utilizing a hand held device called a clicker to input answers to a question posed by the teacher within a Power Point presentation. The questions are usually of a multiple choice design.

The researcher gave Dr. Bender the questionnaire in order to self-report on his use of inquiry in his class. His scores indicated that he felt his class had aspects of all five essential features of inquiry. During observation, the researcher used the same questionnaire as an observation tool. A score of 1 was given for essential feature number 1 concerning question asking as Dr. Bender did engage students in questions he provided. The researcher gave Dr. Bender a score of 2 for essential feature four, connecting evidence to theory as students were directed towards areas and sources of scientific knowledge such as websites and journal articles. The comparison of scores is shown in Figure 8, Appendix D.

Dr. Conroy

Questioning was the focus for Dr. Conroy when asked about inquiry. His remarks enforced this view.

> So, I mean, I am not sure how to define it. To me inquiry would be, you know, asking questions and having students try to answer them in a more formal sense than, "hey, did you see what I just wrote up there, what do you think about that?" or something like that. I think the clicker style thing is something I would see as a good example of inquiry in a lecture class like that.

In clarification, Dr. Conroy observed, "Inquiry, I guess it means engaging students in asking and answering questions, that's a good textbook answer."

Dr. Conroy was observed on April 6, 2010. The class observed was an introductory astronomy class in which approximately 200 students were enrolled. The class was held in an auditorium. The class began when Dr. Conroy put a picture of a nebula on the screen and asked what it was. Several students answered and he then began a demonstration. The demonstration was how to build a scale model with the purpose to show how vast space is and that it is predominately empty space. Dr. Conroy used a tennis ball, Play Dough and a meter stick, asking students for help. The class was using ratios to determine a scale representing the distance from Earth to the sun. He used humor and had many students engaged. The students engaged were the students sitting near the front of the room. Many other students were on their laptop computers on Facebook, checking email and surfing the internet. Some students were talking and Dr. Conroy twice had to ask students to be quiet. Many students in the upper section of the class walked in late and left early. There was one student question that Dr. Conroy answered directly.

After the demonstration, which lasted approximately 20 minutes, Dr.Conroy put up a Power Point presentation and discussed new material. He did ask questions and used jokes and humor to make his point. The questions were not of higher level and mainly asked students to recall information.

While Dr. Conroy attempted to use other aspects of inquiry in his class, he appeared to struggle during the demonstration to maintain class control and to engage more than just a few students. When asked during the interview about the demonstrations, he commented that he tries to do them once a week but they were difficult to do due to the size of the class.

Dr. Conroy responded to a questionnaire for his lecture class as he did not have a laboratory component. He scored himself in the middle of the continuum for all essential features except for essential feature 4, connecting evidence to theory where he placed himself at the point where students are given possible connections. The scores between the researcher and Dr. Conroy were shown in Figure 9, Appendix D. While Dr. Conroy included aspects of the five essential features, they were on the end of the continuum that was more teacher directed.

Dr. Wilson

Dr. Wilson was unable to articulate what inquiry is and his view did not include questioning as part of inquiry but relied more on interactions between student and teacher. His comment illuminates his confusion.

> Define inquiry and inquiry teaching. Umh.. gosh, umh, I guess I have to start I am not entirely sure of what, if there is a particular method to label itself. Inquiry teaching would involve quite a dynamic interaction between student and professor. Often I think it's a balance between giving students enough information vs. allowing students to interpret and then, I guess develop a better idea or ask more questions on top of that. `
> How would one begin teaching inquiry learning? Don't know if I have necessarily done it and always successfully. But I mean a lot of times I think that would have to lend itself to something like starting off with broad conceptual ideas leading into more discussions, interactions, active learning.

Dr. Wilson was then asked to define what he meant by active learning to which he replied, "Well, umh, I guess more engaged learning. So things like labs and applied sort of interactions. And um, yea, I don't."

While the researcher interviewed both Dr. Franklin and Dr. Wilson, only Dr. Wilson's class was observed. Dr. Wilson was observed on April 7, 2010. His Biology II class was held in an auditorium with 250 students enrolled. He utilized a Power Point presentation during his lecture. There were no clicker questions or demonstrations. He spoke without a microphone and used humor throughout his talk. He asked only two questions and answered only one question from a student. Many students had laptops and while some were taking notes, many others were checking email, on Facebook or texting on cell phones during the lecture.

The observation of Dr. Wilson's class supported his incomplete view of what inquiry was and how aspects of inquiry could be used in the classroom. Material was presented through lecture and there was no interaction or discussion with students. The researcher gave a score of zero for all essential features except for number four where a two was given. Essential feature number four is connecting evidence to theory and a score of two demonstrates that students are directed towards areas and sources of scientific knowledge. Dr. Wilson used many figures and graphs during his lecture and used scientific theories in attempts to bridge what students saw with the supporting theory. References were given to students to further investigate. No other evidence of inquiry with respect to the five essential features was noted by the researcher. Figure 10, Appendix D shows the comparison scores between Dr. Wilson and the researcher.

The last three professors had the most complete views of inquiry including aspects other than just questioning in their definition.

Dr. Griffith

Dr. Griffith included questioning as a major focus in her definition of inquiry. In her class and lab, she utilized Socratic questioning techniques. This was evident in her comment:

> So, that's what you will see, if they ask me a question, I never answer the question, I try not to, if it is a disaster I will but normally I just hit them back with another question so it's totally their discovery.

In a subsequent comment, other aspects of inquiry became apparent. Dr. Griffith made the statement that:

> I think for inquiry, it is sort of the discovery process where the students are discovering the knowledge for themselves. I don't know if you are familiar with the old technique of guided design but I taught a class entirely by guided design and it was, I loved it and they learned a lot but they hated it because it is a lot of work on their part. Actually, while I am a fan of inquiry, I am not a total fan of total inquiry.

This statement supports her view that inquiry, while effective, is not practical all of the time. She supported this belief in another comment stating:

> I know some people, I have been to workshops where they do entirely inquiry and constructivist and I think that is really great and wonderful if that is what your whole school has bought into and the students know what they are getting into but to me, I don't think it's real world, maybe I am just too old to change.

These statements illuminate Dr. Griffith's incomplete view of inquiry in that inquiry is all or none.

Dr. Griffith was observed on February 24, 2010. Thirty students were enrolled in the class and 29 were in attendance. The class was arranged with two rows of large, overstuffed chairs at small tables in the front of the room. Behind those chairs were long rows of tables with chairs. Dr. Griffith greeted every student as they entered and seemed to know all of them. The class began with a quiz on metabolism which took approximately 20 minutes. Dr. Griffith than began a Power Point presentation on the cell cycle. The students had a worksheet given prior to this class with the vocabulary they were to know for this class. As Dr. Griffith talked about the cell cycle, she asked the students questions. She would then have them discuss with their partners what they felt the answer would be. She required that the students tell why they answered the way they did. She then called on students to tell the answer of their partner. This led to classroom discussion about the answers to the questions. Dr. Griffith was encouraging and gave positive feedback but never answered the question. After a few minutes of discussion, she would say if they were correct and would possibly add some detail but for the most part, students led the discussion. She drew a picture of a chromosome on the board and asked questions about the drawing again having the students talk to their neighbors about what they thought the answer was. Dr. Griffith asked leading questions. She then put up a picture of the cell cycle and had the students tell each other the steps of the cycle and what happened in each step. She called on students by name to explain the cycle aloud. At one point, Dr. Griffith put an experiment on the screen with results and asked the students why the results were the way they were. She took the student answers and probed for deeper understanding, answering their questions or comments with another question; many times those questions were in the form of "What if." She gave praise frequently and called on prior knowledge.

While Dr. Griffith was one of the professors who incorporated inquiry into all aspects of her class and lab, she did not see that those aspects were inquiry in nature. While she identified questioning as an aspect of inquiry, she did not identify her use of data and data interpretation in the classroom as an aspect of inquiry. The graph comparing her scores on the questionnaire with that of the research is shown in Figure 11, Appendix D.

Dr. Matthews

Dr. Matthews also had a view of inquiry that involved more aspects of the five essential features of inquiry than just questioning. He commented that inquiry in the classroom involved questioning as well as attempts to answer the question and justification of the answer.

> Inquiry teaching is, I hope, if today is a normal class day, what you will see in my class today is I will ask a question, they will try to solve it and throughout the course of the class, everyone is going to have to answer something. And then defend that answer.

Dr. Matthews was observed on February 24, 2010. The class observed was the physics of musical instruments and there was no laboratory component for this class. The class was held in a typical classroom with individual student desks. The class had 25 students registered but 5 had dropped the course and all 20 were present for the class. There was a piano at the front of the room, lying on its side with the strings inside exposed for the students to see. The piano was played and students were able to see the workings of the piano as it was being played. Dr. Matthews began asking questions about the piano strings with respect to length, thickness and sound. He knew the names of all the students and asked the questions of specific students. All students were called on, and he did not allow them to just give short answers but kept probing, requiring that the students justify their answers. He had students go the board to draw pictures to explain their answers. He allowed all questions but rarely gave direct answers, rather he asked probing questions in return. Dr. Matthews also would ask for consensus of answers, especially if students gave conflicting answers.

The class observation demonstrated several aspects of inquiry including the questioning as well as justification of answers. Students were engaged and discussions were lively; questions were asked by the professor to students, by students to the professor and also, by students to students. This was the only class observed where student to student questioning was noted. Figure 12, Appendix D showed the comparison in scores between Dr. Matthews and the researcher.

Mr. Greer

Mr. Greer included other aspects of the five essential features of inquiry into his definition of inquiry. Besides questioning, he included investigation and teacher guidance. He stated that, “Inquiry means that you investigate a question that you already got. (sic). So, if I am a student, inquiry learning, I need to have a question I am trying to find the answer to.” When asked about finding the answer he replied:

> Yeah, that’s where the inquiry teaching would be different from the inquiry learning. I would say I probably do more of the inquiry teaching. I set student up in a situation that I have provided so that they can practice investigating that situation.

In a discussion on questions, he stated:

> That for me is another part of the inquiry learner. They come up with the question that they wanted answered. That for me is the time to help them as opposed to ready or not, here’s what I am teaching.

While the class has a laboratory component, Mr. Greer does not separate the two. He has “time.” The college catalog states that it is a four credit hour class that meets 6 hours per week with four hours of lecture and two hours of lab. He chooses to combine them and calls it “time.” The researcher observed Mr. Greer’s class/lab on March 23, 2010. The class took place in a lab where lab stations were arranged in groups of 4. There were 17 students present at the time of the observation. Mr. Greer knew the names of all his students and greeted them as they entered the room. He started the class with a question. All students were engaged and tried to answer the question. Mr. Greer spent 30 minutes on questioning and discussion. He guided and did not answer questions from students directly but rather called on students to continue the discussion.

Mr. Greer then introduced the “activity” for the class. It was on genetics and students were given an ear of corn with different colored kernels. The students were drawing the different stages of meiosis and mitosis while Mr. Greer walked around. He never answered a question directly but asked questions to lead the student to the answer. His comments were always positive and he used humor a great deal. The students were engaged, working together and seemed to enjoy the time. After the drawings were completed, the next activity consisted of the groups examining an ear of corn that had different colors of kernels. The students were to count how many of each color was present and record this data. The data was then entered into a central computer in an EXCEL spreadsheet as data would be graphed and analyzed in the next class. The purpose of this activity was for students to see the 3:1 ratio of Mendel’s genetics. Again, Mr. Greer walked around encouraging students. There was much questioning and when students answered, Mr. Greer asked for evidence to support their answer. Students were not allowed to answer without giving supporting evidence and everyone had to contribute. Mr. Greer made a point to call on every student in the class.

Some students became frustrated, as they wanted to know if they were right and Mr. Greer would not tell them. He was always respectful and encouraging. Comparison of scores between Mr. Greer and the researcher were demonstrated in Figure 13, Appendix D.

Laboratory Inquiry

The next section described the laboratory component of the classes observed. The researcher gave the professors with a laboratory component the same questionnaire as the one for their class. They were asked to place themselves on the continuum with respect to the five essential features of inquiry and their use in the lab situation. The researcher observed the labs one time and the questionnaire given to the professors was used as an observation tool. The researcher obtained lab manual and examined for evidence of inquiry.

Not all professors had a laboratory component with their class. Those professors who did not have a lab were Dr. Matthews, Dr. Conroy, and Dr. Branson. Dr. Wilson and Dr. Franklin were not actively involved in the development or teaching of the labs for their class but were familiar with how they were run. The researcher interviewed Ms. Yancey, the laboratory coordinator for their labs, and she was given the questionnaire. Mr. Greer was not discussed in the laboratory component as he did not separate his time into class and lab; Mr. Greer was discussed above in the section, Classroom Inquiry.

Mrs. Davis

Mrs. Davis had the most incomplete view of inquiry which was evident in her class as well as her lab. The researcher observed Mrs. Davis's lab on April 5, 2010. The lab had an enrollment of 24 students and 22 were present the day of the observation. The lab was set up with shelves and cupboards along both sides of the room. Long tables were placed in a U format with the teacher's desk and white board at the open part of the U. Handouts were placed on the teacher's desk and students picked them up as they entered. There were different colored handouts for different classes. The class observed had blue handouts.

The handout consisted of a list of anatomical structures of the human reproductive system with numbers that corresponded to different parts. The numbers matched the numbers in the book as well as the labels on the models. For example, number 48 was the ovary. The model of the female reproductive system had a tag of 48 on the ovary and the picture in the book had number 48 representing the ovary. During the lab practical or test, Mrs. Davis changed the numbers. She also set up microscopes set up for students to view slides. Examples of slides that students were to observe were the epididymis, fallopian tubes and seminal vesicles. Students had dissected fetal pigs in an earlier lab, and the teacher gave students instructions to use the textbook to identify certain structures of the fetal pig.

Mrs. Davis began the class by taking attendance and reviewing a case situation which referred to a topic discussed in class. Students used a cooperative group activity, Round Robin, to look at slides. Mrs. Davis also showed actual pictures of some pathology related to the reproductive system such as tubal pregnancy, tubal ligation and hydrocele. There was little student discussion outside of their groups. Material was primarily presented by lecture format with minimal input by students.

Again, the researcher used the same questionnaire to observe the lab as Mrs. Davis had used to place herself on the inquiry continuum. Graph 14, Appendix D, shows the comparison between the scores of Mrs. Davis and the scores of the researcher

It is interesting to note that for both observations, class and lab, the researcher gave Mrs. Davis a higher score than she gave herself for essential feature number 4 which was the connection of evidence to theory. Mrs. Davis did direct her students to other sources of scientific evidence but gave herself a score of 1.5. It was difficult at times to interpret what Mrs. Davis put for a score as she would circle three of them and write off to the side, “all three.” In those instances, an average was given. Mrs. Davis felt she incorporated all aspects of inquiry in her lab but this was not evident to the researcher.

The researcher asked Mrs. Davis for copies of labs and handouts given to students. Mrs. Davis provided two question pools, one for the urinary system and one for the digestive system, a list of four renal clinical case situations and a lab handout. There was minimal evidence of inquiry in these documents. The lab handout consisted of a list of structures of the reproductive system for students to examine on slides and during dissection of the fetal pig. There were no questions asked, and there was no analysis of structures. The two question pools gave a list of questions that would be used for the multiple choice questions on the exam. The questions were not higher order but consisted of listing, naming and drawing. Only two questions asked for students to explain. The renal clinical case situations were essay type questions which did require some analysis and application of what was learned.

Dr. Franklin

Dr. Franklin, while not actively involved in the laboratory, was familiar with how the labs were designed and taught. His comments on the laboratory experience conveyed his frustration as well as his view of inquiry as that which scientists do.

> Unfortunately, due to resource constraints at this university, umh, the lab experience in Bio II is not what it should be. It used to be a three hour laboratory with not as many students. Instead of hiring more TAs to get the job done, the college has decided to take a three hour lab experience and turn it into a 2 hour lab experience and shove more students into it. Probably across the country, we are one of the worst departments in that perspective. Not to mention that our teacher to faculty ratio is just out of whack compared to anywhere else in the country – I mean our faculty to student ratio. Umh… but the laboratory experience has become very limited because of that and so what we try to do is get the students in, 15 minutes to sort of give them idea about what they are doing for two hours which now becomes what they are doing for an hour and 45 minutes. We have to give them a quiz based on what they did in the previous lab and what they are going to be doing for that lab. That takes another 10 minutes away. So basically what we are left is an hour and a half to get them some hands on experience with basic biological principles which you can imagine, is not a lot of time to run a lab. So, it's frustrating and so the students will come in and try to get this hands-on experience where we ask them critical thinking questions along the way. Like we will ask them from hand to reconstruct a phylogeny of organisms and then ask them critical questions about the process of

> constructing that phylogeny and where things might have changed, where deviations in building this phylogeny might have changed. In the hopes that they understand all the caveats that go along with what it is they are doing. Again, we do that on a very limited scale because we just don't have the time or resources to get more involved.

When asked if the labs were scripted and that all questions had a correct answer he replied, "Yes, it's not inquiry based lab, in other words."

Examination of the lab manual supported Dr. Franklin's statement. The labs were primarily "cookbook" labs that could be completed in a short time. Questions were primarily of the lower level with very few higher order thinking questions.

<u>Ms. Yancey</u>

Ms. Yancey was the laboratory coordinator responsible for the development of the labs for the classes of Dr. Franklin and Dr. Wilson. She was interviewed on April 7, 2010. Her understanding of inquiry was along the lines of what scientists do. The labs for the class were scripted because of the volume of students. She stated there are over 900 students and the labs are mandatory which she feels does not allow for inquiry based labs. She stated:

> Wow, to me if I could do inquiry labs, I would love to, kinda just… I don't even have a good experiment in my head at the moment, you caught me by surprise. I would love to set them up with something. A good one we were thinking about doing was a simple pH lab in Bio I with giving them different substances and having them figure out the pH. Some pond water, some ocean water, different water, naturally collected water, rain water, tap water and just kind of have them extrapolate as to what all this means. We talk

about global warming, we talk about acid rain. Kind of have them think outside the box, not just give them these scripted labs, part A, do this, here's your 10 steps, part B, here's your 10 steps. Where they come to the answer but are very much directed towards the answer. I would rather have them start thinking more about how to get to those answers and that all their answers may be different.

Ms. Yancey's description of an inquiry lab, while having many aspects of guided inquiry, limited the definition to what scientists do. Other aspects of inquiry, such as higher order questioning, justification of answers, and evidence to support answers, that could be included in lab situations were not identified.

The laboratory class for Dr. Franklin, Dr. Wilson, and Ms.Yancey was observed on April 7, 2010. The class was held in a typical lab room with long tables running the length of the room. While 48 students were enrolled in the lab, only 39 were present. The lab began with a quiz and then the students filled out an evaluation for the teaching assistants. The quiz asked questions from the previous lab as well as questions from the current lab. Questions were multiple choice and asked students to recall information. Students were expected to read and be prepared before coming to class. Class continued with a Power Point on plant structures which followed the lecture from class. One slide previewed what the next lab would be. Students were to observe slides that were set up around the room with microscopes and make sketches of what they saw. Students were then to make a leaf peel. The lab lasted approximately 45 minutes at which time most students left. There was no discussion about what students saw under the microscope. Minimal evidence of inquiry was noted in the lab. The graph comparing the scores given by Ms. Yancey and the researcher are noted in Figure 15, Appendix D. Scores were similar escept for essential feature five. Ms. Yancey gave a score of 0 while the researcher gave a score of 1. Essential feature five is communication and justification of explanations. The lab observed did have teachers giving students steps and procedures for communication as did all the labs obtained.

The labs obtained were on Dichotomous Keys and Phylogenetic Trees, Vertebrate Comparative Anatomy, and Plant Structure which was the lab observed. All three of these labs were scripted with detailed instructions on what to do and how to do it. There were some questions at the end of the lab. A few were higher order questions but many were recall. A fourth lab was also obtained. The teacher required students to complete a lab report in this lab. The lab was on Prokaryotic Diversity, and it was accompanied by a detailed description of how to write a lab report including many examples. The lab itself was scripted with detailed procedures and directions. While all students would be obtaining different data, the data was to be entered in an EXCEL spreadsheet on a computer in the back of the room. This data for the class was then posted to the online learning site for students to analyze. Also given in the directions was how to use EXCEL for mathematical analysis of the class data. Three different graphs were expected as well as a data table. Examples were given. Four references were required and directions on how to reference, as well as examples of references were included. Students were responsible for turning in a first draft where comments by the teaching assistants were made. Students were to make corrections, and a final copy turned in to Turnitin.com.

This lab had the potential to be more inquiry based than it was. The teacher gave the question and procedures to the students as well as detailed instructions on how to communicate results and alternate sources of information. Because of this component, the level of inquiry was on the teacher end of the continuum. Two essential features were at a level one. Level one is where learners engage in questions provided by teacher and learners are given steps and procedures for communication. The researcher noted higher levels of inquiry with respect to evidence as the students were collecting data and with respect to explanations as the students were given possible ways to use evidence to explain (NRC, 2000). These examples were at levels 3 and 2 respectively.

Dr. Fenton

Dr. Fenton had a view of inquiry as what scientists do but there were many other aspects of inquiry noted in the lab observed. Dr. Fenton's lab was observed on April 20, 2010. The lab was set up with a two long center tables and lab tables projecting at right angles from the center tables. Each workstation had a computer. Students worked in pairs at tables. The lab topic was on pendulums. Equipment was available for students, and they were responsible for setting up the pendulums. Students used a lab notebook to record data. The students were changing the length of the string of the pendulum as well as the mass of the bob. The length of the string and the mass of the bob were chosen by the student pairs. Dr. Fenton walked around speaking to students and asking them questions, encouraging them to discuss questions with each other. He did not answer students' questions directly but rather asked a leading question in response. Dr.

Fenton did not allow the students to use the words “too big” or “too small” but made them quantify their answers.

There was an extension to the lab which was on physical pendulums, and students were to design their own experiment proving the formula discussed in class. Figure 16, Appendix D, shows the graph comparing scores given by Dr. Fenton and the researcher. The scores between the researcher and Dr. Fenton were similar. One major difference was with essential feature number 2, giving priority to evidence. While Dr. Fenton gave himself a 2 corresponding to the students being given data and asked to analyze, the researcher felt the score was closer to a 4 which corresponds to the student being directed to collect certain data. The lab extension required students to collect their own data and then analyze it.

<u>Dr. Barrett</u>

Dr. Barrett had a more complete view of inquiry which included questioning, analyzing data, and making connections between the question and data. This complete view of inquiry was not as evident in her lab as it was in the classroom. Dr. Barrett spoke in the interview of her labs. While she uses many aspects of inquiry in the classroom, she feels she is unable to do so in the lab setting due to the nature of her subject. She teaches chemistry and labs involved chemicals. She stated that the labs were very much scripted for student safety. She would like to make her labs more exciting but student safety factors limit her. When asked how she would change her labs she stated:

> …be more exciting, in other words, have that same newness to it, that talks about current events, to able to move with the times with that bit more. It is difficult with the essence of

having chemicals and working with the lab book and making sure you are safe. In other words, I would like to be more current events oriented but that's kinda hard to incorporate.

The researcher asked if Dr. Barrett had labs that are not in the lab book, but instead were ones she had developed to which she replied that she does but those are "dry" labs and do not involve chemicals.

Dr. Barrett's lab was observed on March 29, 2010. The lab observed was on spectroscopy, a "dry" lab. Dr. Barrett spoke for about 15 minutes on the different gases and their colors, explaining how the color of different gases was applicable to several things such as when astronomers study stars. She then gave a demonstration showing the different colors emitted by different gases. The students then used spectroscopes to examine the spectrum for different lights and gases. She provided a handout for students to use that explained how to use the spectroscopes as well as posed questions. All students were engaged and seemed to enjoy the lab. Again, Dr. Barrett walked around the class, asked probing questions, answered student questions with leading questions and encouraged the students. She gave positive feedback and praised the students' work. The lab included several aspects of inquiry. All students had different gases and so results obtained were different. Questions on the lab write up were of higher order and asked student to apply what they learned to new situations. Figure 17, Appendix D shows the graph comparing scores given by Dr. Barrett and the researcher.

The researcher's score was the same as the score given by Dr. Barrett for essential feature 1, 2 and 4. For both essential feature number 3 and 5, the researcher gave a higher score to Dr. Barrett than Dr. Barrett gave herself. Essential feature number 3 is evidence to explanation. A score of 4, given by the researcher, describes a student who is guided in the process of formulating explanations from evidence. During the lab, Dr. Barrett guided the students a great deal. She did not answer their questions directly, but referred them to other sources and constantly asked them to explain based on evidence they had. This referral to other sources was also the reason the researcher gave Dr. Barrett a 4 for essential feature number 5 which was communication and justification. A score of 4 represented the student being coached in development of communication.

An exam was given to the researcher. The exam consisted of 12 essay questions. There was a bonus question which Dr. Barrett included on all tests. The question stated:

> Did you study something that I didn't include in the exam? Here's your chance. Write your own question and answer it with power and conviction. This question may be worth up to 10 points, depending upon the scope and veracity of your response.

Dr. Barrett also provided the researcher with the lab manual for the class. It was scripted, as stated by Dr. Barrett, with specific directions given for students to follow. There were correct answers for the questions. Again, Dr. Barrett followed this due to safety issues with students using chemicals.

Dr. Bender

Dr. Bender limited his view of inquiry to questioning and admitted that he does not do inquiry. While there was limited inquiry noted in Dr. Bender's class, the lab observed had several aspects of inquiry. Dr. Bender's lab was observed on April 5, 2010. The room was a typical lab room with lab tables placed in rows. There were 11 students as the lab is not a requirement of the course. The lab was taught by a teaching assistant who was pleasant and energetic. The lab began with a quiz as each of the labs do. There were 5 questions within a Power Point presentation. Three of the questions asked “what”, one question asked “why” while the last question asked students to name one of three things. The teaching assistant gave hints to help the students. The quiz was then reviewed. Dr. Bender sat in on the lab for about 15 minutes and then left.

It was interesting to note that the lab observed was the one lab that had more inquiry activities involved. The lab was on nutrition and there was a brief review of the lab via Power Point. The teaching assistant asked questions but then gave the answer when no students volunteered. The students were then allowed to leave as it was a “take home” lab. Students were to keep track of all food intake and drink for 24 hours. They needed kcal and were given a website to find that information if that information was not located on the packages. The students were to report the kcal in grams of all fat, carbohydrates and protein consumed in a 24 hour period. Formulas for all calculations were given.

The graph representing the comparison of scores of the researcher and Dr. Bender on the essential features of inquiry for the lab is visualized in graph 18, Appendix D. The greatest discrepancy was in essential feature number 2, evidence. Dr. Bender gave himself a 2 while the researcher gave a 4. A score of 4 represents that the student is directed to collect certain evidence which they were doing in the nutrition lab. The researcher gave a score of 2.5 for essential feature 5, communication. The students were provided broad guidelines in how to communicate their data but had some leeway in doing so.

The lab manual was written by a professor at the university and was a companion to a textbook written by the same person. While Dr. Bender used the lab manual, he used another book for lecture. The lab manual did not align with the book used by Dr. Bender. There were 12 exercises in the lab manual, they were not called labs. All included objectives, introductions, graphics, step-by-step directions and questions that required a correct answer. It was interesting that the one lab observed, the nutrition lab, was the lab with the most inquiry.

Dr. Griffith

Dr. Griffith had a broad view of inquiry which was evident in her class as well as her lab. Her labs demonstrated the most inquiry of all labs observed. Dr. Griffith's lab was observed on February 24, 2010. The lab was set up with two long rows of tables with students working in pairs on both sides of the tables. Students were involved in doing an experiment on photosynthesis and factors affecting it. Students worked independently and seemed to know how to use the spectometer and how to locate equipment. Dr. Griffith walked around making comments and giving specific praise. As in the class, she did not answer questions directly but asked probing questions in attempts to lead the student to the answer.

Four labs were obtained. Two labs were scripted, telling the student what to do. One was a lab on the care and use of a microscope, and the other was a lab identifying cell types and parts, using a microscope and prepared slides. The other labs were much more inquiry based with directions stating, "Using the skills and knowledge developed so far in the course to examine two microscopic organisms on the given prepared slides, write a report using the course format." The students were to include drawings and compare their results to at least one other published source, commenting on that source's support for the student's results.

The researcher also obtained several labs. Some labs were somewhat scripted but did allow for some variation in procedure and answers. Dr. Griffith's labs had what she called "self-designed extensions." These components were not scripted and allowed students to be more independent. One self-designed extenstion gave the following directions.

> Based upon what you have learned about yeast fermentation, design an experiment to further investigae this process. You and your partner have the option of designing an experiment that determines the effect of either substrate concentration or substrate type on fermentation. Each individual will write up the results of their experiment following the guidelines in the postlab section of LabWrite.com and on pages 83-89 of Writing Papers in the Biological Sciences. The results section must contain both a textual description of your data as well as tables and/or figures that summarize the data.

There was also a lab extension for the lab observed on factors affecting photosynthesis. Each pair of students had to design an experiment testing a factor that may affect photosynthesis and could not be one studied in class. Students were to hand in their research question, research design, and a list of supplies needed prior to the next lab class. They would then perform the experiment at the next lab.

Of all the labs observed, the labs by Dr. Griffith were the most inquiry based. Students were taught how to use equipment, how to design and implement experiments as well as how to graph and communicate results. Students were then expected to use what they had learned in new situations. While topics were given by the professor, the questions, design, intepretation of results and communication of data were developed by the student. These labs would be placed on the continuum at the level of 5 which is more student directed and less teacher directed. Due to safety factors, procedures had to be approved by Dr. Griffith.

Theme Two: View of Role

Professors who participated in this study were asked how they viewed his or her role, as teacher or researcher. This question was asked to determine if how the professor viewed their role may have impacted what occurred in the classroom. This question was followed by a question asking how their teaching had changed. Data from the interviews, observations and questionnaires supported that the professors who viewed their role as researcher, used less inquiry in the classroom and felt that improving their teaching was not a priority. Of the four professors who held beliefs of inquiry as what scientists do, three of them viewed their primary role as researcher. The three professors holding beliefs of inquiry from a scientist's perspective who also viewed their primary role as researcher were Dr. Franklin, Dr. Branson, and Dr. Fleming. While Dr. Fenton saw inquiry from a scientist's perspective, he viewed his role primarily as teacher.

Dr. Franklin

Dr. Franklin stated:

> Well, I am first and foremost a research biologist and I am rather ashamed to say it but teaching pays the bills in order to do your research. That doesn't mean I don't love teaching, I do, I really enjoy it but it is not the primary reason I am here.

When asked how his teaching has changed he stated:

> I was much more, and this might be a stereotypical evolution of an instructor, I don't know but when I first got here I was very hardnosed about what the students needed to bring to the classroom. I will present obstacles in front of you, you must jump over them. For those who make the jump, great, you have your grade and for those who couldn't jump over them, I will see you next year in the same class. And I didn't provide a lot of materials to the students; I didn't provide a lot of feedback to the students. I showed up, I lectured, I left. I think I am trying to become a little more integrative in how I approach the class. I now provide resources on line to supplement my lecture, I provide outlines of my lectures before I go, I provide movies that I found that can help facilitate the understanding of a concept so I am becoming more integrative in the way I have approached the class.

The changes made to the class in attempts to improve his teaching are not based on educational research as to best teaching practices. Dr. Franklin has taken no education courses and has not read educational research.

Dr. Branson

Dr. Branson viewed his role primarily as researcher spending 50% of his time on research, 25% on committee duties, and the remaining 25% on teaching. He viewed inquiry from the scientist's perspective as well. He was asked how his teaching has changed and he replied:

> Yes, well, I am always trying new things and what I do is add content as things develop in planetary and space science and ah, respond to what I think are reactions to what I see in the kids.

He added, "…it's always been a lecture course but what I do is change the emphasis and the order in which things are done in response to how I think the students are responding." Dr. Branson has taken no education courses and has not taken any workshops to improve his teaching. His changes to his course in attempts to improve his teaching come from that of a scientist and not an educator. His improvements to his course were to add new material from current research.

Dr. Fleming

Dr. Fleming held a belief of inquiry from the scientist's point of view and views his primary role as researcher. While teaching takes up most of his time, he would prefer to teach one semester and then do research one semester. He struggles with the time balance between teaching and research. If he only had to focus on one at a time, he could, "…do a lot of development, I could do a lot of, you know, build a lot of different activities and assignments." With respect to teaching, he stated:

> I got my start teaching college science, well, because it is an integral part of the job, the duties, my job here. Before I arrived at this university, I was doing pure research and when I got the job here, I knew coming in that part of it would be teaching science at various levels….I was sort of thrown into it. I certainly didn't learn any pedagogical techniques when I was doing research full time.

He has taken no education courses and does not read educational research.

Dr. Fenton

Dr. Fenton, while viewing inquiry from a scientist's perspective, considered himself a teacher. He was asked if after he graduated with his PhD if he had a desire to teach at a research institution to which he replied:

> No, teaching has always been my passion since I first started out as physics major and got the experience to be a TA. I love working with students, I love the dialogue back and forth and seeing the student who struggles and struggles and struggles and suddenly it just clicks, usually, just one day it just happens.

His classroom had evidence of the essential features of inquiry although he did not see those features as inquiry. He has taken no education courses but does sit in on other professors' classes with the goal to improve his own teaching.

Professors that demonstrated the most inquiry in their classrooms viewed themselves as teachers and while only Mr. Greer had taken any education courses, they all had taken workshops in attempts to improve their teaching. The attempts to improve their teaching and the view that teaching was their primary role seemed to be transformed in the classroom as increased use of inquiry and teaching techniques designed to improve student learning. The teachers with the most inquiry in their classroom were Dr. Barrett, Mr. Greer, Dr. Griffith and Dr. Matthews.

Dr. Barrett

Dr. Barrett knew while doing her PhD that teaching was her passion and research was not. She stated:

> When I was in graduate school I wanted to work on cancer drugs and I actually did do AIDS research. I was working with CDC with Emory and I really enjoyed that but it was a very intense life style. And what I found was that the researchers around me did not have anything outside their work and I am more of a balance oriented person. I have always been service oriented and that's why I wanted to go into medical research; however, I decided that perhaps that wasn't going to be a long term personal healthy option and so I was looking to see what I could do to help national health care kinds of things without sacrificing all of my personal life and I looked at teaching. It was a very logical choice and then I started teaching and I really had a passion for it.

Dr. Barrett has tried to improve her teaching by taking educational workshops offered through the college. She has taken Action Learning and Authentic Assessment as well as others. Many of these courses are taught by people with advanced degrees in education.

Mr. Greer

Mr. Greer viewed his role primarily as teacher. The majority of his time is spent on teaching and teaching related activities such as, "coming up with new lesson plans, working with the lab staff." He stated, "Teaching is the job." He has taken educational courses as well as the workshops provided by his college. Educational courses taken at the graduate level included a few classes in Curriculum and Design. He took an inquiry workshop at Florida Atlantic University and uses techniques learned in the workshop in his class.

Dr. Griffith

Dr. Griffith viewed her role as teacher and stated:

> When I was doing my PhD I decided that while I saw the purpose of research, that was not where my talents or primary interest was so even when I was an undergraduate, I taught. In lab sections I was sort of an undergraduate TA and I really liked that and I think that is where my talents are so when I was finishing up my PhD, of course in those days, I've been at this university for 31 years so, um back in the 70s, you never said that when getting your PhD so I, you know, sort of did my research but focused on a research project that would work for a small school because I just decided that was what I liked to do.

Dr. Griffith has taken no education courses as part of her education, but she has been active in educational in-services as well as educational research. She did summer in-service workshops for elementary education teachers. She worked with the department of education at the college and felt that she learned a lot about education by doing these in-services. Dr. Griffith is currently involved in educational research with the National Association of Biology Teachers with funding from the National Science Foundation. When asked about her research, she stated:

> We are trying to figure out if there is a consensus as to what do students finishing this class need to know, understand and be able to apply. So, not what did they memorize, but what is it and we are looking at both content topics and skills. The idea being that it doesn't matter if the kid took Gen Bio at X university, Y university or Z university, when they are in their 300 molecular biology course, that instructor knows that no matter where they went, they truly understand DNA replication and protein synthesis.

Dr. Matthews

Dr. Matthews began teaching while in the Army. He was assigned to teach at West Point. The Army sent him to get his PhD and then to West Point to teach. He has taken no education courses but states he was taught how to teach when he began his PhD. He stated that he got his PhD from the Institute of Optics at the University of Rochester and:

> I was a little put off when I arrived there to find out that I had 6 weeks of learning how to teach. It was the best thing that ever happened to me….But everyone arrives two months before classes start and you have 6 weeks where they introduce you to not just administration and how things work but they actually teach you how to teach.

He views his role as teacher even though he is involved in research. He views his research as a teaching responsibility stating, "I don't separate them. I mean I do spend a lot of time on my research but all my research is done with undergraduate students. I don't do research myself."

There was a large difference in the amount of inquiry observed between the classes of these professors. The professors who viewed their roles as researchers viewed inquiry from a scientist's perspective and had made no attempts to improve their teaching using research supported educational practices to improve student learning. Their classes had limited if any inquiry. Professors who viewed their roles as primarily teachers incorporated more aspects of inquiry in their classes. While they may not have been aware that many of the activities or lessons they were doing were inquiry based, they all had made attempts to improve their teaching by becoming involved in educational workshops, research and in-services.

Secondary Themes: Factors that hindered the use of inquiry in the classroom.

These secondary beliefs hindered the use of inquiry in the classroom. These included the belief that undergraduates lacked motivation and the understanding necessary to become involved in inquiry; inquiry was time intensive; lack of equipment and class size prevented incorporation of inquiry in the classroom. These secondary beliefs were held primarily by the professors at the large, research institution. Class sizes were frequently in the hundreds while class sizes at the community college and small, private four year college were capped at 24. The professors at the large research institution viewed themselves as researchers with the belief of inquiry as what scientists do. This incomplete view of inquiry gave rise to beliefs about obstacles in incorporating inquiry in the classroom.

Lack of Motivation and Understanding Necessary for Inquiry

The first obstacle was that undergraduates lacked motivation and understanding necessary to become involved in inquiry. Seven of the 12 professors believed lack of student motivation, experience, and preparation limited the use of inquiry in the classroom. Dr. Fleming stated that inquiry would be easier to do with upper level students:

> …because they have been more exposed to the college style. I guess I am not sure about that. There are definitely some upper level undergrads in my classes who are not in, not necessarily a scientific frame of thinking; they are not starting to think like scientists.

Dr. Bender felt that undergraduates were not motivated and are resistant to inquiry. He made several statements supporting this. One comment was, "I don't use inquiry method to teach. Um, it just, again, the nature of the class. Students throw up their hands and they say 'I am not good at science and I don't want to fight that." Another comment as to why he feels students resist inquiry was, "Because it is not anything they are at all interested in….Most of them don't really want to be there, it is a necessary evil to getting a degree."

Dr. Barrett was one of the professors who incorporated many aspects of inquiry in her classroom but still viewed students as having difficulty doing inquiry. When discussing students and inquiry she stated that students are:

> …very dualistic and dualism makes it harder for them to make that connection, that independent connections and so that I think some of that is developmental. I don't want to say that it's information they don't have, it's the ability to formulate questions and connect information.

Dr. Fenton also felt that some students were not prepared to do inquiry. He felt that students needed experiences and a science background in order to do inquiry. Dr. Fenton views inquiry as full and open and so believes that without background experience, students are unable to become involved in inquiry. He stated, "The experiences and background of the students in some ways limits me, if they don't have a good science preparation."

Dr. Griffith was one professor who incorporated a great deal of inquiry in her class and lab but still believes the lack of student understanding and experiences limits her use of inquiry. She stated:

I think to do good inquiry, you have to have a good foundation of some information. You just can't start from nothing; you have to be given a basis of information. …There are some kids who are not performing at the college level because they never got what they were supposed to out of high schools so if you have a weak student it can be very hard.

Dr. Matthews, while utilizing inquiry, felt that the lack of background for students was a limiting factor. This was evident in the following statement.

> Factors that inhibit…lack of background, that's probably the biggest thing I run into. You know it's difficult if they can't solve an algebraic problem….Because you know, they can't do mathematics, they can't do simple mathematics. And these are good students, some of them are really smart. But they can't do simple algebra and in physics, that's our language.

When the researcher asked Mr. Greer what limited his use of inquiry in the class and lab, he simply stated, "Interest by students."

<u>Class Size</u>

Of the six professors at the large research institution, four had class sizes in the hundreds. Class sizes for Dr. Franklin and Dr. Woo had an enrollment of 500 students, Dr. Conroy had enrollments between 200 and 300, and Dr. Bender's class was 264. All four of these professors viewed class size as a limiting factor to inquiry in the classroom and lab. As stated earlier, Dr.

Franklin noted that each lab has 50 students and he stated, “Fifty students is too large of a laboratory class.” Dr. Conroy feels that it is easier to do inquiry with smaller classes. This belief was evident in his comment:

> Obviously if I am teaching the 20 student honor section I am going to be teaching in a somewhat different way. I am still teaching the same topics in roughly the same order and I will even try to keep exams fairly similar and assignments fairly similar but I am more free to do more of this inquiry type stuff, more discussion, more interactive stuff than I can in a lecture class though I still try to keep it.

Dr. Fleming felt the large class sizes did not allow him to maintain control and so was unable to incorporate inquiry. He commented that, “it’s not that easy, it’s very hard to get control of the class, just in terms of classroom dynamics, it can be challenging.” The class observed for Dr. Fleming had an enrollment of 23 students and limited inquiry was noted. The comment with respect to class size and control was in reference to his introductory astronomy classes with 200 students enrolled.

Dr. Wilson felt that inquiry was easier to incorporate into upper level classes because they were smaller. He stated:

> …once you get in upper level classes you can start delving more into discussion. What I like to do in upper level classes is oral presentations or facilitations and that gets students more involved but with 250 students, I find that really difficult.

He followed with, “…because when you start off in the introductory levels the classes are so huge, there is very little interaction. Research methodology is kind of lost in the mid level courses and some upper level courses it reappears." This comment supports his belief of inquiry that is full and open, what scientists do as he refers to inquiry as "research methodology."

Lack of Time

Three professors and the laboratory coordinator viewed lack of time as a limiting factor by three of the professors as well as the laboratory coordinator. As noted earlier, Dr. Franklin, in speaking about the laboratory, felt that two hours was not enough time for the lab experience. Ms. Yancey, the laboratory coordinator for Dr. Franklin's labs, reinforced his statement. In response to the question about what limits inquiry, she stated, "For us, time. Our labs are an hour and 50 minute. Even when we try to do… there are so many labs that would be great… but they just don't work in an hour and 50 minutes." Dr. Barrett also felt time limited her use of inquiry and stated, "Time, actually one of the things that limits." The last professor who believed the lack of time limited the use of inquiry was Dr. Matthews and he commented, "My time constraint is the problem."

Lack of Equipment and Supplies

Four professors felt that lack of equipment and supplies limited the use of inquiry. The professors who felt this way were Dr. Franklin, Dr. Griffith, Dr. Fleming and Dr. Matthews. Dr. Franklin felt because the labs and classes were so large, there were not enough resources to incorporate inquiry. This view was also expressed by Dr. Fleming. The university did not have enough telescopes, and the telescopes that they did have were not of the caliber needed to engage students in inquiry activities. While Dr. Griffith and Dr. Matthews had class sizes of 24 or less, they viewed lack of equipment and resources as limiting their use of inquiry as well.

All of the professors in this study held an incomplete view of inquiry. Professors either held the view of inquiry as full or open, or they were unable to identify all the aspects of the essential features of inquiry. Many professors incorporated various aspects of inquiry in their classroom and laboratory but were not aware that they were features of inquiry. This limited view of inquiry by the professors led to secondary beliefs that further limited the use of inquiry. These included the inability of the student to engage in inquiry due to inexperience and lack of motivation, large class sizes, limited time and lack of resources. Chapter five presented the conclusion, discussion, limitations, and further recommendations.

CHAPTER FIVE: DISCUSSION, CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

College science teachers' beliefs on inquiry in the classroom were examined in this study. Twelve college professors at three different institutions; large research institution, small, private four year college and community college were interviewed. In addition to interviews, classes and labs were observed, the researcher gave the professors a survey of the five essential features of inquiry, and samples of labs and syllabi were obtained. The researcher also interviewed a laboratory coordinator as she was responsible for the laboratory section for two of the professors at the research institution. All schools were located in the southeast United States.

The results for the four research questions were discussed first followed by conclusions, limitations, and recommendations for future research.

Discussion of Research Questions

Definition of inquiry is vague in the literature, and so it is understandable that the definition of exactly what inquiry is would be vague in the classroom. Brown et al. (2006) summarizes this by stating,

> What makes this research difficult to understand is the lack of agreement about what constitutes an inquiry-based approach. The bulk of the research has taken place in precollege classrooms examining the outcomes of various blends of inquiry-based instruction. These studies are hard to compare given the different meanings for inquiry that have been employed (p. 786).

Coburn (2000) also writes, “Perhaps the most confusing thing about inquiry is its definition. The term is used to describe both teaching and doing science” (p. 42) while Anderson (2002) concurs stating, “the research literature on inquiry tends to lack precise definitions” (p. 3).

The incomplete view of inquiry by college professors is not surprising as the literature on inquiry presents an unclear and vague meaning (Buck, Bretz, & Towns, 2006). Inquiry is used as both a way to teach as well as a way for conducting research and according to Buck, et al, the use of inquiry varies between teachers of secondary education and college and university professors. The definition of inquiry utilized for this study is from the National Research Council (1996):

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as understanding of how scientists study the natural world (pg. 23).

While even this definition is broad, the five essential features of inquiry can be used to clarify and focus what is meant by inquiry. The first essential feature is that the learner engages in scientifically-oriented questions. Of the thirteen participants, twelve professors and one laboratory coordinator, nine included student or professor questioning as part of their definition of inquiry. There were three professors from the community college, two of the three were from the private institution and four of the seven from the research institution.

This chapter was divided by research questions and each question was discussed with respect to each institution type. Limitations and recommendations followed.

Question 1: What were college science teachers' beliefs on inquiry in the college classroom?

The perception of inquiry by college science professors has been found to be a barrier to the institution of inquiry in college classrooms. According to the National Research Council (2000), most college science professors hold the view of inquiry as full and open. This statement was supported in the current study. While the professors described constraints to inquiry such as large class size, lack of time, disinterest of students, and lack of equipment, these limitations were due, in part, to the professors' view of inquiry as what researchers do. This was most pronounced with the professors at the large, research institution.

Research Institution

The professors at the research institution viewed themselves primarily as researchers and their view of inquiry was that which researchers do. Questioning was the main focus in the definition of inquiry of three of the professors and the laboratory coordinator; Dr. Fleming, Dr. Bender, Dr. Conroy and Ms. Yancey.

The other three professors at the research institution, Dr. Branson, Dr. Franklin and Dr. Wilson, did not include questioning in their definition. They all viewed inquiry from a scientist's perspective. This incomplete view of inquiry as what researcher's do, may not allow science professors to incorporate inquiry in the science classroom. This lack of inquiry is understandable as the professors at the research institution viewed their role as researcher first and teacher second.

Research literature has supported this finding. The Boyer Report (1995) found that undergraduate education by research facilities was appalling as professors emphasized research over teaching. As the role of research expands, teaching is diminished (Boyer, 1995, Hattie and Marsh, 1996).

Hattie and Marsh (1996), in their synthesis of research studies on the relationship between research and teaching, discuss three reasons why there may be a negative relationship between professors involved in research and teaching. Time was one reason and three professors at the research institution found time to be a limiting factor. Time spent on research, limited time available for teaching and teaching-related activities such as planning for activities; lecture was easier and less time consuming.

While questioning was included in the definition of inquiry by three of the professors and the laboratory coordinator at the large, research institution, the other aspects of inquiry were not. Essential features 2, 3, 4, and 5 were not mentioned. These features included the learner giving priority to evidence in responding to questions, formulating explanations from evidence, connecting explanations to knowledge and communicating and justifying explanations (NRC, 2000).

Private Four Year College

All three professors at the private four-year college viewed their role as teacher. While their definition of inquiry was narrowly defined and did not include all aspects of the essential features of inquiry, inquiry was evident in their classroom and labs. Because their definition of inquiry was incomplete, they did not see that many of the activities and lessons they did were inquiry. While questioning was evident in all three classrooms and labs at the private four year college, there was evidence of the other essential features of inquiry as well. Dr. Griffith used data and data analysis, asking students to collect data and analyze data as well as communicate results. In Dr. Matthews's class and lab there was evidence of data collection, data analysis and communication of results.

Of all the professors included in this study, Dr. Griffith had the most complete inquiry based instructional approach. While Dr. Griffith was one of the professors who incorporated inquiry into all aspects of her class and lab, she did not see that those aspects were inquiry in nature. While she identified questioning as an aspect of inquiry, she did not identify her use of data and data interpretation in the classroom as a facet of inquiry. She made a distinction between the class and the lab having defined inquiry in the laboratory setting as data and data analysis with more open-ended questions that allowed students to design their own investigations.

Dr. Fenton and Dr. Matthews defined inquiry as attempting to answer a question. Dr. Fenton viewed inquiry from a researcher's perspective and yet incorporated aspects of inquiry in his class and lab but did not view these aspects as inquiry.

Dr. Matthews offered two views of inquiry as well as differences between inquiry in the classroom and inquiry in the lab. His two views of inquiry represented the student perspective where the student asked the question and the other perspective where the professor asks the question. While he viewed questioning as inquiry, other aspects of inquiry were noted during observation but these were not seen as inquiry by Dr. Matthews.

The second essential feature is that the learner gives priority to evidence in responding to questions. Only Dr. Griffith and Dr. Matthews from the small, private college included evidence in their view of inquiry. Dr. Griffith discussed data and data analysis as important to inquiry. She required her students to include graphs and error bars. Dr. Matthews required students to justify their answers to questions.

The third essential feature deals with the learner formulating explanations from evidence which again, was only evident in answers from Dr. Matthews and Dr. Griffith.

The fourth and fifth essential features were not included in any definition. Essential feature number four is that the learner connects explanations to scientific knowledge, while essential feature number five is that the learner communicates and justifies explanation.

Community College

All three professors at the community college included some form of questioning in their definition of inquiry. Dr. Barrett and Mr. Greer, two of the three professors at the community college, viewed inquiry in the classroom as more guided than open and had other aspects of inquiry evident in their class and labs.

The third professor at the community college, Mrs. Davis, had a very narrow view of what inquiry was. While she felt that questioning was a part of inquiry, the role of questioning in her definition was limited to the student learning subject matter that had been taught so the student could ask questions about what was being taught. Her idea of inquiry questioning was more confirmatory, the students' questions would demonstrate to her, the professor, that the student comprehended what she was teaching.

In the community college and small, private four-year college, aspects other than questioning were observed in both classrooms and laboratories but these were not included in the definition by the professors. This finding supports that most college professors have a limited and narrow view of what is involved in inquiry. Many science teachers define inquiry as only “open” and are not aware of the many facets of inquiry (Brown, et al). This narrow view may be a limiting factor in implementation of inquiry in the regular classroom setting.

Question 2: How are beliefs on inquiry enacted in the classroom?

Research Institution

At the research institution, observations in the classroom mirrored the beliefs of inquiry. Lecture was the primary instruction in the science classroom, and the labs were scripted and shown to be “cookbook” with little or no evidence of inquiry noted in the labs obtained. All of the professors except for Dr. Conroy, viewed inquiry from the scientist perspective and so incorporating inquiry strategies in the introductory level science courses were seen as not feasible. The lack of a concise definition of what inquiry is also led to confusion about inquiry learning and inquiry teaching.

Dr. Wilson and Dr. Franklin team teach a Biology course and Ms. Yancey is responsible for the required laboratory component of the course. Dr. Wilson was unsure as to what inquiry learning or inquiry teaching entailed but thought that it would involve interactions between the student and the professor. He admits that because of the class size of 500 students, these types of interactions are impossible. Dr. Wilson’s class was lecture-based with Power Point slides. He asked only 2 questions and answered one. While Dr. Wilson had a simplistic view of what inquiry is, even that was not evident in his classroom.

Dr. Franklin's belief on inquiry came from that of a scientist. Dr. Franklin's classroom was not observed as he had taught the first half of the semester while Dr. Wilson taught the second, and so Dr. Wilson's class was observed. Dr. Franklin admitted that his class is predominately lecture with Power Points. Dr. Franklin was also critical of the lab experience as the university had taken a 3 hour lab with fewer students and made it a two hour lab and increased the students to 50. There is neither the time nor the resources to do much inquiry in the labs. When asked about the labs, he readily admitted that they were very much scripted.

Ms. Yancey was the person responsible for the laboratory activities for Dr. Wilson and Dr. Franklin. When asked about the labs, she wanted to do more inquiry-based labs but felt that the size of the class and lack of time prevented the use of inquiry. She viewed inquiry as that which scientists do and because of this belief, inquiry as she defined it was not possible in the lab. During observation of the lab experience, scripted labs were evident with students following preset directions and arriving at correct answers.

Dr. Conroy was the only professor observed at the large research institution who attempted to include anything other than Power Point and lecture in his class. He did a demonstration on scale and got some student involvement, but because of the size of the class, many students were not engaged. While Dr. Conroy has a PhD in physics and teaches astronomy, he does have a Master's in Teaching Science, and he was hired as an instructor and so does no research. This allows him to spend more time in developing activities and demonstrations for his class, which he attempts to do at least one to two times per week. Even with his education background, Dr. Conroy's definition of inquiry was limited to asking questions and having students answer them.

Dr. Branson also viewed inquiry from a scientist's perspective and this belief appeared to limit how inquiry was used in the classroom. During observation of his class, Dr. Branson did walk around asking questions of students. While he did allow students to volunteer, if there were students not participating, he would call on them. The class observed was very small, only 9 students were present. There was no group work and while there were questions being asked of the students, information was presented in a Power Point format. There were several slides with data and students were asked to evaluate that data and question the data.

Dr. Bender's definition of inquiry was people trying to answer questions, and he readily admitted that he did not include any aspects of inquiry in his classroom. He believed that students did not want to learn science and he did not want to fight that. This belief that inquiry was not something students wanted to be involved in impacted how he taught. Class was lecture format with Power Point presentations.

Dr. Fleming had an incomplete definition of inquiry, defining it as Socratic questioning and felt that he used many aspects of inquiry in his class but this was not evident in the observation. The class observed was a smaller, upper level class and the information was presented in a lecture format using Power Point. Dr. Fleming did ask questions but only a few students were involved in answering them and one student dominated the class discussion. There was no group work observed, and Dr. Fleming did not walk around the room as he stated he did.

Private Four-Year College

There was substantial evidence of inquiry at the private four-year college and what was seen in the classroom mirrored what the professors believed about inquiry.

Dr. Matthews divided inquiry into two sections; one where the student asks a question and they (the student and professor) investigate the question together, or where the professor asks the question and proceeds to find out the answer. He believes inquiry teaching to be where he asks questions and the students try to find the answer.

When the class was observed, the description of the class given by Dr. Matthews was what was seen. Dr. Matthews asked questions and did not give answers. He answered the students' answers with another question, frequently calling on other students to comment. He required students to defend their answers and was sure to call on each student in the class. Dr. Matthews encouraged students to go to the board and draw pictures of what they were trying to explain. The class observed had 20 students present, making the interactions seen possible.

Dr. Griffith's beliefs on inquiry were obvious in both her classroom and lab. Her belief is that inquiry is a discovery process where the students are discovering the knowledge for themselves. She believes more in guided inquiry instead of total inquiry stating that there is a time constraint to total inquiry.

There was inquiry observed in the classroom. While Dr. Griffith did have a Power Point presentation, there was limited text and more graphic representations of what she was teaching (cell cycle) as well as data from studies. Dr. Griffith asked the students questions, having them discuss the answer with their partners as well as giving an explanation as to why they answered the way they did. Students discussed the answers in class. She called on students' prior knowledge and did not answer their questions but rather asked a question back, leading the student to the correct answer. She incorporated research into the discussion with analysis of data. The labs were inquiry-based as well. Dr. Griffith taught students procedures such as how to use the mass spectroscopy and other equipment as well as graphing techniques and data analysis. As the course progressed, labs got progressively more inquiry-based with student teams designing their own experiments. Labs were four hours and only 14 students were present. Dr. Griffith walked around asking questions, but students were independently working. Copies of labs obtained demonstrated that they were not scripted and allowed the student to design and investigate on his or her own.

Community College

Two of the three professors at the community college demonstrated the use of inquiry in their classrooms and laboratory.

The use of inquiry in Mr. Greer's class/lab mirrored what he said he believed inquiry to be as setting students up in situations so that they can investigate. Mr. Greer did not divide his "time" with the students into a class and lab. The class is a four-credit class that meets for six hours, two are lab hours and four are lecture hours but Mr. Greer does not distinguish between the two. The class meets for two hours and 45 minutes but Mr. Greer never "lectures" for that long. Mr. Greer also does not call the activities lab activities but rather just activities. He taught the student procedures and techniques, and then had them apply those procedures and techniques learned in a new situation.

The way Mr. Greer described his “time” with the students was what was observed. The class was held in a lab room with lab tables that accommodated four students. Mr. Greer spoke for about 30 minutes, asking questions and clarifying answers. He did not answer students but rather used more questioning to guide students to the correct answer and asked students to support their answers. Dr. Greer walked around constantly asking questions, answering student questions with other questions, and giving encouragement. There were 17 students in the class and all were engaged and working cooperatively.

Dr. Barrett’s beliefs on inquiry were evident in her classroom as well. She readily admits that there is more inquiry in the classroom part of her class than the lab with her reasons being safety and time. While she admits that her labs are scripted, she does have some that are not scripted but they are “dry” labs and do not involve chemicals because of the safety issue. The researcher observed a “dry” lab where students were examining the spectrum of different gases. She circulated around the room asking questions and requiring students to support their answers. She did not answer questions directly but asked another question to help students come to an answer on their own. With respect to her class, she feels that she “inquiry guides” rather than inquiry teaches. She does this by using what she calls the “question-answer cycle.” All classes begin with a quiz and then there is a discussion about the quiz. To determine if students understand, she utilizes a thumbs up, thumbs down approach where students do thumbs up indicating they understand or thumbs down indicating more explanation is needed. Dr. Barrett also has students go to the board to work problems. She uses a piece of chalk that she spins; the person the chalk points to is who goes to the board. The student at the board then spins the chalk for the next person to go. The question- answer cycle in her class was evident. She spoke for only 15 to 20 minutes and then would stop to check for understanding, ask questions, and discuss. At one point, she had students act out what she was attempting to teach.

The third professor at the community college, Mrs. Davis, had a vague and unclear definition of inquiry. What the researcher observed in the classroom mirrored what Mrs. Davis felt good teaching was. Her class was lecture-based. She did not use Power Points but rather used overheads with an outline of what she was going to talk about in class. The students had these outlines as well, and Mrs. Davis called them the student notes. She also had overheads of pictures from the book to help during discussion of the anatomy of the kidney as well as drawing pictures on the board to help explain what she was talking about. She asked only three questions and answered them if no students volunteered.

Mrs. Davis's labs also mirrored her view on inquiry. All anatomy and physiology teachers follow the same labs at the same time. When asked if the labs were scripted, she replied, "They have to follow directions." The researcher asked Mrs. Davis if there was a right answer for everything and she answered, "Yes, it's not inquiry based, in other words." The lab observed began with Mrs. Davis lecturing for approximately 30 minutes, describing a case situation which applied to what students were learning about in class. Students had handouts, and the remainder of the lab was for students to examine models of organs and memorize the parts as well as finish their dissection of a fetal pig. There was very little questioning except by students and Mrs. Davis answered them directly.

Question 3: Was there a difference in the beliefs of college science professors between institution types?

There was a difference in the beliefs between institutions with the professors at the research institution holding the view of inquiry as only “full and open” (Brown, et al) while the professors at the private college and community college included many aspects of the inquiry continuum in their view.

Of the professors at the research institution, Dr. Fleming, Dr. Bender, Dr. Branson and Dr. Franklin considered themselves to be researchers first and teaching second. All of them, while enjoying teaching, would rather be able to spend more time on research but realized that teaching paid the bills. Dr. Fleming commented that he wished he could teach one semester and then do research one semester; he felt he did neither well when he had to do both during the same semester. Dr. Conroy and Dr. Wilson were both hired as lecturers and did not participate in research but wanted to. Dr. Wilson was leaving the university to teach at a small, liberal arts school where class sizes were smaller and he would be able to do research. While Dr. Conroy’s contract stipulated that he do not do research, he did help students do research on his own time. This view of themselves as researchers was mirrored in their belief of inquiry as “full and open” and what is done by scientists. All of them had a deficit view of students and inquiry in that they felt students in introductory classes were not able to do inquiry because they did not have the skills needed; inquiry was only for those upper level and graduate students. All viewed class size as a barrier to inquiry as well.

Dr. Fenton, Dr. Griffith, and Dr. Matthews from the small, private four year college, viewed their role as teacher. While Dr. Griffith no longer did research in microbiology, she was active in research in biology education. Dr. Fenton and Dr. Matthews did research but only in the summer and only with students who had signed up to do the summer research program.

The professors at the community college, Mr. Greer, Dr. Barrett, and Mrs. Davis, all viewed themselves as teachers and did no research. Their primary emphasis was the student.

Question 4: Was there a difference in the beliefs of college science professors between the disciplines of life science and physical science?

There was no difference seen between the disciplines of life science and physical science with the major difference being between institution types. The professors interviewed at the large research institution consisted of three physical science teachers (physics, astronomy) and three life sciences (biology). The professors at the small, private four-year college included two physical science teachers (physics) and one life science (biology) while the professors at the community college included one physical science professor (chemistry) and two life science professors (biology, anatomy and physiology).

Limitations

There were several limitations to this study. The first was limited observations. There were twelve professors in this study, and all were observed in the class one time as well as in the lab one time if there was a laboratory component. Observation of a class only one time did not allow the researcher to get a full picture of what was happening in the classroom or lab. There may have been evidence of inquiry in other classes on other days that was not observed. It was felt, however, that the use of the questionnaire and interview in triangulating the data, helped to paint a picture of what was happening in the classroom and laboratory situations.

Time was the second limiting factor. Ideally, it would have been beneficial if more than one class and lab could have been observed, but the time commitment in doing so was not possible. Further research could focus on observations of classes and laboratory across semesters. This research would provide a clearer picture as to the level of inquiry in the classroom.

An additional limiting factor was that some questionnaires were given prior to observations while other questionnaires were given after observations. Participants who had already seen the questionnaire may have changed their teaching in some way that would not have occurred had the questionnaire been given after observations.

Recommendations

It would seem that in order for inquiry to be utilized as a teaching method as well as a way for students to learn, an agreement on what inquiry is and an understanding of how to carry it out in the classroom is needed. Currently there seems to be three perspectives; that which scientists do, that which teachers of K-16 do and that which students do. There is also a great disconnect between those in education who teach science and those in science who teach science. Teachers who have been taught to do inquiry as part of their education courses are better prepared to incorporate those strategies into their classrooms and thus improve student learning;

while those professors of science who have had no education on inquiry teaching and learning, view inquiry as that which they do during their research, leaving students out of the picture. This is evidenced by research done by The Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) Program at Arizona State University (Adamson, Banks, Burtch, Cox, Judson, Turley, Benford & Lawson, 2003).

The ACEPT Program is a reform effort funded by the National Science Foundation. Through this program, summer programs for professors of college science and mathematics were held where the faculty learned about instructional reforms centering on the use of inquiry in the classroom. It was shown in these initial studies that when college faculty implemented these reform efforts, there was a positive correlation with student achievement (Falconer, Joshua, Wyckoff, & Sawada, 2001; Lawson, Benford, Bloom, Carlson, Falconer, Hestenes, Judson, Piburn, Sawada, Turley, & Wyckoff, 2002).

In the 2003 (Adamson, et al.) study, the working hypothesis was that teachers teach how they were taught. With this in mind, the principles of effective teaching from Science for All Americans, AAAS (1989) (see table 4) were utilized to introduce participants to inquiry teaching methods. Participants included secondary biology teachers who had been enrolled in a college science class taught by college science professors who had attended an ACEPT summer workshop. There were three groups of biology teachers; those teachers who had not been enrolled in college science courses taught by ACEPT faculty and those teachers who had been enrolled. The group of teachers enrolled in an ACEPT class was further divided into two groups: those enrolled in only one ACEPT class, and those enrolled in two or more ACEPT classes.

Student achievement of these biology teachers' classes was assessed. It was found that achievement of those students instructed by teachers taught by ACEPT college faculty were higher than those students taught by teachers who had not been enrolled in an ACEPT college classroom.

Table 4: Principles of Effective Teaching (AAAS, 1989)

Teaching should be consistent with the nature of scientific inquiry: Start with questions about nature; engage students actively; concentrate on the collection and use of evidence; provide historical perspectives; insist on clear expression; use a team approach; do not separate knowing from finding out; deemphasize the memorization of technical vocabulary
Teaching should reflect scientific values: Welcome curiosity; reward creativity; encourage a spirit of healthy questioning; avoid dogmatism; promote aesthetic responses
Teaching should aim to counteract learning anxieties: Build on success; provide abundant experience in using tools; support the role of girls, women, and minorities in science; emphasize group learning
Science teaching should extend beyond the school
Teaching should take its time

These findings, while needing more research and support, clearly indicate the need for professional development in the area of inquiry teaching at the college level. If science reform is to be effective, all levels of science teaching must be involved.

In the present study, many of the professors at the large research institution enjoyed teaching and knew that the way they were teaching was not effective. They wanted to do a better job but did not know how. When the researcher asked about what his preference would be with respect to teaching versus research, Dr. Fleming felt that he would be able to do a much better job at both teaching and research if he only had to concentrate on one at time, possibly teaching one semester and doing research one semester.

Dr. Branson also commented that he enjoyed teaching and would not give it up. When asked if he would give it up he replied that he would not want to give up teaching and do 100% research.

Dr. Conroy was hired as a lecturer and enjoys the teaching. When asked about getting his PhD, he commented that he enjoyed the teaching better than the research. He feels that he should be better at teaching.

Dr. Wilson has not taken any education courses but would like to, and Dr. Franklin, who co-teaches the Biology course with Dr. Wilson, also enjoyed teaching but felt it took away from his research.

The only professor at the large research institution who had no desire to change or improve his teaching was Dr. Bender. He had retired from another university to come to his current position. He commented, “Yeah, right, I am an old fart. I am on in my years so I don’t put a lot of effort into trying to teach better. I figure I have already done that.”

The professors at the small, private four-year college and the community college viewed teaching as their primary role and were actively involved in activities to improve their teaching; education was important to them. The small, private college had sponsored programs that encouraged cross curricular involvement, and the community college offered courses to assist in professors improving their teaching.

It would seem that programs such as the ACEPT Program would be beneficial to those professors of science who have a desire to improve their teaching but are unaware of educational research defining best teaching practices. Further research into programs such as ACEPT would be beneficial in improving student learning.

If science teaching is to improve across all grade levels, K to college, reform efforts need to include the science professors at the college level. It was evident from this current study that there is a great divide in effective science teaching between the community college, small, private four year college and the large, research institution. One reason is the way the role of professor is viewed. While those professors at the community college and small, private four year college viewed their roles as teacher and sought out teaching positions where teaching was the focus, those professors at the large, research institution viewed teaching as secondary behind their research; teaching was a way to pay the bills.

While the professors at the large, research institution viewed teaching as secondary, they expressed that they found teaching enjoyable and would like to be able to improve but did not know how to do this. Programs such as ACCEPT (Adamson, Banks, Burtch, Cox, Judson, Turley, Benford & Lawson, 2003) would help to improve the teaching of science at the college level. It has also been suggested that universities should employ those who do research and those who teach, keeping the roles separate so that both research and teaching are done well (Scott, 1991: Weisner, 1992; Westergard, 1992). It would seem that financial concerns also assist in keeping inquiry from some college classrooms as enrollment in introductory science classes can be large (500 in the current study) and laboratory components were cut.

Other research questions become apparent when examining the results of this study. They include but are not limited to; (1) How do beliefs of college science professors affect instructional choices? (2) Do beliefs of college science professors change over time and if so, what are the causes of these changes? (3) How can we improve our methods of research into beliefs to help better express and understand the relationship between beliefs and practice? (4) What type of professional development programs can be developed to assist college professors in incorporating aspects of inquiry in the classroom?

It is crucial that more research be undertaken to examine the connection between college science teachers stated beliefs and teaching practices in order that an understanding of how college professors learn to teach becomes clear. This understanding will benefit future teachers enrolled in the undergraduate science courses. As the call for reform in science education continues and research continues to support the benefits of inquiry teaching, classroom teachers must be taught in the manner in which they are expected to teach. It then becomes the responsibility of college science teachers to assume this role.

APPENDIX A: APPROVAL OF EXEMPT HUMAN RESEARCH

lo University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Janet Bisogno**

Date: **October 21, 2009**

Dear Researcher:

On 10/21/2009, the IRB approved the following activity as human participant research that is exempt from regulation:

Type of Review:	Initial Review
Project Title:	College Science Teachers' Inquiry Beliefs and Practices in the Science Classroom
Investigator:	Janet Bisogno
IRB Number:	SBE-09-06426
Funding Agency:	None

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB.

Please submit the appropriate approvals from institutions where you plan to conduct your research when they become available.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Joseph Bielitzki, DVM, UCF IRB Chair, this letter is signed by:

Signature applied by Janice Turchin on 10/21/2009 02:31:43 PM EDT

Janice M. Turchin

IRB Coordinator

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APPENDIX B: QUESTIONNAIRE AND OBSERVATION TOOL

Using the essential features of classroom inquiry and considering your lecture class and laboratory class, in general and on average, where would you place yourself on the continuum?

1. Question asking **The learner engages in scientifically oriented questions**	Student engages in question provided by teacher, materials, or other source 0 1	Student sharpens or clarifies question provided by teacher, materials, or other source 2 3	The student selects among questions, poses new questions 4	The student poses the question 5
2. Evidence **The learner gives priority to evidence in responding to questions**	Student is given data and told how to analyze 0 1	Student is given data and asked to analyze 2 3	Student is directed to collect certain evidence 4	Student determines what constitutes evidence and collects it 5

3. Evidence to explanation **The learner formulates explanations from evidence**	Student is provided with evidence 0 1	Student is given possible ways to use evidence to formulate explanation 2 3	Student is guided in the process of formulating explanations from evidence 4	Student formulates explanation after summarizing evidence 5
4. Connecting evidence to theory **The learner connects explanations to scientific knowledge**	Students are given possible connections 0 1	Students are directed towards areas and sources of scientific knowledge 2 3	Students independently examine other resources and forms the links to explanation 4 5	
5. Communication and justification of explanations **The learner communicates and justifies explanations**	The student is given steps and procedures for communication 0 1	The student is provided broad guidelines to sharpen communication 2 3	The student is coached in the development of communication 4	The student forms reasonable and logical arguments to communicate explanations 5

APPENDIX C: QUESTIONS FOR INTERVIEW

RATIONALE	**QUESTION**	**PRODUCT**
To provide background	How did you get your start teaching college science?	Description of teacher and educational background.
	Have you taken any education courses? (If so, what?)	
	What is most important about what you teach? (Why do you feel that way?)	
	What is most important for students to learn?	
	How is the course designed to help them learn that?	
	What activities help students learn?	
To determine how teachers' view students and their learning	Where do you think learning primarily takes place, inside the classroom or outside the classroom? Why?	Understanding of their view on students and student learning.
	How do you feel students learn?	
	How has your teaching changed with regards to this course?	
	How have you tried to improve your ability to teach this course?	
	Can you describe your typical grade distribution? Why do you	

	think that is? How do you feel about this?	
To determine how the teacher views him/herself	In a week, how do you divide your time?	Understanding of how the teacher views their role: administrator, researcher or teacher.
	Do any of your classes have a laboratory component?	
To begin to determine if inquiry is part of the laboratory situation.	Can you describe a typical lab?	Knowledge and use of inquiry.
	How would you evaluate your labs? Do students enjoy them? Do you develop the labs?	Understand the teacher's involvement in the lab situation.
To understand the teacher's meaning of inquiry	What does inquiry teaching look like?	Understanding of inquiry.
To begin to understand what the teachers see as barriers to inquiry teaching	What are some of the factors that influence the way you design your class and labs.	Beliefs on inquiry.
	Can you give me a description of your class?	

APPENDIX D: GRAPHS

Graphs were comparisons of the scores self-reported by the participants and the researcher as to use of inquiry in the classroom and laboratory. The five essential features of inquiry were used as a template (See Appendix B). The graphs are divided into classroom and laboratory.

Classroom Graphs

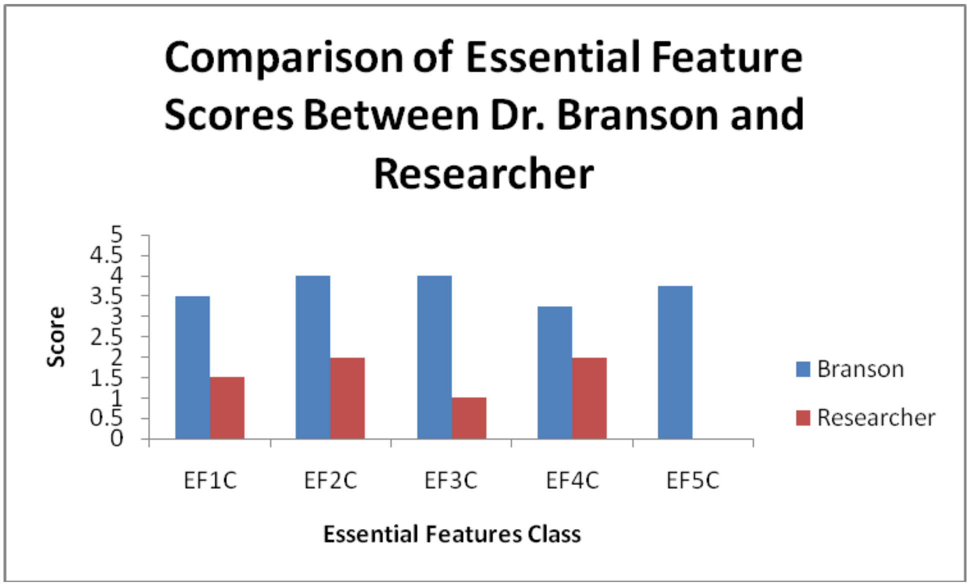

Figure 3: Comparison of Scores between Researcher and Dr. Branson

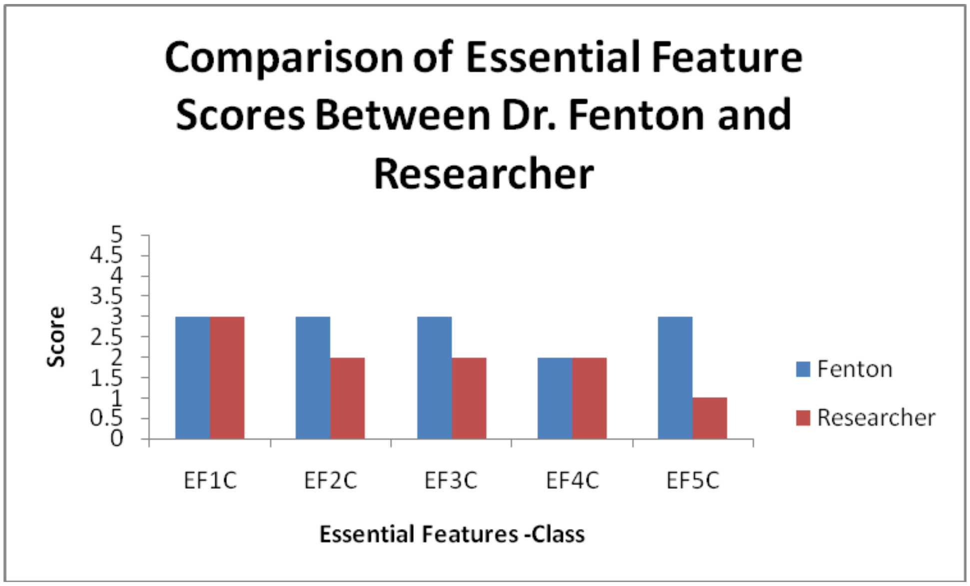

Figure 4: Comparison of Scores between Researcher and Dr. Fenton

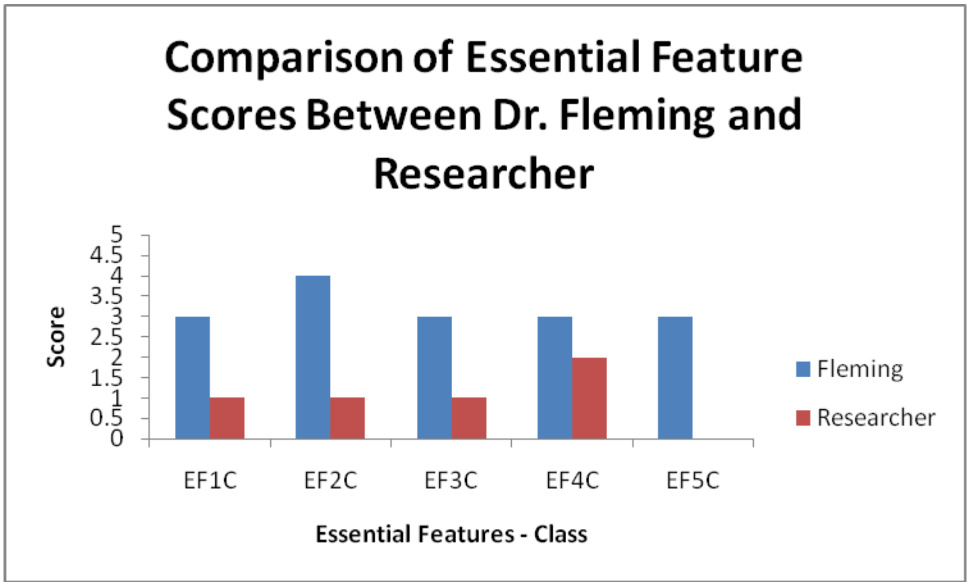

Figure 5: Comparison of Scores between Researcher and Dr. Fleming

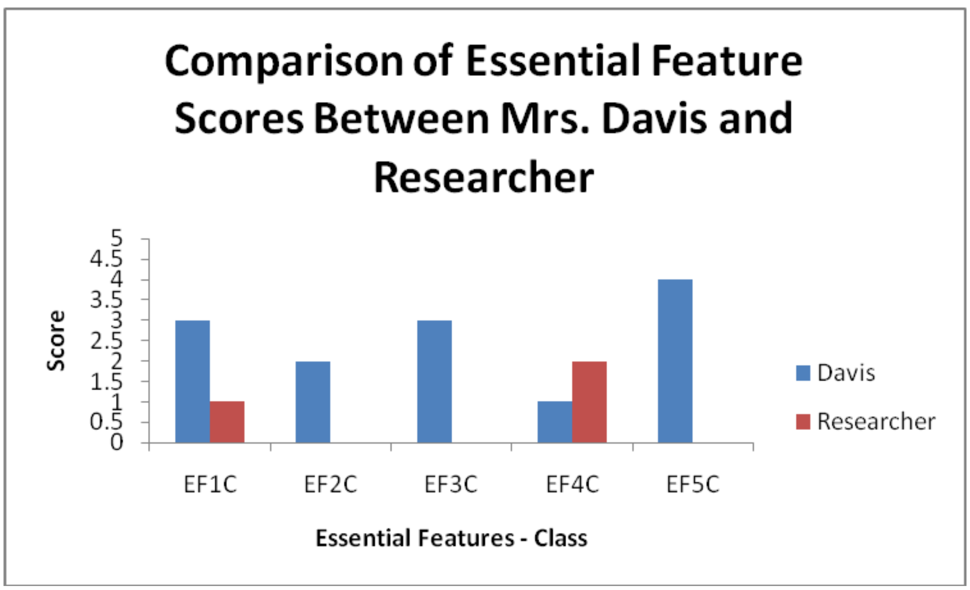

Figure 6: Comparison of Scores between Researcher and Mrs. Davis

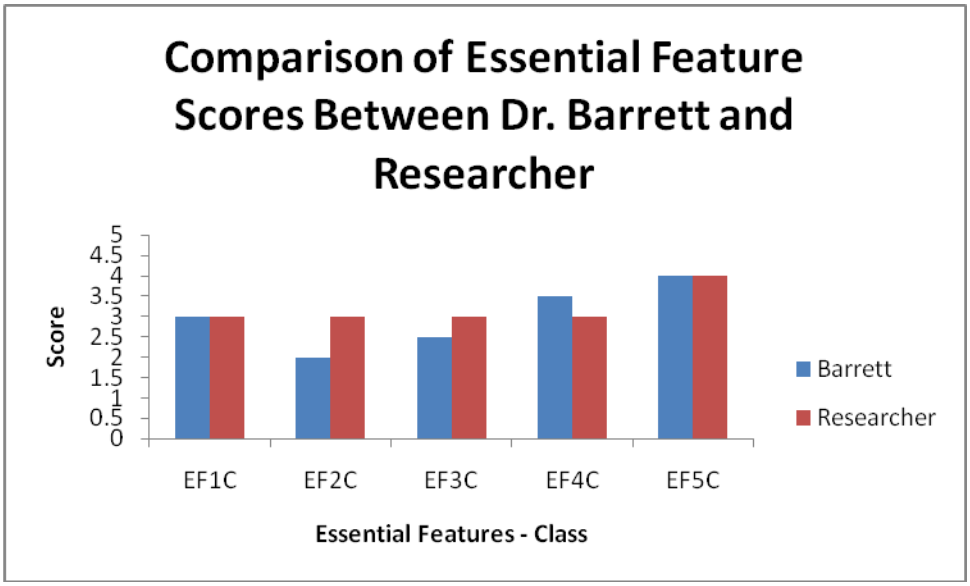

Figure 7: Comparison of Scores between Researcher and Dr. Barrett

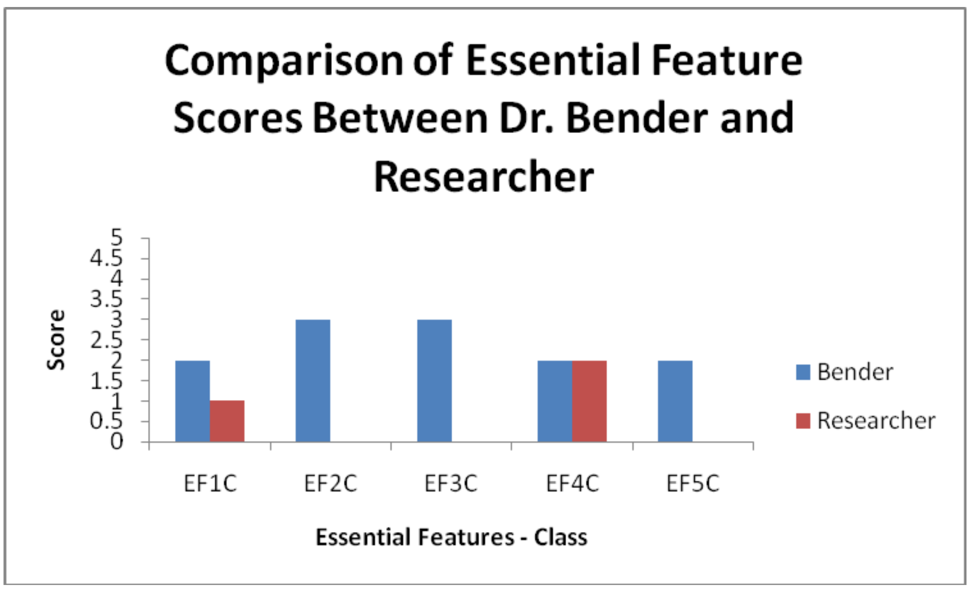

Figure 8: Comparison of Scores between Researcher and Dr. Bender

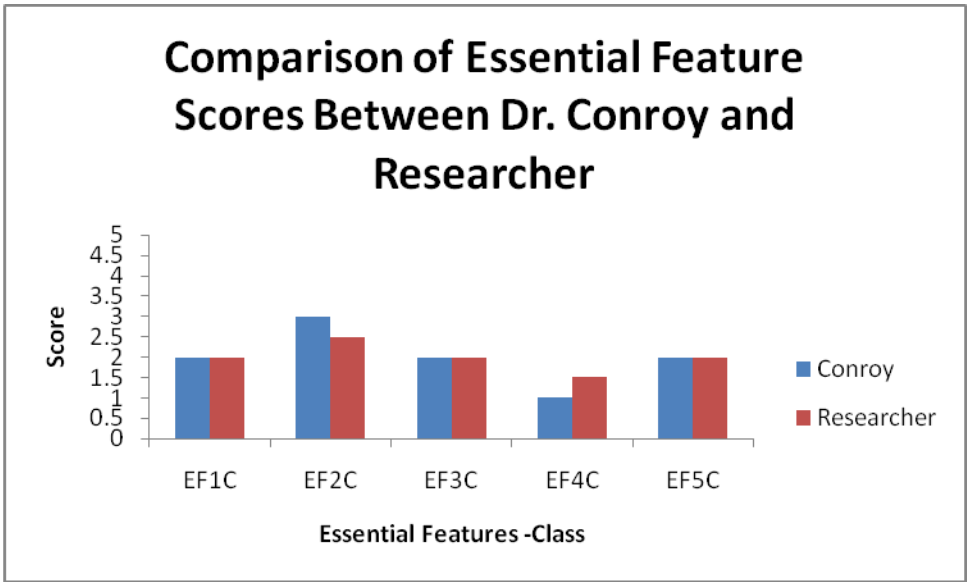

Figure 9: Comparison of Scores between Researcher and Dr. Conroy

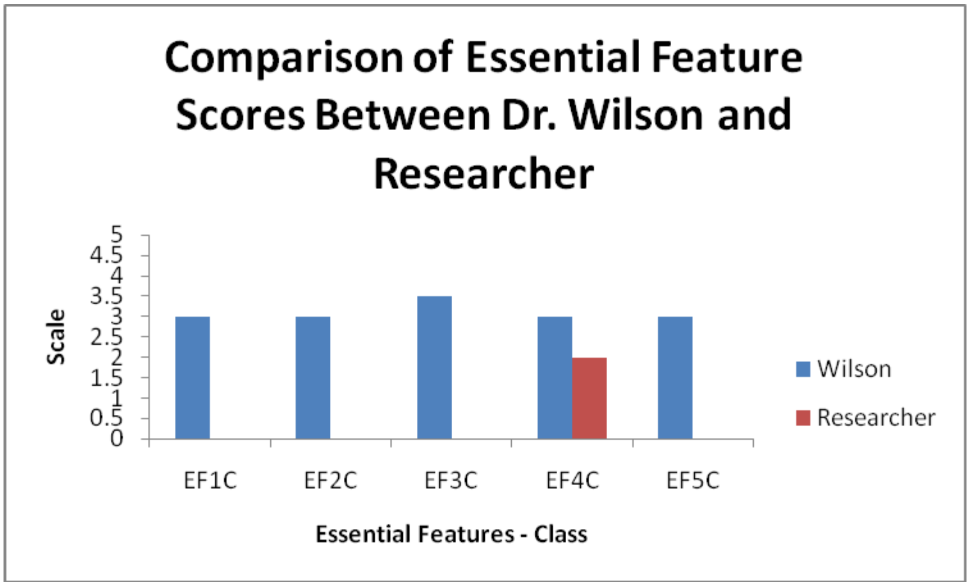

Figure 10: Comparison of Scores between Researcher and Dr. Wilson

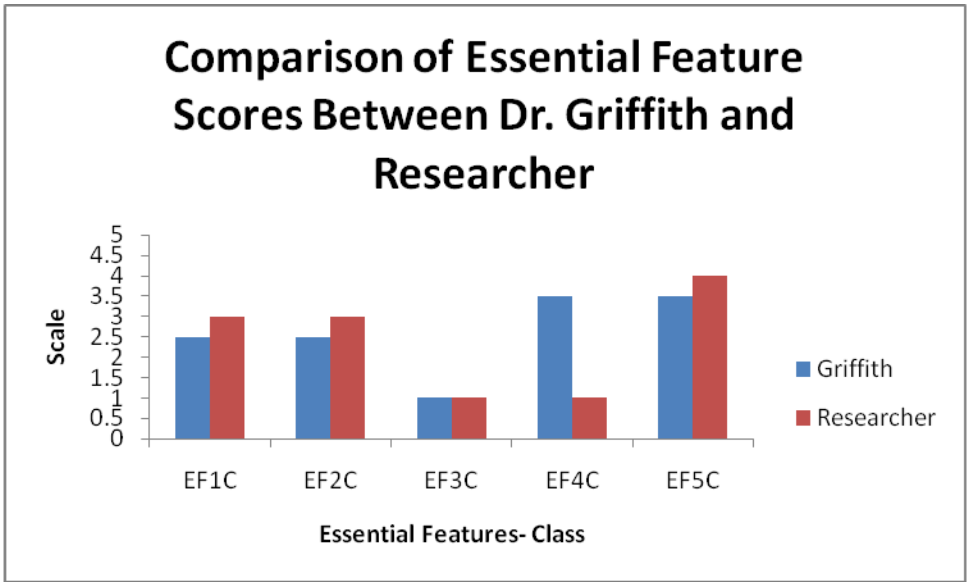

Figure 11: Comparison of Scores between Researcher and Dr. Griffith

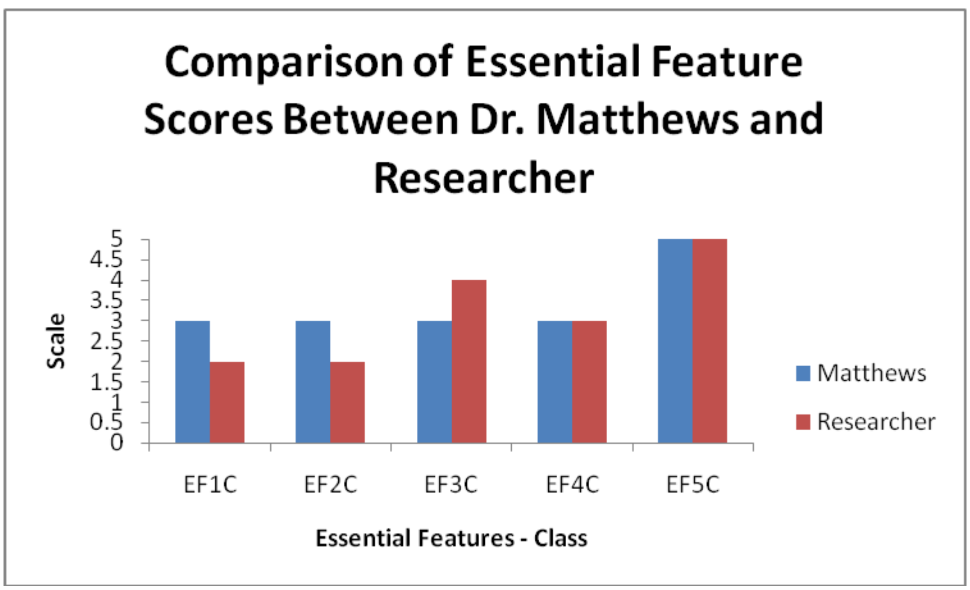

Figure 12: Comparison of Scores between Researcher and Dr. Matthews

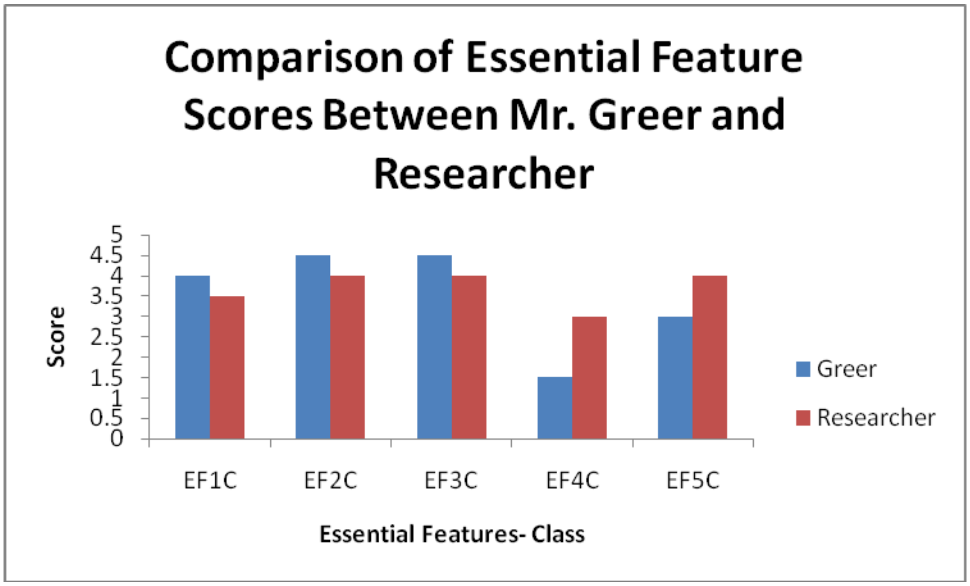

Figure 13: Comparison of Scores between Researcher and Mr. Greer

Laboratory Graphs

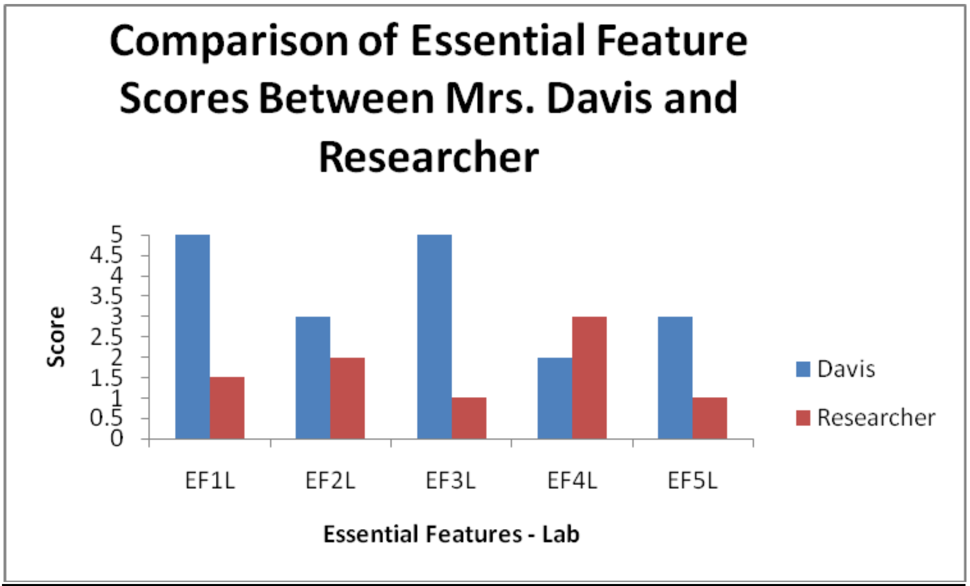

Figure 14: Comparison of Scores between Researcher and Mrs. Davis

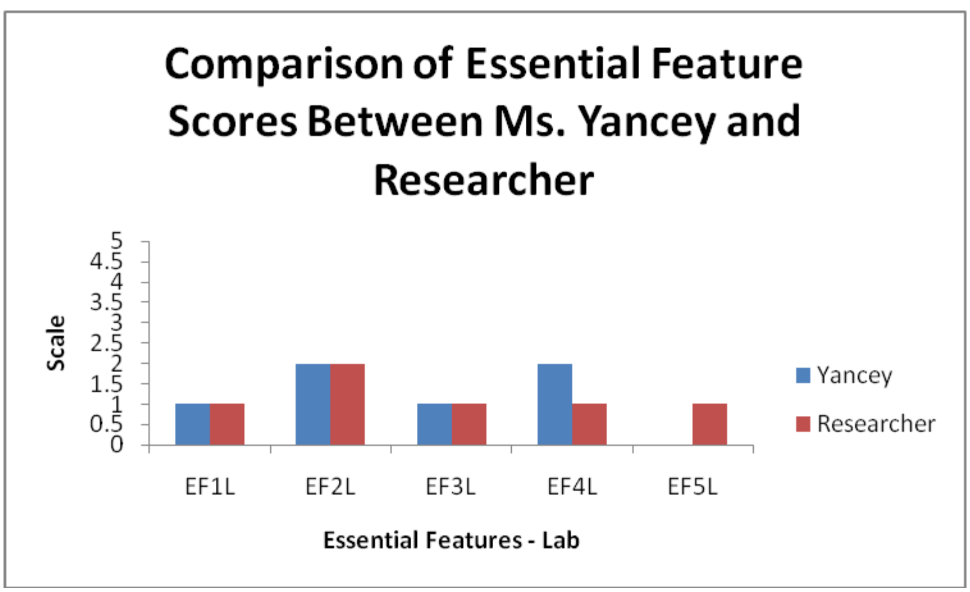

Figure 15: Comparison of Scores between Researcher and Ms. Yancey

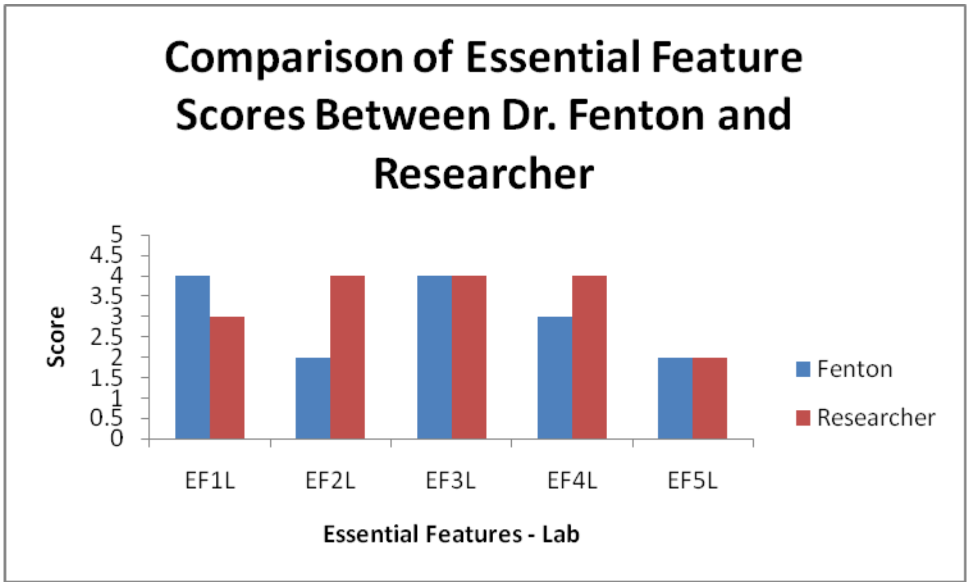

Figure 16: Comparison of Scores between Researcher and Dr. Fenton

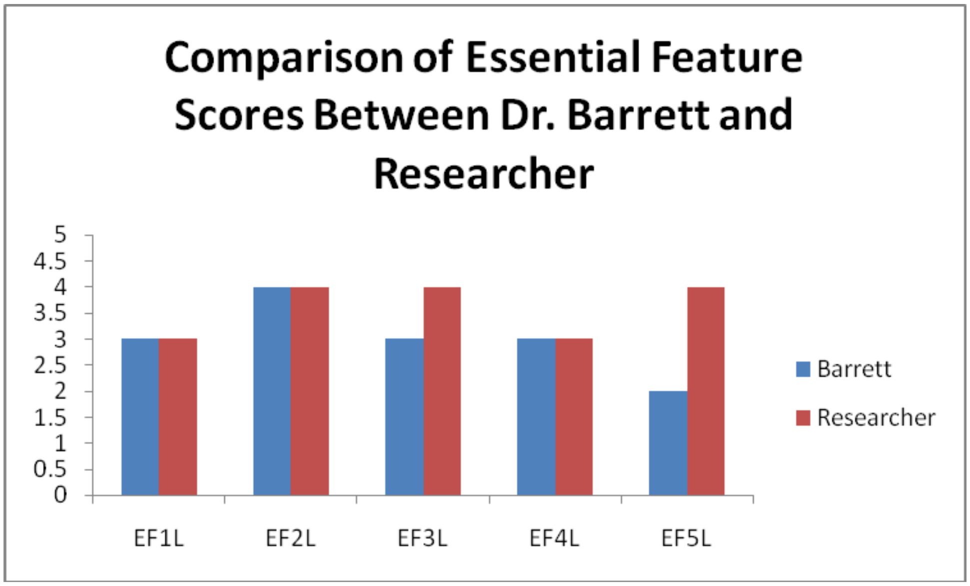

Figure 17: Comparison of Scores between Researcher and Dr. Barrett

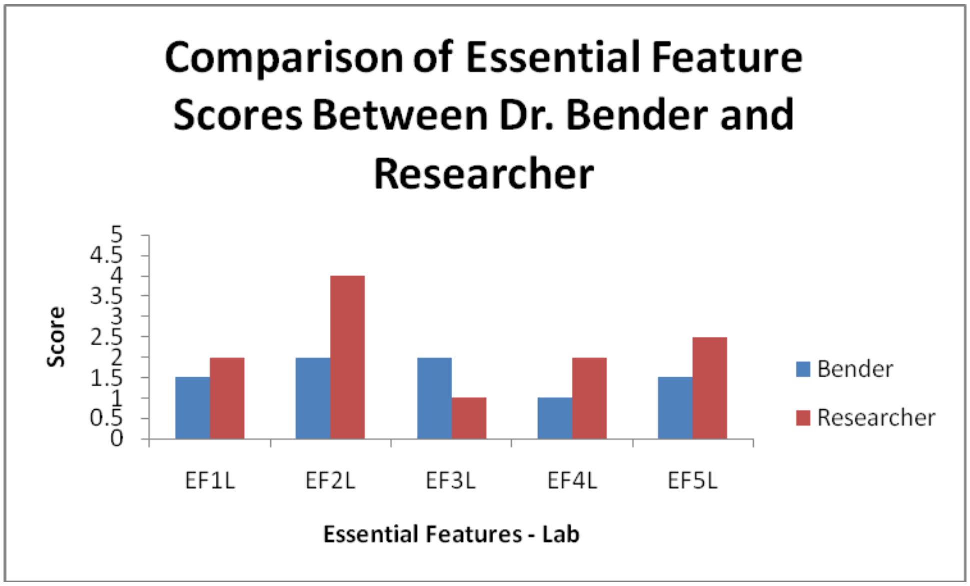

Figure 18: Comparison of Scores between Researcher and Dr. Bender

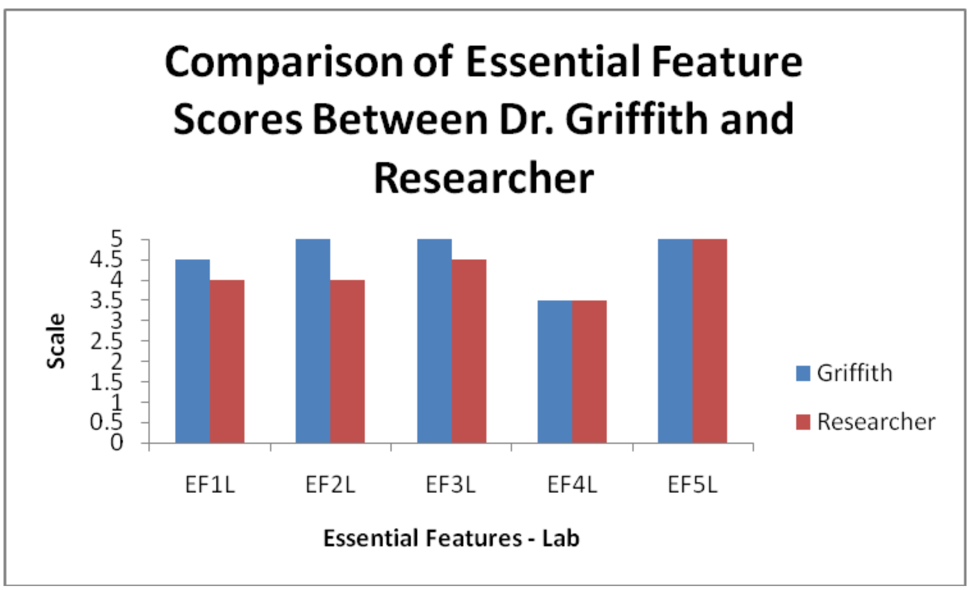

Figure 19: Comparison of Scores between Researcher and Dr. Griffith

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