

TEACHER'S LEVEL OF INQUIRY-BASED CHEMISTRY
AND STUDENT'S ATTITUDE ABOUT
HIGH SCHOOL CHEMISTRY

by

CHARLES E. HOLLOWAY, JR.

JAMIE D. MILLS, COMMITTEE CHAIR

BECKY ATKINSON
JOHN DANTZLER
DEE GOLDSTON
STACY SURMAN

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ABSTRACT

With the push for more student-centered, inquiry-based instruction in the forefront of science education, especially with the implementation of the Next Generation Science Standards (NGSS), it is important to understand how inquiry-based instruction in chemistry affects students and teachers alike. Chemistry is important in the field of science because it is central to understanding all of the branches of science (Brown & Lemay, 1977). Since chemistry was first introduced into the secondary classroom, little has changed with the instructional practices since the early 19th century (Cooper, 2010; Johnstone, 2009; Shepard & Robbins, 2005). The National Science Foundation (1996) and the Next Generation Science Standards (2013) as well as numerous researchers want to move away from lecture-type learning and cookbook-type labs to a place of inquiry-based teaching and learning.

This study explored how a teacher's attitude of chemistry is related to the use of inquiry-based instruction. This study was designed to provide insight on the experience of a chemistry teacher and explore factors that affect a high school chemistry teacher's willingness and ability to use the inquiry-based approach to instruction in their classroom. The results were similar to that of a Cheung (2009) study of chemistry teachers in Hong Kong. Teachers reported that time, resources, and professional development were important when deciding whether or not to use the 5E model of inquiry-based instruction.

Teachers self-assessed their practice and were placed into groups of high, medium, or low inquiry-based teachers based on their self-assessment. Students were asked questions about their attitude toward chemistry. The student's score on the attitude survey and the teacher's level

of inquiry-based instruction were not found to have statically significant relationship. However, the student's attitude toward chemistry provided insight to how a secondary student views chemistry instruction.

Teachers must become comfortable with this method of teaching chemistry and understand that the old model of lecturing in chemistry is not the model needed to enhance chemistry instruction. With the push to inquiry-based science instruction from the NGSS, it is important now more than ever to understand inquiry-based instruction in chemistry.

DEDICATION

This dissertation is dedicated to two people: my sister Carla Holloway and my mother Brenda Holloway. My sister lost her battle with ovarian cancer while writing this document. She was so brave in her fight with cancer and whenever I wanted to give up I remembered her bravery and courage.

I also dedicate this to my mother. She listened to me work on this document for what seems like an eternity. She was a constant source of support during this entire process. My mom has always believed in me and her encouragement and support was so need and appreciated during this process. She stood by me the entire way as this document evolved into what it is today.

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CHAPTER I:
INTRODUCTION

Background

The teaching and learning of chemistry in American classrooms was introduced in the early 19th century (Sheppard & Robbins, 2005). It was right around that time that many cutting-edge discoveries in chemistry were being reported; this time period was an exciting time for the field of chemistry. Chemistry continues to be an integral part of the secondary school curriculum. Chemistry is often referred to as the central science because of its role in connecting the physical sciences with the life sciences and applied sciences such as engineering and medicine (Brown & LeMay, 1977). Balaban and Klein (2006) have more recently proposed a diagram showing partial ordering of sciences in which chemistry may be argued as “the central science” since it provides a significant degree of branching to all other disciplines of science.

By the late nineteenth century, chemistry was necessary for admittance to college. It was not until the middle of the twentieth century that the study of chemistry really became a popular field of study particularly in the 1960s in response to the perceived need for more robust and rigorous technical education (Cooper, 2010) and the need to compete with other countries for scientific supremacy (Johnstone, 2009).

The manner in which chemistry is taught has not changed drastically since the nineteenth century. Traditionally, lecture style teaching is the main mode of instruction for chemistry classes (Sheppard & Robbins, 2005) with laboratories and demonstrations added into the curriculum in the latter part of the nineteenth century. In 1996, the National Science Foundation published a recommendation for reform in science education and at the center of this reform was inquiry-based science instruction. Instead of sitting in a classroom where lecture is the main mode of instruction, inquiry-based teaching and learning is the process by which students are actively engaged in the learning process (National Science Foundation, 1996). Students must take ownership in their learning when being taught through inquiry-based techniques. Inquiry-

based instruction requires both students and the teacher to take a new approach to teaching and learning.

Haury and Rillero (1994) believe that all science instruction needs to consist of direct physical manipulation of objects, equipment, and materials to be as successful as a science student. Deep understanding of most science concepts comes with inquiry-based instruction that requires students to investigate the nature of science. Important process skills such as recording data, communicating, and measuring can be seen in traditional-based instructions; however, the higher level processing skills of predicting, inferring, hypothesizing, experimenting, and identifying and controlling variables can only truly occur through inquiry-based experiences (Mastropieri & Scruggs, 1994).

Inquiry Defined

Inquiry is a difficult word to define; policy makers, educators, and researchers do not have a common definition of inquiry. The National Science Foundation (1996) has defined inquiry instruction as

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)

Inquiry is not a new concept to the field of teaching. In fact, inquiry is a term that has been central to reform efforts, certainly those included in the 1996 National Science Education Standards (NSES). Inquiry was a term used to define what science is as well as how science should be taught (Brown, 2012). However, the term inquiry goes back much further to the early 1900s and John Dewey.

The Learning Cycle

John Dewey, who was a science teacher himself, recommended the inclusion of inquiry into K–12 science curriculum (Barrow, 2006). Dewey believed that an inquiry-instructional approach is based on experience and requires reflective thinking; simply doing hands-on activities in science is not enough to be considered inquiry-based (Bybee, 2006). In the 1950s, research into Dewey's ideas produced the learning cycle. The learning cycle was created by

Karplus (1962) and fully conceptualized by Atkin and Karplus (1962) as “guided discovery.” In 1967, two researchers Karplus and Thier, coined the learning cycle that consisted of three phases: exploration, invention, and discovery (Bybee et al., 2006; Barman, 1993). The learning cycle was used in the Science Curriculum Improvement Study (SCIS) (1967) and proved to be successful in different educational settings (Bybee et al., 2006). It was in the 1980s when the Biological Sciences Curriculum Study (BSCS) (1985) added two new stages to the beginning and end of learning cycle: engage and evaluation (Bybee et al., 2006). This is now known as the 5E Learning Cycle.

5E Learning Cycle

The National Science Foundation (1996) as well as the Alabama State Department of Education (2005) has adopted the inquiry-based instruction 5E Learning Cycle modified by Bybee and Trowbridge in the late 1980s (Goldston, Dantzler, Day, & Webb, 2013). This cycle helps to fine tune how the process of inquiry-based learning can take place in lesson and labs in the science classroom. Each element of the five “E’s” is carefully crafted to promote student construction of knowledge. These elements consist of

1. Engagement—The purpose is to elicit the learner's prior ideas about the topic and evoke interest. Various techniques can be used to ascertain prior knowledge. For example, one might use one of the following: asking the learner to make predictions, asking open-ended questions, skits, and discussions;
2. Exploration—Provide a common base of activities in which current concepts are identified and conceptual change is challenged if the student has misconceptions. This phase should be student-centered and may contain hands-on/ minds-on activities, including student questions, use of processing skills, and include a method of formative assessment for student learning;
3. Explanation— This phase involves discussions emerging from student’s experiences during the exploration. There is a focus on a particular aspect of engagement to provide opportunities to demonstrate conceptual understanding, process skills, or behaviors. This phase also provides an opportunity for teachers to directly introduce a concept, process, or skill to guide students toward a deeper understanding;
4. Elaboration—teacher provides learning activities that provide opportunities for students to apply and extend newly acquired concepts/skills into different or authentic settings. This is a place to reinforce conceptual understanding and skills

within a different context to develop deeper and broader understanding and application; and

5. Evaluation—Teachers assess students understanding and evaluates student progress toward educational objectives. (Bybee et al., 2006; Goldston, Dantzler, Day, & Webb, 2013)

The use of the 5E model in the classroom is an important part of the ALSDE mission for Science. However, it has been documented that the use of the learning cycle models are underutilized as an instructional planning tool due to the lack of understanding and practice with the approach (Settlage, 2000).

Next Generation Science Standards

In July 2011, the National Research Council (NRC) released *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which identifies key scientific ideas and practices all students should learn by the end of high school. The framework serves as the foundation for new K–12 science education standards that will replace the old NSF standards developed in the 1990s (Pratt, 2012). The framework served as a guide to develop the Next Generation Science Standards (NGSS) (2013). The overall goal of the NGSS is to help all learners in our nation develop an understanding of science and engineering that is needed to live a successful, informed, and productive life. Additionally, NGSS hopes that students will gain the science knowledge that will help them sustain the planet for the future generations (Krajcik, 2013).

The framework (2011) and NGSS (2013) have emphasized inquiry-based instruction but in a new light. Rather than equating “scientific practice” with “inquiry” as other standards tend to do, they recognize a full range of key inquiry, application, and communication practices (Anderson, 2013). To help ease some of the confusion around the word inquiry, the NGSS has chosen to replace “inquiry” with “practices.” The team responsible has chosen to avoid the term

since so few seemed to know its meaning and use associated with current reforms (Brown, 2012). Nevertheless, since inquiry was used to drive the new standards of NGSS it remains important to have an understanding how inquiry-based instruction should be utilized in the science classroom. Based on how other researchers have used the words *inquiry*, *inquiry-based instruction*, or *practices*, the three terms will be used synonymously throughout this document describing the same concepts.

Teachers and Inquiry-based Instruction

Teaching and learning in the inquiry mode of instruction in science remains difficult for both teachers and students alike (Anderson, 2002; Brown, 2012; Colburn, 2000). Reasons why inquiry is not commonplace include the following: 1) confusion about the meaning of inquiry, 2) beliefs that inquiry only works with high ability students, 3) unpreparedness on the part of the teacher, 4) views that inquiry-based teaching is difficult to manage, and 5) an allegiance to teaching facts (Colburn, 2000).

Teachers have to be open to change in order to be a good teacher of inquiry. Anderson (1996) reported three main problems when a teacher or school is trying to implement inquiry-based instruction in the classroom: technical problems, political problems, and cultural problems. Technical problems included limited teaching abilities, prior commitments (for example, to a textbook), the challenges of assessment, difficulties of group work, the challenges of new teacher roles, the challenges of new student roles, and inadequate in-service education. Political problems included limited in-service education (i.e., not sustained for a sufficient number of years), parental resistance, resistance from principals and superintendents, unresolved conflicts among teachers, lack of resources, and differing judgments about justice and fairness. Cultural problems were identified as the most important because beliefs and values are central (Anderson,

1996). Cultural problems may include textbook issues, views of assessment, and the “preparation ethic” (i.e., an overriding commitment to “coverage” because of a perceived need to prepare students for the next level of schooling) (Anderson, 1996).

Meaningful and effective professional development may enable teachers to understand the true meaning of inquiry (Luft, 2001). Even the best of professional development may not aid teachers in the full understanding of inquiry style of teaching (Sawada, Piburn, Judson, Turley, Falconer, & Russell, 2002; Luft, 2001). Inquiry-based teaching is not the way most educators were taught when they were a student. Rushton, Lotter and Singer (2011) reported that teachers with traditional, lecture-style chemistry lessons are less likely and less interested in learning about inquiry and how to implement inquiry in the science classroom. Long-term and comprehensive inquiry-based professional development is a requirement for the success of an inquiry-based teacher (National Science Education Standards, 2000).

Research on Inquiry-based Instruction and Attitudes Toward Science

Teacher’s Attitudes toward Science

Inquiry-based teaching and learning is a constructivist approach to teaching and learning that can result in positive experiences for students. Rubeck and Enochs (1991) have asserted that teachers who are capable of constructivist formats tend to be those who have positive attitudes toward science and science teaching and are effective teachers. Gibson and Chase (2002) reported that inquiry style learning is what holds the attention of the students in middle and high school. Teachers who feel capable of teaching inquiry-based science lessons tend to be those who have positive attitudes toward science and science teaching and are effective teachers of science and have students who are successful in learning (Rubeck & Enochs, 1991). Finson, Perdson, and Thomas (2006) as well as Rubeck and Enochs (1991) both have concluded that a teacher who is capable of constructivist formats tend to be those who have positive attitudes toward science and as a result the students also have better attitudes of science.

Student's Attitude toward Science

Attitudes toward science can be defined as “favorable or unfavorable feelings about science as a school subject” (Morrell & Lederman, 1998, p. 41). Simpson and Oliver (1985) have found that a student's attitude toward science steadily declines with each year of school completed. However, Gibson and Chase (2002) found that students who were taught with inquiry-based instruction were more interested than those who are taught with more traditional methods that included lectures, note taking, and lab demonstrations rather than student directed lab explorations. Students indicated in interviews that they preferred having the opportunity to be more in control of their learning and laboratory exercises. Lawton (1997) reported that students who are exposed to an inquiry approach to science expressed a more positive attitude to learning in all areas, show increased enjoyment of school, and have increased skill proficiency in many areas, including independent thinking abilities, than those students taught in the traditional manner. All of these findings suggest that when science is taught using an inquiry-based instruction, students remain interested and become motivated to put more effort into their studies.

One important factor that might contribute to a student's attitude about science in general has to do with how much science instruction a student receives. If a student is receiving little, if any, science instruction, it is difficult to get excited about science. Research indicates that early exposure to science in elementary and middle school plays an important role in a student's interest in science (Tai et al., 2006).

The impact of a student's attitude toward science is incredibly important (Allum, Sturgis, Tabourazi, & Smith, 2008; Cheung, 2009). It has been shown that individuals who are scientifically literate have more positive attitudes to science in general. Limiting the number of hours a student receives science instruction can have an impact in their attitudes about science (Allum et al., 2008). Research indicates that nearly 50% of students may lose interest in science by the third grade (Weinburgh, 1998). Participation in science is also being affected as the number of students preparing for a science-related career is on the decline (Chapman, 1997). Although the state of Alabama course of study for K-12 science is based around the 5E model of

inquiry, it is important to note that not all students may be receiving adequate inquiry-based science instruction or science instruction at all. A survey by the National Science Teachers Association (NSTA) (2012) reports that 67.8% of respondents said the No Child Left Behind Act had hurt their schools. The 2005 State of Science Standards document suggests that the current focus on reading and mathematics testing as a result of the No Child Left Behind has decreased emphasis on science in school curricula. Encouragement of interest and exposure to science should not be ignored in favor of an emphasis on standardized test preparation (Tai et al., 2006).

Inquiry-based Teaching and Learning in Chemistry

With the proper professional development training, teachers can implement inquiry-based instruction in the chemistry classroom. Empirical research findings on the effect that inquiry-based instruction has on students learning experiences in chemistry are missing from the literature. Moreover, the attitudes that a chemistry teacher may have about the field of chemistry and how that effects instruction have yet to be investigated.

Chemistry education in secondary school has multiple purposes, and one of them is to develop a student's positive attitudes toward chemistry as a subject in the school curriculum (Cheung, 2007). Cheung (2009) reported that there are a limited number of studies that examine the relationships between attitudes and chemistry. Breslyn and McGinnis (2011) have reported that a chemistry teacher's personal attitudes are more likely than curriculum to play a role in whether or not inquiry is used in their chemistry class. With the limited number of research studies in chemistry education, it is important to investigate the links between teacher attitudes about inquiry-based learning and how it affects not only the type of instruction but also how it can mold and shape the attitudes that students have about the field of chemistry.

Statement of the Problem

Little has changed in the field of chemistry education; problems with chemistry education were identified in the 1970s but despite 40 years of research little has been done to reform the

practice of chemistry education (Johnstone, 2009). Cooper (2010) has argued that we need to focus on the standards set forth by the National Science Foundation and focus on the inquiry and excitement of chemistry rather than the acquisition of facts and figures. Inquiry-based chemistry instruction could be a means to change the attitudes toward science. Johnstone (2009) has called for a total reexamination of how chemistry is taught in high schools. The educational community needs to examine and re-assess best practices in chemistry education. Lloyd (1992) believes it is time to take a long hard look at teachers of general chemistry and their reluctance to implement change. Chemistry should be presented in ways that capitalize on what students are familiar with and through a mode of instruction that facilitates exploration and excitement (Johnstone, 2009).

A teacher's attitude toward chemistry as well as a teacher's attitude toward inquiry-based instruction may influence a student's perception of chemistry. Research has shown that several factors influence a person's attitude toward science including previous experiences and social influences (Weinburgh, 1998). In addition, a chemistry teacher's personal attitudes are more likely than curriculum to play a role in whether or not inquiry is used in their chemistry class (Breslyn & McGinnis, 2011).

Student attitude is an important factor that is correlated with science achievement. Previous research has found that attitude to scientific inquiry and classroom enjoyment in science are strong independent predictors of chemistry achievement scores (Ali & Awan, 2013; Ferreira, 2003; Dhindsa & Chung, 2003; Freedman, 1997; Papanastasiou & Zembylas, 2002; Simpson & Oliver, 1990). Many research findings have an over arching theme which indicates that inquiry-based instruction increases a student's desire to learn, a student's achievement in science, and a student's positive outlook toward science (Ali & Awan, 2013; Ferreira, 2003;

Dhindsa & Chung, 2003; Freedman, 1997; Papanastasiou & Zembylas, 2002; Simpson & Oliver, 1990).

Research in chemistry education is very limited. The literature does not offer a comprehensive look at the overall field of chemistry as it relates to student attitudes about chemistry nor does it offer a look at best instructional practices in chemistry. In response to the lack of literature in this area, this research is an attempt to understand to what extent inquiry-based instruction in chemistry can affect a student's attitude. This research also investigated how a chemistry teacher's attitude toward chemistry may affect how inquiry-based the teacher's lessons may be. Most research in secondary sciences focus on biology or on the idea of science as a whole. Investigation is needed to specifically examine the field of chemistry in the secondary classroom. Lastly, research is needed to examine what obstacles a chemistry teacher may face when trying to implement this inquiry-based instruction.

Purpose of the Study

The primary purpose of the study was to explore the relationship between a high school chemistry teacher's inquiry-based approach to instruction and their students' attitudes about chemistry. This study also explored how a teacher's attitudes of chemistry are related to the use of inquiry-based instruction. Lastly, this research sought to explore the factors that affect a high school chemistry teacher's willingness and ability to use the inquiry-based approach to instruction in their classroom.

Theoretical Framework

Many sources of information are available regarding placing inquiry-based teaching and learning into practice. Piaget's cognitive constructivism theory (1967) and Vygotsky's social constructivism theory (1978) have shaped inquiry-based instruction.

As constructivist approaches permeated much of educational practice in the 1970s, constructivism became particularly prominent in science education through the focus on inquiry (Minner, Levey, & Century, 2010). Constructivist theory can explain how knowledge is constructed given that new knowledge has to have contact with existing knowledge that has already developed by previous experiences (Creswell, 2007; Ishii, 2003; Kim, 2001). Constructivist approach emphasizes that new knowledge is constructed through active thinking, organization of information, and the replacement of existing knowledge.

However, there is another similar framework that must be considered along with constructivism. Vygotsky (1978) studied social constructivism and he concluded that learning is a social construct that is facilitated by language via social discourse. Vygotsky (1978) placed an emphasis on the idea that social interaction was crucial for students to construct answers for themselves. The work of Prewat (1997) concluded that social constructivism allows learners to construct their reality of new knowledge through human activity.

The National Science Foundation (2006), Next Generation Science Standards (2012), and science education researchers (Bybee et al., 2006; Minner, Levey, & Century, 2010) have emphasized the importance of teachers helping students build their own knowledge. Constructivist approaches emphasize that knowledge is constructed by an individual through active thinking, organization of information and integration with existing knowledge (Cakir, 2008). Constructivism-based materials are commonly classified as inquiry-based as means to motivate and engage students while making science concepts concrete (Minner, Levey, & Century, 2010; Cakir, 2008).

Both constructivist and social constructivist theories are useful in developing lessons in an inquiry based classroom (Jonassen, 1994). Collaborative learning among learners and

teachers has been studied and instructional models around social constructivism have been shown to be effective in developing an inquiry-based learning environment (Kim, 2001; Lave & Wenger, 1991; McMahon, 1997).

The teacher's role in constructivist learning has been studied by Jonassen (1991). Jordan, Carlile, and Stack (2008) identified ten different characteristics necessary for teachers to be effective constructivist teacher. Jonassen (1994) proposed how both constructivism and social constructivism can be expedited in teaching and his work correlates to the core definition of inquiry-based instruction. Therefore, the lens of constructivism and social constructivism will be used in this study to investigate how chemistry teacher attitudes and willingness to use inquiry-based instruction and the field of science influence the type of instruction given in their classroom.

Research Questions

The questions investigated included the following:

1. What are the characteristics of a high school chemistry teacher based on his/her level of inquiry (high, medium, low) from the Chemistry Teacher Self-Assessment and their responses to the Chemistry Teacher Interview Questions;
2. What are the differences in student attitude about chemistry based on his/her high school chemistry teacher's level of inquiry instruction (high medium, low), as measured by the Chemistry Teacher Self-Assessment, and the Chemistry Student Attitude Survey; and
3. How do high school chemistry teachers describe their willingness to use the inquiry-based approach to instruction in their classroom, as indicated by open-

ended questions during an interview that corresponds to the Chemistry Teacher Self-Assessment?

Significance of the Study

The literature does not offer a comprehensive look at the overall field of chemistry as it relates to student attitudes about the chemistry field nor does it offer a look at secondary high school instruction in chemistry. In response to the lack of literature in this area, this research is an attempt to understand to what extent inquiry-based instruction in chemistry can affect a student's attitude. This research also investigated how a chemistry teacher's attitude toward chemistry may affect how inquiry-based the teacher's lessons may be. Information on student attitudes and performance in chemistry with a comparison to a teacher's level of inquiry instruction could be helpful to teachers in introductory high school chemistry courses. Finally, as NGSS is implemented in the high school science classrooms, it will be important to understand the obstacles that chemistry teacher's face when trying to implement inquiry-based instruction. Knowing the challenges that inquiry-based instruction brings to a chemistry teacher will be helpful to science educators allowing them to devise meaningful professional development for chemistry teachers. As a result of a more inquiry-based chemistry teacher, students may enjoy the benefits of learning in an inquiry-based environment.

Assumptions

The assumptions of this study included the following:

1. Teachers took the time needed to self-reflect on their practice as they answer the Revised 5E questionnaire;
2. The participants gave honest responses to the modified Chemistry Student Attitude survey; and

3. The information obtained from the participants in the qualitative phase represents their truth.

Limitations

The limitations of this study included the following:

1. The participants in this study were enrolled in two high schools located in a suburban school district;
2. The school district is located in the southeastern region of the United States;
3. The fact that the researcher could be recognized as a teacher in the school district could influence information provided by the students who were interviewed; and
4. Due to the subjective nature of qualitative research, the researcher might introduce his bias as a high school chemistry teacher in the interpretation of the results of the study.

Definition of Terms

Attitude - Attitudes toward science can be defined as, “favorable or unfavorable feelings about science as a school subject” (Morrell & Lederman, 1998, p. 41).

Constructivism - Constructivism is a theory used to explain how knowledge is constructed in the human being when information comes into contact with existing knowledge that had been developed by experiences (Crewell, 2007).

Inquiry-based instruction - 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 (National Science Education Standards, 1996).

5E model of inquiry - The 5E Instructional Model has five stages that include engagement, exploration, explanation, elaboration, and evaluation (Bybee, 2006).

Summary

The teaching and learning of chemistry can be impacted by the mode of instruction. There have been many researchers who have recommended using inquiry-based techniques to teach chemistry (Bruck & Towns, 2009; Chatterjee, Williamson, McCann, & Peck, 2009; Gaddis & Schoffstall, 2007; Khan, Hussain, Ali, Majoka & Ramzan, 2011; Van Rens, Pilot, & van der Schee, 2010); however, the research in the field of chemistry is limited specifically to a topic lesson or topical lab. Research on teacher's attitudes toward chemistry has not been studied and warrants investigation to assess if the long-term practices of inquiry-based instruction are the best mode of instruction in chemistry. Also, research that relates a student's attitude to a teacher's level of inquiry-based instruction has not been examined. Gathering information about the teacher's and student's attitude related to chemistry and applying how it may relate to inquiry-based instruction may be useful as the Next Generation Science Standards are implemented.

An introduction, including the background, problem, purpose of the research, along with a brief overview of the research and significance of the study were presented in this chapter. Chapter II will present a review of the literature and Chapter III will explain the methodology for this study. Chapter IV presents the results and Chapter V provides the summary, discussion, limitations, and recommendations for further research.

CHAPTER II:
LITERATURE REVIEW

Overview

This research sought to understand the relationship between inquiry-based instruction and a student's attitude towards chemistry. It also examined the link between a teacher's attitude toward chemistry and how that may or may not influence the teacher's decision to use inquiry-based instruction. Lastly, this research examined what obstacles teachers may face when choosing to use inquiry-based instruction in the chemistry classroom.

This chapter will discuss the literature related to general science, chemistry, and inquiry as well as a teacher's barriers to teaching with inquiry-based instruction. First, a look at the origin will provide a detailed history of how inquiry has been in science education for some time. An attempt to understand what inquiry-based instruction is and how it is used will be addressed in this chapter. The discussion will outline how inquiry and the 5E model became synonymous as well as how the future of inquiry looks through the Next Generation Science Standards. Related literature about what inquiry-based teaching is and how inquiry-based instruction can take on various levels will be discussed followed by a discussion about how inquiry-based instruction can influence attitudes toward chemistry will be discussed. The literature related to teachers attitudes of inquiry-based learning will be discussed as well as the barriers teachers may face when trying to implement inquiry-based learning in the chemistry classroom. Finally, the chapter concludes with what is known about inquiry-based learning in chemistry.

Inquiry Defined

Although inquiry-based teaching is one key theme of the current literature in science education, the meaning of inquiry remains without consensus. Since its inception, the term *inquiry* has been in an identity crisis (Barrow, 2006) and is thought of as a vague term with varying definitions. “Inquiry is the dynamic process of being open to wonder and puzzlements and coming to know and understand the world” (Galileo Educational Network, 2013, para. 1). The term originated from the longstanding dialogue about the nature of learning and teaching, in particular from the work of Jean Piaget, Lev Vygotsky, and David Ausubel (Minner, Jurist, & Century, 2010). Colburn (2000) defined inquiry as “the creation of a classroom where students are engaged in essentially open-ended, student centered hands-on activities” (para. 4). Colburn (2000) described numerous approaches to inquiry, which include structured inquiry, guided inquiry, open inquiry, and the learning cycle. French and Russell (2002) wrote that inquiry-based instruction relates to the student’s learning as a scientist. This type of instruction places the responsibility on the student to engage in the scientific process to learn about topics and perform activities (French & Russell, 2002).

Scientific inquiry refers to “the systematic approaches used by scientists in an effort to answer their question of interest” (Lederman, 1992, p. 1). The National Science Education Standards (1996) referred to inquiry as a process to involve students in a form of active learning that emphasizes questioning, data analysis, and critical thinking.

The next sections will discuss the origins of inquiry-based instruction and outline how it has evolved over the years with the learning cycle and 5E models of instruction followed by where inquiry-based instruction in science headed in the future.

Origins of Inquiry-based Teaching

Inquiry-based instruction is a result of educators trying to make learning more meaningful to the learner. An inquiry-based teaching practice encourages students to learn inductively and has a firmly established place in pedagogical tradition (Colburn, 2004). Inquiry has always been a part of education. It was Johann Herbart, a German philosopher, who proposed that instruction should allow students to discover the relationships of content among their experiences (Bybee, 2006). However, credit for inquiry is often given to the American science teacher and philosopher John Dewey with promoting ‘learning by doing’ (Bybee, 1997). Dewey’s reform of the educational system led to the first inquiry-based learning in the United States. Dewey advocated child-centered learning based on real-world experiences and reflective thinking (Dewey, 1933). Dewey believed that learning should not only be a hands-on experience, but also a minds-on experience as well (Bybee, 2006). Dewey encouraged K–12 teachers of science to use inquiry as a teaching strategy where upon the scientific method was rigid and consisted of the six steps: sensing perplexing situations, clarifying the problem, formulating a tentative hypothesis, testing the hypothesis, revising with rigorous tests, and acting on the solution. With this model, the student is actively involved, and the teacher has a role as facilitator and guide (Barrow, 2006; Goldston, Day, Sundberg & Dantzler, 2009).

It was not until the 1950s that inquiry-based instruction would undergo a rebirth in the United States, with a space satellite known as Sputnik bringing inquiry back to the forefront of education practices (Barrow, 2006; Chiappetta, 1997; Simpson, 2012, Bybee, 2006). Throughout the twentieth, century science teachers predominantly used expository teaching methods consisting of the presentation of science concepts through lectures and readings. After thorough explanation of the concepts, the teacher would then take their students to the laboratory to verify

the conceptual understanding (Simpson, 2012). When the Soviet Union launched Sputnik in the late 1950s, scientists, science teachers, and government leaders alike were concerned that Americans had fallen behind in math, science, and critical thinking skills (Barrow, 2006; Bybee, 2006; Simpson, 2012).

It was during the same time as Sputnik that research into Dewey's ideas produced the learning cycle. Robert Karplus, a theoretical physicist, and Myron Atkin, a science educator, became involved in science education in the 1950s and they were both interested in connecting psychology to the design of science teaching. Karplus volunteered to help elementary schools in Berkley where he observes science lessons and was not impressed by the methods being utilized in the elementary science classroom (Fuller, 2003; Simpson, 2012). Karplus collaborated with Atkin and this lead to the creation of the learning cycle. The learning cycle was created by Karplus and fully conceptualized by Atkin and Karplus (1962) as "guided discovery." It was later in 1967 that Karplus and his colleague Herbert Their first coined the terms in the learning cycle that consisted of three phases: exploration, invention, and discovery (Barman, 1993; Bybee, 2006; Goldston, Dantzler, Day, & Webb, 2013).

The Learning Cycle

The learning cycle is not a method or model of teaching but rather a comprehensive approach. It is a specific organization of phases dominated by the integrity of the whole and the relationships of the phases to each other for experiencing science by inquiry and for organizing science curricula (Marek, Laubauch, & Pederson; 2003). The learning cycle, by design, accommodates all tools and methods of teaching (e.g. technology, questioning strategies, group work, demonstrations, laboratory investigations, field trips, lectures) as well as all models of instruction (e.g. jigsaw, cooperative learning, direct instruction). The learning cycle advances

scientific inquiry by allowing students to question and formulate solvable problems; to reflect on and construct knowledge from data; to collaborate and exchange information while seeking solutions; and to develop concepts and relationships from empirical experience (Marek, Laubauch, & Pederson, 2003).

The learning cycle involves students in a sequence of activities beginning with the exploration of an idea or skill, leading to a more guided explanation of the idea or skill, and culminating in the expansion of the idea or skill through additional practice and trials in new settings (Sunal, 2013). During the exploration phase of the learning cycle, students have an initial experience with the phenomena being studied. Later, students are introduced to new terms associated with the concepts that are the object of the study in the invention phase. In this phase, the teacher is more active, and learning is achieved by explanation. Lastly, in the discovery phase, students apply concepts and use terms in related but new situations. Learning is achieved by repetition and practice such that new ideas and ways of thinking have time to stabilize (Bybee, 2006). The learning cycle may be effectively used with students at all levels to accomplish many purposes as it is designed to adapt instruction to help students in several ways. They include 1) become aware of their prior knowledge, 2) foster cooperative learning and a safe positive learning environment, 3) compare new alternatives to their prior knowledge, 4) connect it to what they already know, 5) construct their own “new” knowledge, and 6) apply the new knowledge in ways that are different from the situation in which it was learned (Sunal, 2013).

This learning cycle allows students to apply knowledge gained in the classroom to new areas or situations, because students are more aware of their own reasoning. As a result of being able to test their conceptions and knowing how to produce and apply procedures, students can see where their knowledge is applicable in other areas and gain more confidence (Sunal, 2013).

The learning cycle was used in the Science Curriculum Improvement Study (SCIS) in the 1970s and proved to be successful in different educational settings (Bybee, 2006). There are a vast number of articles that examine the SCIS study and the effectiveness of using the learning cycle. Several frameworks for the learning cycle have been suggested by Barnes (1976), Driver (1986b), Karplus (1977), Erickson (1979), Nussbaum and Novic (1981), Renner (1982), Rowell and Dawson (1983) and others. A review of these learning cycle frameworks by Sunal (2013) indicates that whereas the frameworks are all slightly different, they all share a sequence of activities that include exploration, explanation, followed by elaboration. Even though the researchers may have used different wording in their frameworks, the sequencing of their framework all lead to the same ideas (Sunal, 2013).

5E Model

In the 1980s, the Biological Sciences Curriculum Study (BSCS) added two new stages to the beginning and end of learning cycle: engage and evaluation (Bybee, 2006). This is now known as the 5E Learning Cycle. This model helps to fine tune how the process of inquiry-based learning can take place in lessons and labs in the science classroom. Each element of the five “E’s” is carefully crafted to promote student construction of knowledge. The 5E model has been adopted by the National Science Foundation (1996) as well as the many state departments of education as the standard for science education. Each ‘E’ is a phase in the learning cycle and has distinct characteristics.

In the *engagement* phase, the main purpose is for the teacher to elicit the learner’s prior ideas about the topic and evoke interest. Research in cognitive science indicates that eliciting prior understanding is a necessary component of the learning process (Bransford, Brown, & Cocking, 2000). Various techniques can be used to establish prior knowledge. For example, a

teacher may use one of the following in their lesson: asking the learner to make predictions asking open-ended questions, skits, or discussions (Bybee, 2006). Teachers must learn what prior knowledge a student possesses. Failure to understand a student's background knowledge may result in students learning concepts different from what the lesson intends (Bransford, Brown, & Cocking, 2000).

In the second phase, *exploration*, teachers provide student with a common base of activities in which the students are encouraged to explore the lessons topic and thus concepts are identified and conceptual change facilitated. This phase should be student centered and may contain hands-on/minds-on activities, including student questions and processing skills, and include a method of formative assessment for the teacher to assess student learning (Bybee, 2006; Goldston, Dantzler, Day, & Webb, 2013; Trowbridge & Bybee, 1996).

Explanation is the third phase of the 5E model. This phase involves the teacher facilitating discussions emerging from a student's experiences during the exploration. Students explain their understanding of concepts and processes. There is a focus on a particular aspect of engagement to provide opportunities to demonstrate conceptual understanding, process skills, or behaviors. The explanation phase also provides an opportunity for teachers to directly introduce a concept, processes, or skills to guide student toward a deeper understanding.

The *elaboration* phase ties directly to the psychological construct called the transfer of learning (Arkansas Department of Education, 2011). The Elaboration phase allows teachers to provide learning activities that provide opportunities for students to apply and extend newly acquired concepts/skills into different or authentic settings. This is a place for a teacher to challenge conceptual understanding and skills through new experiences to develop deeper and broader understanding and application. For example, a teacher may present students with

problems similar to what they have been studying and allow the students to work out a solution based on their prior knowledge allowing the student to make connections to the material and expand on their knowledge.

The last phase of the 5E cycle is *evaluation*. In this phase the teacher assesses for understanding and evaluates the student progress toward educational objectives (Bybee, 2006; Goldston, Day, Sundberg, & Dantzler, 2010; Goldston, Dantzler, Day, & Webb, 2013). The evaluation phase is for teachers to reflect on the concept and determine the level of learning and understanding that has taken place. It is critical to note that evaluation should be an ongoing process of formative assessment as well as summative assessment. Teachers can evaluate student learning throughout the four phases of the model by asking questions, observing body language, listening to student teams discuss concepts or readings, and responding to student work (e.g., journal entries, lab reports, data charts, graphs, tables, etc.) (Bybee, 2006). The teacher can provide diagnostic tools that can be used in the evaluation process, which may include rubrics, scoring guides, teacher observation, student interviews, portfolios, and journal entries. The teacher must remember that evaluation is an ongoing process and provides opportunities for students to consider ways to improve their work (Bybee, 2006). The 5E model has been used in science classrooms since the 1980s: first, in the biology curriculum and later spilling into the physical sciences (Bybee, 2006).

Next Generation Science Standards

Inquiry-based instruction and science curriculum is currently undergoing further changes. Bybee, Fensham, and Laurie (2009) have called for a rethinking of the goals, content, and pedagogy of science education. A student's attitude about science have led to many initiatives and coalitions to bring science back into the forefront, particularly in the United States. For

example, one of the goals of Project 2061 is to improve student literacy in science, mathematics, and technology (Advancing Science Serving Society, 2012). In addition, the National Science Foundation Graduate Teaching Fellows Program for K-12 education has worked to improve the communication, collaboration, and team-building skills of future science professionals for the 21st century (National Science Foundation, 2012). More recently, the Obama administration announced a campaign called Educate to Innovate (White House, 2012). The campaign's goal is to promote the improvement of participation and performance of America's students in science, technology, engineering, and mathematics (STEM). One obstacle that still exists, however, is developing and encouraging student participation and interest in the science/STEM-related fields.

In July 2011, the National Research Council (NRC) released *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which identifies key scientific ideas and practices every student should learn by the end of high school. The framework serves as the foundation for new K–12 science education standards that will replace those developed in the 1990s (Pratt, 2012). The framework acted as a guide to develop the Next Generation Science Standards (NGSS). The overall goal of the NGSS is to help all learners in our nation develop the science and engineering understanding needed to live successful, informed, and productive lives, which will help sustain the planet for the future generations (Krajcik, 2013).

NGSS Approach to Teaching

As NGSS is integrated into the new science curriculum teachers must determine *how students know* as much as *what students know* and provide students with opportunities to craft interdisciplinary scientific arguments that require evidence-based claims from their data

(Sampson, Enderle, & Grooms, 2013). The overall goal of the framework and NGSS is for teachers to use inquiry-based instruction to support all learners in our nation to develop the science and engineering understanding that they need to live successful, informed, and productive lives (Krajcik, 2013).

The framework and the NGSS focus on inquiry with a new approach called *practices*. While examining the document closely, the actual word inquiry is not included in the NGSS; however, the practice of inquiry still exists as inquiry is embedded in many of the practices of the NGSS (NGSS, 2013). Rather than equating scientific practice with inquiry, as other standards tend to do, they recognize a full range of key inquiry, application, and communication practices (Anderson, 2013). To help ease some of the confusion around the word inquiry, the NGSS has chosen to replace inquiry with practices. The team responsible has chosen to avoid the term since so few seemed to know its meaning and associate inquiry with current reforms (Brown, 2012).

As seen in the NGSS as well in the framework, inquiry remains central to standards of the future of science education. Padilla and Cooper (2012) have warned against letting the small and subtle changes in standards lull the educator into thinking “same old, same old.” They asserted that evolution of inquiry to the new conception of practices will require a reformulation of how science educators talk and think about science teaching as well as how we get students to think and talk about science (Padilla & Cooper, 2012). Whereas the actual word inquiry may be phased out, the guiding principles and practices that drive this type of instruction will be central to science teaching reform. Students at all grade levels, in every domain of science education, should be afforded the opportunity to use scientific inquiry (Bell, Smetana, & Binns, 2005). It is important that teachers, both seasoned professionals as well as up and new science teachers, are

immersed in the practice of inquiry so that they may keep up with the standards and offer the best science experience possible.

Instructional Levels of Inquiry-based Instruction

Teachers may provide students with varying levels of information, thus leading to the idea of the levels of inquiry instruction. Schwab, in 1962, first described different levels of inquiry. Herron (1971) later identified three levels of openness for inquiry in science activities that included confirmation, structured or guided inquiry. The level of inquiry is contingent upon exactly how much information the teacher may provide to the student. Inquiry-based instruction can take on one of four levels: confirmation inquiry, structured inquiry, guided inquiry, or open inquiry. The continuum of information focuses on how much information a teacher gives to the students about a given lesson or lab (Bianchi & Bell, 2008; Bell, Smetana, & Binns, 2005).

The confirmation level of inquiry is the most basic of levels. Students confirm a principle through an activity when the results are known in advance. Students are provided with a question, procedure, and solution from the teacher. Confirmation inquiry is useful when a teacher's goal is to reinforce a previously introduced idea; to introduce students to the experience of conducting investigations; or to have students practice a specific inquiry skill such as collecting and recording data (Bianchi & Bell, 2008). For example, a student could be given a number of metal samples and asked to find the specific heat of each metal. Their results could be compared to the literature value for each metal to confirm the identity of the metal. The amount of teacher direction is great while the amount of self-direction from the learner is minimal.

Structured inquiry allows students to investigate a teacher-presented question through a prescribed procedure; the teacher does not give the solution to the problem (Bianchi & Bell, 2008). For example, a student may carry out an investigation to stoichiometrically figure out the

amount of aluminum left over when reacted with copper chloride solution. The teacher will help them set up the problem and walk the students through the procedure. However, it is left to the student to figure out how to complete the investigation through stoichiometry, data collection and processing, and write a conclusion based on their results. This level of inquiry is slightly more student centered and slightly less teacher directed than the confirmation level of inquiry.

In guided inquiry, students investigate a teacher-presented question using student-designed procedures. Guided inquiry has a teacher-presented question, but the students must design their own procedures, compare data, and look for trends to answer the question. For example, a teacher may present students with data about materials that need to be separated using their densities. Given the information the students will have to write their own procedures on how to separate the materials and assess what they think is the best way to answer the research question. There may be more than one correct way to answer the question so the teacher must be open to seeing more than one right answer to the question (Bianchi & Bell, 2008).

Lastly, with open inquiry, the student investigates questions that are student formulated through student design. This is the most complex of the levels because a question, procedure nor solution is given to the student. It depends on the student's higher order thinking skills (Bianchi & Bell, 2008; Bell, Smetana, & Binns, 2005). An example of open inquiry may be where a student is presented with a demonstration, but with no information. The students use items presented to them to explain what they may see in the demonstration. Another use of open inquiry is for the students to pick a topic in chemistry and build a project based on their interest. This type of inquiry is student-centered and the amount of teacher direction is minimal and may be difficult for teachers since their role is more of a facilitator/ resource person to the students learning (Smetana & Binns, 2005).

In addition to the four levels of inquiry, Wenning (2005) developed a hierarchy of inquiry-based instruction that focuses on the control of the teacher. His levels or hierarchy has more levels than the ones outlined by Herron (1971) and integrates demonstrations and real world applications into the levels. In both Wenning (2005) and Bianchi and Bell (2008) levels of inquiry, the focus is on how much control the teacher has verses how much the student controls the learning process. The levels that Wenning (2005) suggests are, in order from right to left on his scale, are discovery learning, interactive demonstration, inquiry lesson, inquiry lab, real-world applications, and hypothetical inquiry. It is in the middle of the scale, inquiry lesson and inquiry lab, that allows for what Wenning calls *intellectual sophistication* and serves as a locus of control in the teaching process. Wennings' levels were developed for the field of physics but would be transferable to any science discipline.

As students experience the multiple levels of inquiry, they will develop the abilities and understandings of scientific inquiry. Teachers do not need to use each level of inquiry for each topic/lesson being presented. In fact, not ever topic in chemistry may lend itself to inquiry (Alabama State Department of Education, 2005). However, teachers *do* need to construct lessons that allow students to experience science through direct experience, consistently practicing the inquiry skills and seeking deeper understanding of science content through their investigations (Bianchi & Bell, 2008).

Theoretical Framework

Many sources of information are available regarding placing inquiry-based teaching and learning into practice. Piaget's cognitive constructivism theory (1967) and Vygotsky's social constructivism (1978) theory have shaped inquiry-based teaching theory. This section will offer a definition of both constructivism and social constructivism, discuss how constructivism and

inquiry are interconnected, and how a teacher might apply these theories of learning into practice in their classroom.

Constructivism

Constructivism is a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in (Creswell, 2009; Kim, 2001). The main tenet of constructivist learning is that people construct their own understanding of the world, and in turn their own knowledge (Ishii, 2003).

The work of Piaget (1967) believed that children learn through personal interactions with physical events and objects in their daily lives. Piaget (1967) felt that quality instruction should provide opportunities and practical activities that challenge a learner's prior conceptions and encourage them to reorganize their personal beliefs and theories.

As constructivist approaches permeated much of educational practice in the 1970s, it became particularly prominent in science education through the focus on inquiry (Minner, Levey, & Century, 2010). Constructivism is central to the current reforms in science education and causes shifts in the focus of teaching and learning from how students learn science to how teachers learn to teach science in teacher education programs (Taskin-Can, 2011).

Principles of constructivism in math and science are outlined by Ishii (2003) and include 1) learning must start with the issues around which students are actively trying to construct meaning; 2) learning process focuses on primary concepts, not isolated facts; and 3) the purpose of learning is for an individual to construct his or her own meaning, not just memorize the correct answers and regurgitate someone else's meaning.

Social Constructivism

Social constructivism may be viewed as a learning theory with strong epistemological elements (Kim, 2001). Social constructivism places an emphasis on the importance of culture in understanding what is occurring in society and then constructing knowledge based on this understanding (Kim, 2001). Learning is not a purely internal process, nor is it a passive shaping of behaviors; learning is a social construct, which is mediated by language via social discourse (Vygotsky, 1978).

Vygotsky (1978) believed a major social interaction should be between an expert and the student and that the teacher is present to help the students construct answers for themselves. It is essential that the student's disposition to view objects and events in new and imaginative ways be modeled by the teacher, who must take care to avoid being the dispenser of knowledge on one hand, or a mere facilitator on the other (Prawat, 1995).

The work of Prawat (1996) concluded that social constructivism allows learners to construct their reality of new knowledge through human activity. People create meaning through their interactions with each other and the objects in the environment (Prawat, 1997). These ideas and the principles of inquiry-based instruction are similar in that both stress that the learning is a social process and learning occurs when people are engaged in social activities (Bybee, 2006; Kim, 2001; Prawat, 1997).

Social constructivism is founded on two main assumptions: a) knowledge is constructed by people who are active participants in the process; and b) social interactions within an individual or between individuals play an important role in constructing knowledge (Ferguson, 2007). As new knowledge is gained, it can be tested and modified based on new experiences. Social constructivism is the belief that knowledge is affected by our social interpretation of

activities - there is no meaning in the world until we construct it (Kim, 2001). Learners do not transfer knowledge from the external world into their memories; rather, they create interpretations of the world based upon their past experiences and their interactions in the world (McMahon, 1997).

Constructivism and Inquiry-based Teaching

For inquiry-based learning to succeed, it is essential for students to investigate their environment and eventually work out problems for themselves (Bybee, 2006; National Science Foundation, 2006). Inquiry-oriented teaching is often contrasted with more traditional expository methods and reflects the constructivist model of learning (Haury, 1993). Cakir (2008) explained that constructivism has helped teachers to shape instructional materials. Constructivism-based materials are commonly classified as inquiry-based and include hands-on activities as means to motivate and engage students while making science concepts concrete (Minner, Levey, & Century, 2010; Cakir, 2008). Constructivist approaches emphasize that knowledge is constructed by an individual through active thinking, organization of information and integration with existing knowledge (Cakir, 2008).

Teacher's Role in the Inquiry-based Classroom

Jonassen (1991) has researched the role of teachers using the constructivist framework. His work assembled a number of design principles needed for effective constructivist lessons that include

1. create real-world environments that employ the context in which learning is relevant;
2. focus on realistic approaches to solving real-world problems;
3. instruct a coach and analyzer of the strategies used to solve these problems;
4. stress conceptual interrelatedness, providing multiple representations or perspectives on the content;
5. instructional goals and objectives should be negotiated and not imposed;

6. evaluation should serve as a self-analysis tool;
7. provide tools and environments that help learners interpret the multiple perspectives of the world;
8. learning should be internally controlled and mediated by the learner. (Jonassen, 1991, pp.11-12)

Instructional models based on the social constructivism stress the need for collaboration among learners along with teachers (Lave & Wenger, 1991; McMahon, 1997). Social constructivist approaches can include reciprocal teaching, peer collaboration, cognitive apprenticeships, inquiry-based instruction, anchored instruction and other methods that involve learning with others (Kim, 2001).

Both constructivist and social constructivist theories are useful in developing lessons in an inquiry based classroom. Jordan, Carlile, and Stack (2008) identified ten different characteristics necessary for teachers that include

1. the teacher should consider the knowledge and experiences students bring to class;
2. learning is presented as a process of active discovery, not lecture;
3. teachers provide assistance with assimilation of new and old knowledge;
4. learning will be sufficiently flexible to permit development along lines of student inquiry;
5. teachers will allow students to interpret information in different ways;
6. teachers should create situations where the students feel safe questioning and reflecting on their own processes;
7. teacher should present authentic tasks to contextualize learning through real-world, case-based learning environments;
8. teacher should support collaboration in constructing knowledge, not competition;
9. teacher should provide scaffolding at the right time and at the right levels;
10. lastly, teachers should provide opportunities for all students to learn from each other. (Jordan, Carlile, & Stack, 2008)

Jonassen (1994) also proposed how both theories can be facilitated in teaching. This includes

1. provide multiple representations of reality;
2. represent the natural complexity of the real world;

3. focus on knowledge construction, not reproduction;
 4. present authentic tasks (contextualizing rather than abstracting instruction);
 5. provide real-world, case-based learning environments, rather than pre-determined instructional sequences;
 6. foster reflective practice;
 7. enable context-and content dependent knowledge construction;
 8. support collaborative construction of knowledge through social negotiation.
- (Jonassen, 1994, p. 35)

The next section discusses how inquiry-based instruction can affect both teacher and student attitudes toward science. Also, a discussion about the barriers a teacher may face when deciding to use inquiry-based instruction is discussed in detail. A discussion about the effects of inquiry-based instruction on chemistry is discussed. Finally, the importance of inquiry-based professional development for teachers is addressed.

Related Literature

Attitudes toward Science

Attitude can be defined as the feelings that a person has about an object, based on his knowledge and belief about that object (Kind, Jones, & Barmby, 2007; Morrell & Lederman, 1998). A student's feelings as well as prior knowledge of a science subject are important factor when studying attitudes of science (Ebenezer & Zoller, 1993). Science educators have long agreed that the development of a positive attitude toward science should be an important goal of the school curriculum (Aiken & Aiken, 1969; Colburn, 2000; Cheung, 2009, George, 2006; Koballa, 1988). Developing a student's positive attitudes for science lessons in school is important for two main reasons (Cheung, 2009). First, research has confirmed that attitudes are linked with academic achievement (Weinburgh, 1995; Freedman, 1997). The second reason is that attitudes can help to predict future behaviors in science (Cheung, 2009; Glassman & Albarracín, 2006).

Studies report that the general public (that is, non-science majors) does not generally have positive feelings toward science or scientists (Movahedzadeh, 2011; Rogers & Ford, 1997). A study performed by Harris Interactive (2011) found that while most parents of K–12 students (93%) believe that STEM education should be a priority in the U.S., only half (49%) agree that it actually is a top priority for this country. It was found in the same study that only 1% of the people surveyed indicated that the discipline of chemistry was identified as the student's favorite subject. A concern for many countries is the failing number of students choosing to pursue the study of science (Barmby, Kind, & Jones, 2010). It has been recently documented that students who choose a career in science are twice as likely to graduate with a degree in the life sciences verses a degree with the physical sciences (Tai, Liu, Maltese, & Fan 2006).

Young people often cited a lack of relevance and applicability in the science curriculum as a reason for disengagement from the science subject (Osborne & Collins, 2000) as could certainly be the case in field of chemistry because of the abstract and conceptual nature. In a 1998 study, Weinburgh showed that several factors influenced a person's attitudes toward science, including previous experiences in the classroom, personal experiences and social influences. Gogolin and Swartz (1992) reported that the quality of exposure to science could affect change in attitudes toward science.

If a student is excited about his subject, the desire to learn increases. A concern for many countries is the declining number of students choosing to pursue the study of science combined with the lessening recognition of the importance and economic utility of science knowledge (Barmby, Kind, & Jones, 2010). Akpinar, Yukduz, Tatar, and Ergin (2009) stated that more positive attitudes toward science are associated with positive attitudes about the utility of science.

Osborne and Dillon (2008) studied the relationship between student achievement and student attitudes toward science and concluded that less than 30% of the students in the United States have a positive attitude towards science. Negative attitudes towards science and science teaching are issues with long standing attention and interest in science education. Attitudes, like academic achievement, are important outcomes of science education in secondary schooling. According to Cheung (2009), the development of a student's positive attitudes regarding science as a school subject is one of the major responsibilities of every science teacher. Research has indicated that much of what goes on in science classrooms is not particularly attractive to students across all ages (Stark & Gray, 1999). This is the case not only in the United States but also there are publications of this negativity toward science reported in the United Kingdom (Public Attitudes Towards Science, 2011; Barmby, Kind, & Jones, 2010), Kenya (Majere, Role, & Makewa, 2012), Barbados (Ogunkola & Sammual, 2011), Greece (Salta & Tzougraki, 2003), and Hong Kong (Cheung, 2007), among many others. One common thread among all the researchers across the countries is that an increase in a student's enjoyment and attitudes in science is desirable because of the potential increase in the pursuit of scientific careers.

It has been stated that all students start out liking science and that students develop either a positive or negative attitude based on their school experience (Gibson & Chase, 2002; Koballa & Crawley, 1985). Attitudes toward science steadily decline with each year of school completed (Barmby, Kind, & Jones, 2010; Doherty & Dawe, 1985; George, 2000, 2006; Osborne, Simmon & Collins, 2003; Simpson & Oliver, 1985, 1990; Yager & Yager 1985). In addition, it has been reported that negative and declining attitudes toward science are greater with females than with male students (Barmby, Kind, & Jones, 2010; Doherty & Dawe, 1985; Gibson & Chase, 2002),

but more recent work carried by George (2006) has found that the opposite to be true, that male pupils' attitudes decline faster.

Student's Attitude about Science and Instructional Methods

A student's attitude about science and the type of instructional methods have been shown to be related in the literature. Research indicates that students begin to lose interest in math and science around their middle school years based on type of science instruction (Finson & Enochs, 1987; Simpson & Oliver, 1985). Gibson and Chase (2002) reported similar results and theorize that high school science classes are taught with more traditional methods. In addition, it is suspected that the inquiry-based style of instruction in middle school is what holds the attention of the students. Foley and McPhee (2008) found that students in hands-on classes generally are more favorable to science and had a better understanding of the nature of science than students in textbook-based, lecture classes.

Studies indicate that teachers who use an inquiry-based instruction had improved student attitudes toward both science and school while other studies show more negative student attitudes resulting from traditional methods (Gibson, 1998; Shrigley, 1990). It has also been shown that the teacher instructional choice is the most significant factor-determining student attitude in science, not curriculum (Osborn, Simmons, & Collins, 2003). Cheung (2007) and Woolnough (1994) have also highlighted the importance of the teacher in enthusing pupils in science. Positive science behaviors may contribute an interest in science and the learning of science (Cheung, 2009). It is not only the type of instruction but the role of the teacher that needs to be addressed in order to tackle the perceived decline in pupils' attitudes towards science (Barmby, Kind, & Jones, 2010).

Students will be more likely to be successful in science if they acquire successful science experiences and positive feelings about science from the beginning (Akpinar, 2009). With this in mind, teachers are encouraged to effectively use inquiry-based learning strategies to motivate students about science (Rosenzweig, Carrodegau, & Lucky, 2008). When properly introduced, inquiry-based activities increase student interest and motivation. The student becomes a fellow investigator, with motivation shifting from an extrinsic desire for a higher grade to an intrinsic one for satiating a curiosity of nature (Baker, Lang, & Lawson, 2002). Students demonstrate significant learning gains through inquiry-based learning (Palincsar, Magnusson, & Collins, 2001).

For example, Chang and Mao (1998) studied the impact of two weeks of traditional lecture-type instruction versus two weeks of inquiry-based instruction on secondary students' achievement in an earth science class. They found that students who were taught using the inquiry-based instructional method scored significantly higher on an achievement test than those who were taught using the traditional lecturing approach. Padilla, Okey, and Garrand (1984) studied the impact of a 14-week unit on integrated process skills for middle school students with a control group that received no direct instruction on integrated process skills. After 14 weeks, they found that middle school students in the treatment group had significantly higher scores in process skills than the control group. Both studies demonstrated positive impact immediately following the inquiry-based instruction, but the long-term outcome was not assessed.

Student's Attitude about Chemistry

The literature about attitudes in science tends to focus on science as a whole and it has been suggested that researchers need to distinguish between the branches of science when examining attitude so as not to distort the data (Spall, Dickson, & Boyles, 2004). Cheung (2009)

has indicated that there are a limited number of studies that examine the relationships between attitudes and chemistry. In a study by Cheung (2009), it is reported that both males and females are marginally positive about chemistry lessons during the years of secondary schooling.

Researchers and science educators agree that negative attitudes toward chemistry and science cause a crucial problem and that further research in attitudes will contribute to the explanation of the persistent problem of the alienation from chemistry among young people (Cheung, 2009; Salta & Tzougraki, 2003).

The Effects of Inquiry-based Instruction on Chemistry Outcomes

Inquiry-based instruction can have lasting effects on chemistry outcomes and there have been studies conducted all over the world that shows these effects. A study carried out in Pakistan studied the effect of inquiry-based instruction as a strategy for academic achievement in secondary students in chemistry (Khan, Hussain, Ali, Majoka & Ramzan, 2011). The researchers enlisted two groups for the study that were both taught by traditional means. The experimental group, however, was also taught with inquiry methods. Achievement scores of each group were analyzed to determine if there was a difference in the groups. The overall results of the study indicated that inquiry-based instruction, as a backup strategy to support traditional teaching methods, improved a student's achievement in the subject of chemistry (Khan, Hussain, Ali, Majoka, & Ramzan, 2011). This study looked only at student achievement and did not consider the level of inquiry a teacher may have used.

Ruston and Lotter (2011) investigated level of inquiry-based instruction a teacher was using to a group of practicing teachers to examine the beliefs and practices of seven high school chemistry teachers. They used a mixed methods approach to administer the Reformed Teaching Observation Protocol (RTOP), which investigated their expertise and beliefs of inquiry. Also, a

Likert scale was used to assess the teacher's methods in addition to the observations of the researcher. This study concluded that teachers with a more constructivist mindset are more likely to be able to carry out inquiry instruction as opposed to those with the notion that science knowledge is a lecture style mode of instruction.

In 2010, Smithenry performed a case study of a chemistry teacher and her students. The study's findings suggested the extent and frequency to which teachers can realistically integrate guided inquiry into existing science curricula. It also addressed how a teacher can make effective transitions into and out of guided inquiry. Lastly, it highlighted how teachers enlist an effective driving purpose to all of the guided inquiries that the students experience. The study's findings suggest three main points: (1) it is not always easy to integrate inquiry and not all topics lend themselves to inquiry-based teaching methods, (2) approaches for teachers to make effective transitions into and out of a guided inquiry are suggested, (3) teachers must set a goal to bring a purpose to all of the guided inquiries that the students experience. Smithenry (2010) stressed that both new and more experienced teachers alike will need professional development to implement inquiry-based instruction. This was a case study that took a purely qualitative look at a classroom in the mid-west of the United States so its findings should be viewed with that perspective.

College students' performances and attitudes toward inquiry-based chemistry were studied by Coll, Dalgety, and Salter in 2002. They developed a questionnaire called the Chemistry Attitude and Experience Questionnaire (CAEQ) and discovered that this tool could be useful for assessing students after a semester of college chemistry. Their findings indicated that different teaching and learning styles at the college level both in the lab and in lecture result in different student outcomes both in attitude and in overall class performance (Coll, Dalgety, &

Salter, 2002). Their results may be transferable to chemistry at the secondary level but a study designed to examine secondary students could not be found in the literature.

Laboratory Experience and Inquiry-based Learning

When educational practices in chemistry are studied it is investigated in a way that only isolates particular topics and often times in a laboratory setting (Cheung, 2009; Johnstone, 2009). Laboratories have had a place in the chemistry classroom for years and are seen as an important part of the chemistry experience. However, it is well known that traditional laboratory work is not without limitations. In traditional laboratory classes, students follow step-by-step (cookbook) instructions to complete an experiment. By concentrating on the completion of individual steps, students often do not have a deep understanding of the experimental design (Cheung, 2007). Numerous science educators (e.g., Abd- El-Khalick et al., 2004; Hodson, 1998; Lunetta, 1998; National Research Council, 2000) have advocated the use of inquiry-based laboratory work. Many students' laboratory experiences consist of the manipulation of equipment, but not the manipulation of ideas (Hofstein & Lunetta, 2004).

Deters (2005) surveyed 571 high school chemistry teachers in the United States and found that 45.5% of the teachers did not provide students an opportunity to write experimental procedures. Similarly in Australia, Hackling, Goodrun, and Rennie (2001) surveyed 2,802 secondary science students and found that 33% of the students had never planned their own experiments. At the college level, it has been found that 91% of universities often or almost always use a direct instruction format for laboratories and lecture (Meyer, Hong, Fynnewever, 1997).

The benefits of inquiry-based laboratory work are well documented in the literature. Inquiry-based instruction in labs is an effective mode of learning to improve a student's content

knowledge (Lord & Orkwiszewski, 2006; Bruck & Towns, 2009). Inquiry-based lab instruction may also increase scientific process skills (Deters, 2005; Hofstein, Shore & Kipnis, 2004), attitudes toward school science (Gibson & Chase, 2002; Jones, Gott & Jarman, 2000; Lord & Orkwiszewski, 2006), motivation to learn science (Tuan et al., 2005), understanding of the nature of science (Backus, 2005), and communication skills (Deters, 2005). However, Bruck and Towns (2009) have asserted that students must possess the appropriate background knowledge before inquiry labs can be successful. Additionally, it is important to understand that students cannot just be thrust into inquiry-based teaching; a transition between traditional teachings with inquiry styles is necessary for the students to be successful (Bruck & Towns, 2009; Gaddis & Schoffstall 2007). It has been determined that students are more interested when inquiry based experiments are performed versus expository types of experiments (Gaddis & Schoffstall, 2007).

Specific laboratories have been studied to assess how inquiry instruction can affect the laboratory experience (Gaddis & Schoffstall, 2007; Bruck & Towns, 2009; Chatterjee, Williamson, McCann, & Peck, 2009). A study of a student's attitude toward inquiry labs reveals how students really feel about this type of instruction (Chatterjee, Williamson, McCann & Peck, 2009). Students in a general chemistry class were surveyed at the end of the course. This survey appears to have been developed by the faculty in the department of chemistry. The study results indicate that students have a more positive attitude toward guided-inquiry laboratories than open-inquiry laboratories and those students believe that they learn more with guided-inquiry laboratories than open-inquiry laboratories.

Teacher Inquiry-based Instructional Barriers

There are many difficulties when choosing to teach using the inquiry-based approach. In fact, it may be easier to choose another approach to teaching chemistry; inquiry-based instruction

is one mode of instruction delivery for science. Problem based learning, expository learning, and discovery based learning are other methods that can be seen in the classroom setting (Domin, 1999). In every mode of instruction except for inquiry learning, the outcomes of the lessons are all predetermined or undetermined. Expository and problem-based activities typically follow a deductive approach in which students apply a general principle toward understanding a specific phenomenon. Discovery and inquiry lessons are inductive; by observing particular instances, students can derive the general principle (Domin, 1999).

A teacher may think he is primarily using inquiry-based methods, when, in fact, he is using a more problem-based type of instruction (Colburn, 2000; Luft, 2001). Many teachers do not understand what is involved in the inquiry-based instruction or recognize how it differs from some of the other instructional models. Few science educators have developed the strategies needed to help practicing teachers implement inquiry-based instruction in the classroom (Cheung, 2009). As Anderson (2002) pointed out, “While research says inquiry teaching can produce positive results, it does not, by itself, tell teachers exactly how to do it” (p. 4).

Teaching and learning through inquiry-based instruction in science remains difficult for both teachers and students alike (Anderson, 2002; Cheung, 2009; Colburn, 2000). There are many barriers to the implementation of inquiry-based instruction in both the science classroom and lab. Cheung (2009) cited eleven different barriers that teachers must overcome to be successful inquiry-based teachers. These include lack of time, teacher beliefs, lack of effective inquiry materials, pedagogical problems, management problems, large classes, safety concerns, fear of abetting student misconceptions, student complaints, assessment issues, material demands.

Lack of time. Time is of the essence in any classroom. It has been determined that inquiry-based instruction and experiments require more time than traditional methods (Cheung, 2009; Anderson, 2002; Colburn, 2000). Many other science educators (Backus, 2005; Cheung, 2006; Costenson & Lawson, 1986; Deters, 2005) also reported that many teachers perceive that inquiry-based instruction is too time-consuming and thus they cannot cover the curriculum. Booth (2001) surveyed fourteen science teachers and found that their primary concern when using inquiry-based laboratory work was the lack of time.

Teacher beliefs. Teacher beliefs play an important role in how inquiry-based instruction is used in the classroom. It is well documented that many teachers believe that only high-ability students can complete inquiry-based activities successfully (Colborn, 2000; Costenson & Lawson, 1986; Welch, Klopfer, Aikenhead, & Robinson, 1981). Brown, Abell, Demir, and Schmidt (2006) interviewed nineteen college science professors and found that the teachers believed that inquiry-based work was a totally student-directed, unstructured, and time-consuming activity. Roehrig and Luft (2004) found in their study of fourteen beginning science teachers that these teachers believed that science was a body of knowledge that should be transmitted from teacher to student. Some teachers feel they have an allegiance to teach the facts to students and that inquiry-based instruction takes away from authentic learning (Colburn, 2000).

Lack of effective materials. For any science teacher, materials are of the essence when planning lessons. Inquiry-based materials for secondary chemistry students are scarce and it is reported that teachers have a difficult time finding inquiry materials because the market is flooded with cookbook-style modes of instruction (Cheung, 2007; 2009). Therefore, extra time and effort must be given to developing good inquiry-based lessons (Cheung, 2009; Deters,

2005). It is also important in the development of these lessons that they have a real-life application (Deters, 2005). Unfortunately, many of the experiments developed by Lechtanski (2000) are disconnected from daily life, making inquiry-based instruction that much more complex for the practicing teacher.

Pedagogical problems. Teachers may not use inquiry-based instruction due to a lack of pedagogical knowledge (Roehrig & Luft, 2004). Constenson and Lawson (1986) gave a comprehensive list of pedagogical problems a teacher may face in the classroom which includes that inquiry-based lessons require too much energy to teach; inquiry-based lessons are risky because the administration may not understand what is going on and think that the teacher is doing a poor job; and inquiry-based textbooks lock a teacher into a particular teaching sequence and the teacher cannot skip material because there is too much new material in each lesson. Teachers may have a difficult time deciding when and how they should intervene at different stages of the student's investigation of a topic (Anderson, 2002; Colburn, 2000; Furtak, 2006; Gallet, 1998). Moreover, a teacher may find it difficult to withhold information during investigations in order to maintain an atmosphere of inquiry (Furtak, 2006).

Management problems. Science teachers generally view inquiry teaching as very difficult to manage because they cannot control what is going on in the lessons (Anderson, 2002; Cheung, 2006; Colburn, 2000; Costenson & Lawson, 1986; Deters, 2005; Jones & Erik, 2007; Welch, Klopfer, Aikenhead, & Robinson, 1981). Gallet (1998) wrote about how teachers perceive inquiry-based instruction and how teachers reported an increased amount of work as well as an increase in questions as students tried several different procedures. Additionally, inquiry-based instruction in lab setting require the teachers to stay longer, require more teacher availability, and teachers reported an increasingly untidy lab (Gallet, 1998).

Large classes. When trying to be an inquiry-based teacher, the larger the class, the more logistical issues arise (Brown, Abell, Demir, & Schmidt, 2006; Cheung, 2009). Teachers in undeveloped or developing countries tend to have much larger classes than those in developed countries (Cheung, 2009). Nevertheless, a smaller class size tends to foster more of an environment of inquiry (Colburn, 2000; Cheung, 2009), although the literature does not seem to indicate what a small class size is.

In 2007, Cheung concluded through his research that there are six criteria that must be in place in order to overcome the obstacle of large classes that include (1) the laboratory work should be designed as a guided inquiry rather than an open inquiry, (2) the guided inquiry must engage students in solving real-world problems, (3) the solution to the guided inquiry should not be predictable, (4) the teacher should require a few groups of students to present their experimental plans orally so that a feasible procedure for collecting data can result from a consensus approach, (5) teacher questioning is critically important during student oral presentations, and (6) assessment criteria must be given to students in advance (Cheung, 2007).

Safety issues. Safety is a concern in the science classroom, especially in the chemistry classroom. One of the basic concepts of inquiry is that students are able to design their own learning based around the materials. Deters (2005) reported that teachers are often afraid that students may design unsafe procedures. Staer, Goodrum, and Hackling (1998) reported that teachers are concerned that the student-designed experiments would often be too dangerous and that the students might blow themselves up – a concern of many chemistry teachers.

Fear of student misconceptions. Teachers fear that, without their guidance, students may wrongly learn a concept; thus, the misconception must be corrected (Furtak, 2006). For inquiry-based laboratory work, there is a possibility that students will prepare a crude plan, arrive

at erroneous results, or fail to draw appropriate conclusions based on the results (Deters, 2005). Cheung (2006) has prepared a teacher's guide for some common chemistry labs highlighting how to teach the labs, highlighting to teach with inquiry-based instruction as well as common misconceptions students have with each lesson. This guide may help to ease fears of teachers who are concerned with misconceptions in these particular labs.

Student complaints. Students do not feel comfortable when they are asked to plan their own learning when they are usually accustomed to a detailed procedure (Anderson, 2002; Cheung, 2009; Colburn, 2000). Teachers then feel frustrated trying to get students into the mindset of inquiry and away from the dependency of having a set of instructions or specific procedures (Anderson, 2002; Costenson & Lawson, 1986; Deters, 2005; Roehrig & Luft, 2004). Changing students into inquiry-based learners will take time for both the students and teachers alike (National Science Foundation, 1996; Alabama State Department of Education, 2005).

Assessment issues. Teachers are hesitant to include inquiry-based techniques in their lessons because they are unsure about how to assess student performance (Cheung, 2009). Additionally, inquiry-based lab reports require more time to grade as opposed to worksheets or teacher made write-ups (Deters, 2005).

Material demands. The last factor, which some teachers perceive as a barrier to implementing inquiry-based laboratory work, is the need to have adequate equipment and the appropriate chemicals available at their school (Cheung, 2009). Teachers are worried that too much diversity of equipment is required and that this equipment is not always available (Staer, Goodrum, & Hackling, 1998). Teachers also believe that it is too expensive to equip the classroom and/or laboratory for inquiry-based instruction (Costenson & Lawson, 1986).

Professional Development for Inquiry-based Instruction

Overcoming the barriers to inquiry-based instruction is important for a teacher to implement inquiry-based lessons. Meaningful and effective professional development may enable teachers to understand the true meaning of inquiry (Luft, 2001). Even the best of professional development may not aid a teacher's full understanding of inquiry-based style of instruction (Luft, 2001; Sawada et al., 2002). Rushton and Lotter (2011) wrote about how teachers with traditional, lecture styles chemistry lessons are less likely and least interested in learning about inquiry-based instruction and how to implement inquiry-based instruction in the chemistry classroom.

Despite the positive value of science teaching through inquiry that is nearly universal in the literature, implementing inquiry-based instruction pedagogy has proven to be problematic (Foley & McPhee, 2008). Understanding the learning cycle and inquiry-based instruction is a difficult, complex, and abstract concept for science teachers to understand (Odom & Settlage, 1996; Marek, Laubauch, & Pedersen, 2003). Inquiry can also seem confusing and overwhelming for teachers, especially new teachers, which can impede the use of inquiry in the classroom (Wee, Shepardson, Fast, & Harbor, 2007; Wheeler, Maeng, & Bell, 2013). In order for teachers to become good practitioners of inquiry-based learning, they must learn to deliver lessons using the practices of inquiry. Professional development must be both intensive and sustained (Cheung, 2007). Anderson (2002) pointed out that while research says inquiry teaching can produce positive results, it does not, by itself, tell teachers exactly how to teach through inquiry-based instruction. Friedrichsen et al. (2006) indicated that special science education courses are needed to help prospective science teachers develop identities as inquiry-oriented teachers. Lazarowitz

and Tamir (1994) believe that it is crucial that teachers have some kind of research activity themselves in order to be able to create an investigative laboratory environment.

Conclusion

This chapter has offered a look at the literature related to inquiry, the learning cycle, 5E model, NGSS, constructivist and Social constructivist framework and chemistry instruction. The origins of chemistry and a historical look at how inquiry-based learning came into practice was outlined. A definition of what inquiry-based instruction is and the 5E model was explained as well as how the future of inquiry looks through the Next Generation Science Standards. A discussion about what inquiry-based teaching is and how inquiry-based instruction can take on various levels were discussed. A discussion about how inquiry-based instruction can influence attitudes toward chemistry was discussed. Inquiry-based instruction in chemistry was discussed as well as how inquiry-based instruction can be used in the laboratory. The eleven barrier that teachers face when deciding to use inquiry-based learning were discussed as well as the barriers teachers may face when trying to implement inquiry-based learning in the chemistry classroom. Finally, this chapter concludes with a brief discussion on how professional development could be a catalyst for implementing inquiry-based instruction in the chemistry classroom. The following chapters will describe the methodology that will be used in this study as well as a discussion of the findings and a conclusion.

CHAPTER III:
METHODOLOGY

Introduction

This chapter describes the methodology of the research study. The purpose of this study was to investigate how a teacher's level of inquiry-based instruction in a high school chemistry class can affect a student's attitude of the field of chemistry. This study also investigated how a chemistry teacher's attitude toward chemistry affects the level of inquiry-based instruction that is given. Additionally this study also seeks to understand the willingness of a chemistry teacher to use inquiry-based instruction in the classroom. Specifically, the study addresses the following questions:

1. What are the characteristics of a high school chemistry teacher based on his/her level of inquiry (high, medium, low) using the Chemistry Teacher Self-Assessment (see Appendix B) and their responses to the Chemistry Teacher Interview Questions (see Appendix C);
2. Is there a difference in student attitude about chemistry based on his/her high school chemistry teacher's level of inquiry instruction (high medium, low), as measured by the Chemistry Teacher Self-Assessment (see Appendix B), and the Chemistry Student Attitude Survey (see Appendix E);
3. How do high school chemistry teachers describe his/her willingness to use the inquiry-based approach to instruction in their classroom, as indicated by open-ended Chemistry Teacher Interview Questions (see Appendix C) during an

interview that corresponds to the Chemistry Teacher Self-Assessment (see Appendix B)?

Sample

This study employed a convenience sample to collect data that included chemistry teachers from two school districts. A convince sample was used because of the distance from the researcher. All the chemistry teachers from the two districts were asked to participate in the study. The students in the study were selected based on enrollment in a chemistry class of the teacher who chose to participate in the study. The students were first year chemistry and their ages ranged from 14-18 years of age.

Procedure

The items on the Chemistry Teacher Self-Assessment and the Chemistry Student Attitude Survey were created in Microsoft word so that a paper version could be printed. After IRB approval was granted, the researcher emailed all the chemistry teachers in the two school systems in February 2014 asking for their participation in the study. Superintendents and principals of both schools systems were e-mailed a cover letter indicating support for the research study and asking them to encourage their chemistry teachers to participate.

Once teachers indicated their interest and willingness via email to participate in the study, the teachers were supplied with consent letters to be sent home with their students for the Chemistry Student Attitude Survey. Since the students are minors, parental consent must be collected. The student letter included the purpose of the study and the right to refuse to be included in the study. Students who return a signed letter were allowed to take the survey.

The researcher then set up a time to visit the chemistry class to administer both the Chemistry Teacher Self-Assessment (see Appendix B) and the Chemistry Teacher Interview

Questions (see Appendix C) to the teacher. It took the teacher participant approximately 15 minutes to complete the surveys. While the chemistry teacher took the surveys the researcher administered the Chemistry Student Attitude Survey to the students in the chemistry course. Before the survey began, a cover letter explained that the participants have the right to withdraw from the study and the risk associated with participating in the research. It took the student participants approximately 10 minutes to complete the survey.

Teachers also were interviewed using the Chemistry Teacher Interview Questions (see Appendix C) about 5E inquiry-based instruction in their chemistry classroom. This gave the teacher an opportunity to express their views on inquiry-based teaching and learning. The researcher recorded the responses and later the teacher's responses were transcribed. The transcription was then analyzed for themes and codes from the teacher's responses. Any recordings and/or notes were kept in a secure location and participants' confidentiality was maintained.

Sample Setting

The two school systems used in the study were located in the same county in the Southeastern United States. Both school systems were chosen as a convenience sample (Creswell, 2005). The schools are located within 25 miles from the residence of the researcher.

School System One

The first school system used in the study had two high schools and both were used in the study. The student enrollment of *school system one* is 8,734 total students. There were 597 certified teachers in the school system with 29 administrators and 498 support personnel who supported these students. The two high schools consisted of 2,620 total students with 158 certified teachers between the two schools.

The first high school in this school system was the newer of the two high schools in the aforementioned system. It was started in 1962 and it was thought at the time that the school

would never become as large as it is today. The school is an open-air campus that is comprised of thirteen different buildings on its campus. The student enrollment of this school at the time of the study was 1,529 students. There were 91 certified staff, 4 counselors, 2 librarians, 3 assistant principals, and one principal. Of the 91 certified staff, 12 were certified to teach science (6 of whom taught chemistry).

The second high school in this system is located in one of the older, but more affluent parts of the city. This site is one large, brick, two-story school building. This school at the time of the study had a student population of 1,091 students. There were 67 certified staff, 4 counselors, 2 librarians, 3 assistant principals, and one principal. Of the 91 certified staff, 8 were certified to teach science (3 of whom taught chemistry).

School System Two

The second school system used in the study has five high schools and are all used in the study. The student enrollment of the school system two is 7,723 total students. There were 499 certified teachers in the school system with 26 administrators and 465 support personnel who supported the students. The five high schools from the *school system two* used in the study consist of 10,482 students with 156 certified teachers between the two schools.

The first high school had a student enrollment of 863 students. There were 57 certified staff, 2 counselors, 1 librarian, 2 assistant principals and 1 principal. Of the 57 certified staff, 5 were certified to teach science (1 of whom taught chemistry).

The second high school had a student enrollment of 418 students. There were 27 certified staff, 1 counselor, 1 librarian, 1 assistant principal, and 1 principal. Of the 27 certified staff, 3 were certified to teach science (1 of whom taught chemistry).

The third high school had a student enrollment of 403 students. There were 24 certified staff, 1 counselor, 1 librarian, 1 assistant principal and 1 principal. Of the 24 certified staff, 4 were certified to teach science (1 of whom taught chemistry).

The fourth high school had a student enrollment of 445 students. There were 28 certified staff, 1 counselor, 1 librarian, 1 assistant principal, and 1 principal. Of the 28 certified staff, 3 were certified to teach science (1 of whom taught chemistry).

Lastly, the fifth high school had a student enrollment of 353 students. There were 20 certified staff, 1 counselor, 1 librarian, 1 assistant principal, and 1 principal. Of the 20 certified staff, 3 were certified to teach science (1 of whom taught chemistry).

Table 1

Site Demographics

School Site	Student Enrollment	Faculty	Certified Science Faculty	Chemistry Teachers
System One				
School 1	1,529	91	12	6
School 2	1,091	67	8	3
System Two				
School 1	863	57	5	1
School 2	418	27	3	1
School 3	403	24	4	1
School 4	445	28	4	1
School 5	353	20	3	1
Totals	5,102	314	39	14

Instrumentation

Chemistry Teacher Self-Assessment

An instrument for high school chemistry teachers was revised based on the Science Learning Cycle Lesson Plan Rubric instrument developed by Goldston, Day, Sundburg, and

Dantzler (2010) and the Science Teacher Inquiry Rubric (STIR) developed by Beerer and Bodzin (2004). In 2010, Goldston, Day, Sundburg, and Dantzler developed a rubric for assessing 5E Learning Style Lesson Plans. This rubric was designed for observers to assess a 5E lesson plan while the teacher was giving instruction. In 2003, the Science Teacher Inquiry Rubric (STIR) was created for elementary science teachers. This instrument was developed to serve as a self-assessment tool for elementary school teachers to understand how they implement the essential features of inquiry into their classroom (Beerer & Bodzin, 2004).

The Chemistry Teacher Self-Assessment (see Appendix B) is a 20-question, Likert type self-assessment of a teacher's use of inquiry-based instruction. Questions consist of items that would assess a teacher's use of inquiry-based instruction in chemistry using five subscales, which include *engage*, *explore*, *explanation*, *elaborate*, and *evaluate*. An engaging question would ask about how a teacher engages a student's prior knowledge before a lesson begins. An example of an engagement subscale question from this instrument is "I have students make predictions, estimations, and/or hypotheses about the lessons topic."

An exploration subscale question on the survey assesses how a teacher allows students to gather evidence about the topic. An example of an exploring subscale questions would be "when I conduct my lessons I encourage my students to seek and value alternative modes of problem solving."

An explanation subscale question would assess how a teacher uses inquiry-based instruction to have the students explain the subject matter in the student's own words. An example explanation question would be "I consistently ask open-ended questions to encourage students to think at higher levels."

In the elaboration subscale, teachers are asked how often they ask students to find real-world applications about the subject matter. Lastly, in the evaluation subscale, teachers are asked how they evaluate students and if evaluations are multi-faceted. “I use open-ended questions to assess student learning” could be asked as part of the evaluate section. The overall goal of the Chemistry Teacher Self-Assessment is to capture the level of inquiry-based instruction a teacher is providing. A teacher may not employ inquiry-based instruction every day but they may be overall an inquiry-based teacher. A high overall score on the inventory indicates a high level of inquiry-based instruction and a low overall score indicates a more traditional approach to instruction.

Chemistry Teacher Interview Questions

Open-ended questions on the Chemistry Teacher Interview questions (see Appendix C) were created based on the Chemistry Teacher Self-Assessment (see Appendix B) and the reported literature on teacher barriers to inquiry-based instruction (Cheung, 2009; Deters, 2005). The questions were chosen to further capture the data of why a teacher in chemistry may or may not use inquiry-based instruction in the chemistry classroom. The nine, open-ended questions (see Appendix B) were asked through interviewing the teacher individually. The chemistry teacher’s responses allowed a thick and rich description to further understand the type of instruction a chemistry teacher may decide to choose to use in their lessons.

Chemistry Student Attitude Survey

The Chemistry Student Attitude Survey (see Appendix E) was created for this study to capture the attitudes of high school students after being in their first chemistry course. The Chemistry Student Attitudes Survey was created based on instruments developed for college chemistry students by Coll, Dalgety, and Salter (2002) and a middle school science survey

developed by Gibson and Chase (2002). The Chemistry Student Attitudes Survey created consists of 10 questions and a 5-point Likert scale.

The Chemistry Opinion Survey, a 10-question, 5-point Likert scale instrument, was given to the students to gauge their attitudes of chemistry after their first semester in a high school chemistry class. Sample questions that were on the instrument included “chemistry lessons are boring” and “I look forward to going to chemistry class.” This questionnaire takes elements of both the Science Opinion Survey and the CAEQ and makes a shorter, more concise instrument for high school students.

Validity and Reliability

Reliability refers to the degree of consistency of the scores over repeated administrations (Crocker & Algina, 1986). Validity refers to the degree that an instrument or method measures what it is supposed to measure (Creswell, 2009). It is important to measure the level of consistency across the construct being measured (Creswell, 2009). When one modifies an instrument or combines instruments in a study, it is important to re-establish validity and reliability of the newly formed instrument (Creswell, 2009, p 150). In this study, the reliability of the revised instruments was estimated using Cronbach’s alpha, an index of internal consistency that provides information on how consistently the participants perform across the survey items. To establish face validity, each instrument was sent to experts in the field of chemistry as well as statistical experts to review the content, format, and clarity of each instrument. Detailed information regarding establishing reliability and validity are provided below for each instrument.

Chemistry Teacher Self-Assessment and Chemistry Teacher Attitude Survey

After developing the Chemistry Teacher Self-Assessment (see Appendix B) and the Chemistry Teacher Attitude Survey (see Appendix C), the instruments were sent to an expert in the content field and two measurement experts for validity testing. Also, a chemistry specialist from Alabama Science in Motion (ASIM) reviewed the instrument before it was given to ensure the questions captured the data of inquiry-based instruction. The reviewer provided feedback on the surveys wording and format and whether the survey was appropriate for the sample. In addition, the reviewer called attention to any difficulties that were not anticipated by the researcher. Additionally, a measurement expert also reviewed the instrument and made recommendations for the survey as needed before it was administered. Additionally, two high school chemistry teachers were given the survey to assess for any questions or gaps the survey may have. All of these steps helped to establish the content validity of the revised instrument in order to ensure that it would serve as a useful measurement (Crocker & Algina, 1986, p. 218). As mentioned previously, Cronbach's coefficient alpha was used to assess reliability and the Chemistry Teacher Self-Assessment had a value of .914 which indicates a high reliability factor (Crocker & Algina, 1986).

Questions from the Chemistry Teacher Self-Assessment and from the literature (Cheung, 2009; Deters, 2005) were used to guide the open-ended questions for the Chemistry Teacher Interview Questions (see Appendix C). Three techniques were used to ensure reliability of the interview data. First, the researcher provided a detailed account of the interviews, the researcher's role, and the informant's position and basis for selection. Next, triangulation of the data was used to strengthen the reliability as well as internal validity. Finally, member checking

was used to check for reliability to ensure that a clear and accurate picture of the informants was captured during the interview (Creswell, 2009).

Chemistry Student Attitude Survey

After developing the Chemistry Student Attitude Survey (see Appendix E), it was sent to several experts in the content field and measurement experts for validity testing. The same procedures for establishing reliability and validity discussed earlier in the Chemistry Teacher Self-Assessment section will be used. Additionally, a small group of high school chemistry students was given the survey to assess for any questions or gaps the survey may have. Cronbach's coefficient alpha was used to assess reliability and the Chemistry Student Attitude Survey had a value of .605 which indicates a moderate reliability (Crocker & Algina, 1986).

Research Design

A cross-sectional design was used to examine the research questions in this study. A cross-sectional design is the most predominate in survey research (Frankfort-Nachmias & Nachmias, 1996). Cross-sectional design allows data to be obtained at one point in time, but from different groups of different ages and/or at different stages of development (Gail, Gail, & Borg, 2007). The main advantages of cross-sectional studies are that they may be carried out in natural settings and may permit the researcher to use random probability samples (Frankfort-Nachmias & Nachmias, 1996).

Surveys can be useful when a researcher wants to collect data on phenomena that cannot be directly observed (Creswell, 2009). A scheduled-structured interview survey was used to capture the data from both the students and the teachers. In a scheduled interview, the number of questions and the wording of the questions are identical for all respondents (Frankfort-Nachmias & Nachmias, 1996). The choices of answers to the questions are close-ended and standardized

in the order in which questions are asked of survey respondents, so the questions are always answered within the same context (Frankfort-Nachmias & Nachmias, 1996). A scheduled-structure survey allows for consistency among all respondents minimizing the impact of context effects, where the answers given to a survey question can depend on the nature of preceding questions (Frankfort-Nachmias & Nachmias, 1996; Gail, Gail, & Borg, 2007).

Scheduled-structured interviews with open-ended questions were used to further investigate the phenomena why a teacher may or may not choose to employ inquiry-based instruction in the chemistry classroom. The interviews were used to capture information that would help to better tell the story about the teacher's decisions to use inquiry-based instruction. For a structured interview, it is usually necessary for researchers to develop an interview schedule, which lists the wording and sequencing of questions. This was accomplished by using the pre-written qualitative questions found in Appendix E. Structured interview questions are a means by which researchers can increase the reliability and credibility of research data (Creswell, 2009). The teachers who participated in the Teacher Self-Assessment Survey also participated in the interview questions.

Data Analysis

The following data management plan describes the plan for data analysis for each research question. The data management plan can be found in Appendix G.

Research Question 1

“What are the characteristics of a high school chemistry teacher based on their level of inquiry (high, medium, low) from the Chemistry Teacher Self-Assessment and their responses to the Chemistry Teacher Interview Questions?” To answer this question, the teachers were placed into one of three groups (high, medium, or low) of inquiry based on their answers on the

Chemistry Teacher Self-Assessment. The group's responses to the Chemistry Teacher Interview Questions were examined for themes and codes within the groups. Characteristics of the teachers were reported based on their level of inquiry and their responses to the interview questions.

Research Question 2

“Is there a difference in student attitude about chemistry based on their high school chemistry teacher's level of inquiry instruction (high medium, low), as measured by the Chemistry Teacher Self-Assessment, and the Chemistry Student Attitude Survey?” To answer this question, the analysis was Analysis of Covariance (ANCOVA) with the teacher's years of experience serving as the covariate.

Analysis of covariance (ANCOVA) is a general linear model that combines ANOVA and regression (Hinkle, Wiersma, & Jurs, 2003). ANCOVA evaluates whether population means of a dependent variable are equal across levels of a categorical independent variable while statistically controlling for the effects of other continuous variables that are not of primary interest, known as covariates (Hinkle, Wiersma, & Jurs, 2003). ANCOVA can be used to reduce within-group error variance as well as to eliminate any confounding variables that may exist (Gail, Gail & Borg, 2007).

Power Analysis

A power analysis was estimated to determine the minimum size of the sample required to detect group differences if any existed. This estimate takes into consideration the number of groups involved, the probability of rejecting the null hypothesis when the null hypothesis is false (i.e., power = $1 - \beta$), and an estimate of the treatment effects.

For research question 2, the estimated minimum sample size per group was estimated based on a power of .80 for a medium effect size ($d = .5$) at the .05 level of significance.

According to Maxwell & Delaney (2004), the minimum sample size for each group is 79, for a total sample size of $N = 237$.

Research Question 3

“How do high school chemistry teachers describe their willingness to use the inquiry-based approach to instruction in their classroom, as indicated by open-ended questions during an interview that correspond to the Chemistry Teacher Self-Assessment?” The teacher’s responses were recorded and analyzed for patterns of emerging themes and categories. A rich, thick description of the interviews was transcribed and reported while attempting to understand themes and categories from the data.

Sample size for this part of the study is small due to the specialized nature of the participants being studied. At best, 14 chemistry teachers are in the two school systems being studied. Creswell (2007) asserted that in qualitative research that it is acceptable to study few participants; however, it is important to collect extensive, detailed accounts of the participants.

Creswell (2009) stated that the typical analytic procedures for qualitative data fall into four steps: (1) organizing the data; (2) reading and re-reading the data for understanding of what the participants are saying; (3) generating categories, themes, and patterns; (4) search for explanations from the patterns, themes, and categories. The qualitative data from the interviews were about the teacher’s willingness to use inquiry-based instruction in their chemistry lessons and more specifically teaching chemistry using the 5E Instructional Model.

After the interviews were conducted, they were transcribed into written format. All interviews were read numerous times to ensure that the researcher understood exactly what the participants were expressing in the interview. The participants’ responses to each interview question were coded according to the theme of the response. For example, if the participants

talked about training, the words ‘training’ were coded for that question. Similarly, when the participants talked about ‘science in motion’ the words ‘resources’ were coded for this theme.

Conclusion

This chapter has described the methodology for this study that includes the research design. Both qualitative and quantitative data were collected because the qualitative data helps to understand the quantitative data. This chapter also has described the rationale for the study’s design and has described the strategies the researcher intends to engage for data collection and data analysis procedures. Chapter IV will provide the results of the study and Chapter V will be a discussion about the results as well as recommendations for further investigation and researcher reflections about the study.

CHAPTER IV:

RESULTS

The use of inquiry-based instruction in high school chemistry has been recommended; however, there have been very few empirical studies that examine its benefits and teachers willingness to use this type of instruction. The purpose of the study was to explore the relationship between a high school chemistry teacher's inquiry-based approach to instruction and their student's attitudes about chemistry. This study also explored how a teacher's attitude about chemistry is related to the use of inquiry-based instruction. Lastly, this research investigated the factors that affect a high school chemistry teacher's willingness and ability to use the inquiry-based approach to instruction in their classroom.

The following research questions that were proposed for this study were:

1. What are the characteristics of a high school chemistry teacher based on their level of inquiry (high, medium, low) from the Chemistry Teacher Self-Assessment and their responses to the Chemistry Teacher Interview Questions;
2. What are the differences in student attitude about chemistry based on their high school chemistry teacher's level of inquiry instruction (high, medium, low), as measured by the Chemistry Teacher Self-Assessment, and the Chemistry Student Attitude Survey; and
3. How do high school chemistry teachers describe their willingness to use the inquiry-based approach to instruction in their classroom, as indicated by open-

ended Chemistry Teacher Interview questions during an interview that corresponds to the Chemistry Teacher Self-Assessment?

This chapter presents the results of both the student and teacher questionnaires and answers to the research questions. This chapter will begin with some descriptive statistics about the participating teachers and then each research questions will be examined. Research questions one and three employ the use of qualitative analysis while research question two will be using a quantitative approach to understand the data. The qualitative and quantitative data work together to strengthen one another. The combination of qualitative and quantitative data can improve the evaluation of the study participants' responses (Creswell, 2009).

Research Question 1

This section will explore the research question “What are the characteristics of a high school chemistry teacher based on their level of inquiry (high, medium, low) from the Chemistry Teacher Self-Assessment and their responses to the Chemistry Teacher Interview Questions?” This section will include teacher participant demographics, a description how the teachers were identified as having a low, medium, or high level of inquiry-based instruction, and discuss the characteristics of each level.

Teacher Participant Demographics

There were nine teachers who agreed to take part in the study. The sample size is similar to that of Cheung (2009) who had 7 teachers in his study. Of the 9 teachers, 5 were female (56%) and 4 were male (44%). Their years of experience ranged from nine years of experience to thirty-four years of experience. The participants were from the same county but taught either in a city or county school system. The number of chemistry courses taught during the 2013-14 school

year ranged from one to four chemistry classes per day. Table 2 outlines the teacher's demographics.

Table 2

Teacher Participant Demographics

Teacher Participant	Type of School System	Years of Experience	Gender	Chemistry Courses Taught During 2013-14 School year
1	City	14	Male	3
2	City	20	Female	2
3	City	17	Female	3
4	City	15	Male	2
5	County	9	Female	1
6	City	34	Female	3
7	County	28	Male	3
8	County	21	Female	4
9	County	10	Male	1

Chemistry Teacher Self-Assessment Survey

Nine teachers took the Teacher Self-Assessment Survey. The data were collected and tallied such that the teacher participants would have an overall self-assessment score for data analysis. On a scale ranging from 20-100, with 100 equaling 100% 5E inquiry-based, the scores for the teachers ranged from 54 to 96. For data analysis purposes the teachers were placed into three groups of low, medium, or high inquiry-based teachers according to their reported frequency of implementation of the 5E approach on the survey. Following is a description of characteristics of the practices teachers at each of the three levels of inquiry demonstrate.

Low inquiry-based teacher practices. A low inquiry-based teacher would be a teacher who reported on the survey that he/she does not frequently elicit the students prior knowledge while teaching, a high portion of their classroom time is lecture, has a limited use of lab and/or activities to assist in teaching the chemistry lesson, does not allow the students much time to discuss, reflect, and collaborate about lessons and chemistry concepts with other students, frequently use multiple choice questions for assessment, uses of science note booking and/or science portfolios is limited, and little time is spent by the students and the teacher reflecting on the learning standards. For data analysis and grouping purposes, a score of 54 and 56 will be identified as low level of inquiry indicating that the teachers reported using 5E inquiry-based instruction at least 50% or less of the time during instruction.

Medium inquiry-based teacher practices. A medium inquiry-based teacher does more than the low inquiry-based teacher but could still use some refining in their practice to bring the best inquiry-based lessons and investigations to their chemistry classroom. A medium inquiry-based teacher tries to bring in the students prior knowledge, allows some discussion and reflection time and may have a varying amount of open and closed ended questions. A medium inquiry-based teacher still lectures often but may also try other modes of delivery. A score of 71, 72, 79 will be identified as medium level of inquiry because this indicates the teachers reported using 5e inquiry-based instruction at least 70% of the time in their instruction

High inquiry-based teacher practices. High inquiry-based teachers allow time for students to discuss, reflect, and collaborate about the lesson and allow for learning to take place in small groups. High inquiry-based teachers limit the time they lecture and aim to integrate activities and labs into their lessons to help enhance the learning experience and also use science note booking and portfolios as a reflective piece to the 5E inquiry learning cycle. Lastly, a score

of 80, 86, and 96 will be identified as high level of inquiry indicating the teachers reported using 5E inquiry-based instruction a minimum of 80-90% of the time in their instruction.

These three groupings will assist in answering the research questions in this study. A summary of the teacher participant scores can be found in Table 3 and a frequency table and percentage summary of the entire Chemistry Teacher Self-Assessment Survey can be found in Appendix G.

Table 3

Chemistry Teacher Inquiry-based Level

Teacher Participant	Score	Level (High, Medium, Low)
1	86	High
2	72	Medium
3	71	Medium
4	80	High
5	56	Low
6	86	High
7	54	Low
8	96	High
9	79	Medium

There were four teachers who were identified as having a high level of inquiry-based instruction, three teachers who were identified as having a medium level of inquiry-based instruction and two who were identified as having a low level of inquiry-based instruction. The data from the interview questions were separated into the three groups (low, medium or high) according to their self-assessment score and the groups were examined for characteristics.

Chemistry Teacher Interviews

Below is the analysis of the Chemistry Teacher Interview Questions along with their level of inquiry-based instruction (high, medium, or low). Four themes were present from all of the interviews and will be discussed below: experiences and use of 5E inquiry-based model, time, professional development, and Alabama Science in Motion.

Experiences and use of 5E inquiry-based model. There was no evidence that indicated that years of experience influenced the teacher's level of inquiry-based instruction. The years of experience from the low inquiry group ranged from 9-28 years of experience, medium group ranged from 10-20 years of experience and the high group ranged from 9 to 34 years of experience. Gender, also, did not play an important role.

From the interview questions, there were some common threads among the groups. All nine of the teachers report that their college chemistry class was primarily lecture based with a required lab component attached to the course. The low inquiry-based group lab did not seem to have a practically enjoyable college lab experience. "Labs in college were long and tedious and thank goodness for my lab partner who did most of the work," reported a teacher in the low inquiry group. The high group reports that lab was more of an enjoyable experience and discusses in their interview the importance of lab in learning chemistry. "Chemistry labs were one of the most fun experiences because it made learning the material easier," reported one of the teachers in the high inquiry group.

It appeared from that data that all three groups, overall, enjoy lab work. There was only one teacher who was very adamant about not enjoying doing labs with the students nor did he enjoy labs in college. Interestingly, this teacher scored lowest on the Chemistry Teacher Self-Assessment.

Time. All teachers agreed that “time” was an important factor in whether or not they used the 5E model of inquiry-based instruction. Both of the teachers in the high inquiry-based group assert that they use the 5E model of inquiry-based instruction, but do not think about it in their lesson plans. “I think that inquiry instruction takes a lot more time and we do not always have a lot of time to do activities” reported one of the teachers in the low inquiry-based instruction group.

Professional development. As for professional development the three groups held different opinions. The low inquiry-based group reports that they do not need any additional professional development with the 5E model of inquiry-based instruction however the medium and high groups reports that they would like more professional development with 5E. The high group seemed open to learning new strategies to take to the classroom. Their attitudes were more open to learning and focused on how they could ensure student success. The low group felt they had the years of experience and know how to effectively teach using inquiry-based methods and had no interest in further professional development.

Alabama Science in Motion. Lastly, seven of the nine teachers mention that they have had training in 5E instruction in Alabama Science in Motion trainings. Three of teachers in the middle inquiry-based group as well as one teacher in the high inquiry-based group believe that the workshops should be focused more on “make and take activities” and this would make the training more desirable. Teachers indicated that they do not need any more training notebooks but rather desire a product they can take back to their classroom and put into practice. One participant indicated, “I have enough notebooks, we get them all the time at all the seminars we go to. I bring them back and they get put on the shelf – give me something at a seminar I can use.

Not another notebook.” Other participants shared the idea that they are inundated with notebooks of labs and information that is used very little if at all by the teacher.

Research Question 2

This section will explore the research question “What are the differences in student attitude about chemistry based on their high school chemistry teacher’s level of inquiry instruction (high medium, low), as measured by the Chemistry Teacher Self-Assessment, and the Chemistry Student Attitude Survey?” This section will include student participant demographics and an analysis of the data using Analysis of Covariance (ANCOVA) analysis.

Student Participant Demographics

Students from the nine teacher’s classes were invited to participate in the Chemistry Student Attitude Survey. Those who returned the signed parental permission form and also signed the student assent form took the survey. There were 192-student participants from 7 different high schools. There were 107 female students (56%) and 85 male students (44%) who participated in the student survey. The grade level of the students ranged from 10-12th grade with 54% of the students from 10th grade, 36% from 11th grade, and 10% from 12th grade. Table 4 provides a summary of the demographics.

Table 4

Student Demographics

Teacher Participant	Female	Male	Total
10 th grade	63 (61%)	40 (39%)	103 (54%)
11 th grade	41 (59%)	29 (41%)	70 (36%)
12 th grade	6 (32%)	13 (68%)	19 (10%)

Information from the survey reveals chemistry students attitudes about chemistry after a year in chemistry. The survey was a 5-point Likert Type Scale (strongly agree, agree, neither agree or disagree, disagree, strongly disagree). The survey reveals that the students do enjoy chemistry lab ($M= 1.65$, Mode=1) and that chemistry labs help them understand the material ($M=1.94$, Mode =1). The students agreed with the idea that chemistry is important in everyday life ($M=2.40$, Mode=2) and the students like it when the teacher makes the learning applicable to everyday life ($M=1.69$, Mode=1). Table 5 provides the means responses of each survey item. A frequency table and percentage summary of the Chemistry Student Attitude Survey can be found in Appendix H.

Table 5

Survey Response Means (n=192)

Survey Questions	Mean	Std. D.	Mode
Chemistry lessons are boring.	3.34	1.25	4
I would like to learn more about chemistry.	2.56	1.11	2
I look forward to going to chemistry class.	2.76	1.32	2
I do not enjoy chemistry labs.	4.10	1.15	5
I wish we did more labs and hands-on activities in chemistry class.	1.65	.98	1
A career as a chemist would be interesting to me.	3.30	1.20	4
Chemistry classes I take in the future will be interesting to me.	2.81	1.09	3
Choosing a career that required chemistry courses would make me reconsider my career choice.	3.45	1.18	4
Chemistry labs help me to understand the material covered in class.	1.94	1.09	1
I enjoy sharing data from experiments with other students.	2.47	1.03	1
My thoughts and ideas are valued in my chemistry class.	2.50	1.21	2
I believe there is more than one way to answer a question.	1.85	.86	2
I enjoy chemistry lab when I have to make my own procedure.	2.66	1.16	2
I like with when I can extend what I have learned in chemistry class to real world ideas.	1.90	1.00	3
I like with when my teacher connects what I know to what we are about to learn.	1.69	.77	1
Chemistry can be useful for solving everyday problems.	2.40	1.11	2

1=Strongly Agree, 2=Agree, 3=Not Sure, 4=Disagree, 5=Strongly Disagree

Analysis of Covariance (ANCOVA)

The analysis of covariance (ANCOVA) was proposed to answer this research question. The dependent variable in this case will be student attitude score; independent being the teacher's level of inquiry (high, medium, or low) and the covariate was the teacher's year's chemistry teaching experience. The assumptions for this analysis, in order to make inferences back to the population, require that (1) the subjects are independent of one another, (2) the scores are normally distributed in the population, (3) the variances are equal across groups, (4) homogeneity of regression slopes, and (5) there is a linear relationship between the dependent variable and the covariate (Gail, Gail, & Borg, 2007).

Assumptions were first assessed before the ANCOVA was run. First, the assumption of independence was satisfied due to the lack of dependence or relationship among the participants. Second, the statistical tests of normality assume that the dependent variable (*student attitude score*) is normally distributed in the population. A visual check of the histogram was assessed for normality. The mean and median of the dependent variable ($M = 37.70$ and $Mdn = 36.50$) were approximately equal, which indicates that the distribution is approximately normally distributed. Normality was also examined based on the criteria that the skewness and kurtosis of the dependent variable fell within the acceptable range from -1.0 to +1.0 (Gall, Gall, & Borg, 2007). Both of these test supported the assumption of normality for the *student attitude score* variable.

Levene's test for variance was used to assess the assumption that the variances between the three groups (high, medium, and low inquiry-based teachers) were the same. Levene's test revealed $F(2, 189) = .791, p = .455$. Because the observed p -value is greater than an alpha of

.10 for this test, the assumption of homogeneity of variances was also met. These findings support equal variances between the three groups.

Next, the assumption of homogeneous regression slopes was assessed. The significance of the interaction term was tested to evaluate this assumption. This tests whether the relationship between the number of years of chemistry teaching experience (covariate) and teacher inquiry score (independent variable) was the same among the groups. The results revealed $F(2, 186) = .717, p = .489$. This indicates that the relationship is the same among the three groups (i.e., $p > \alpha$) and that the interaction term can be removed from the model. Table 6 shows the findings from of the interaction.

Table 6

ANCOVA Interaction Table

	Type III SS	df	MS	F	Sig	Eta Squared	Observed Power
Corrected Model	240.866	5	48.173	.460	.806	.012	.172
Intercept	33517.826	1	33517.826	319.813	.000	.632	1.000
Teacher Group	103.692	2	51.846	495	.611	.005	.130
Years of Experience	160.364	1	106.364	1.530	.218	.008	.234
Teacher Group*							
Years of Experience	150.349	2	75.175	2.717	.489	.008	.170
Error	19493.613	186	104.804				
Total	292592.000	192					
Corrected Total	19734.479		191				

The purpose of including a covariate in the model may be for two reasons. First, the ANCOVA analysis will attempt to adjust the dependent variable (*student attitude scores*) based on any differences present in the covariate (*years of chemistry teaching experience*). The second

purpose is to have a powerful statistical test and reduce the error variance. The researcher may choose to exclude the covariate if the relationship is not statistically significant. The test results revealed $F(1, 188) = .416, p = .520$. Table 7 shows the results of the ANCOVA test. The effect size, eta squared, revealed .003, which is indicative of a very small effect size based on the Cohn's guidelines (Hinkle, Wiersma, & Jurs, 2003). This value indicates that less than one percent of the variance in student attitudes, .3%, can be explained by the teacher's level of inquiry-based instruction.

Table 7

ANCOVA Table

	Type III SS	df	MS	F	Sig	Eta Squared	Observed Power
Corrected Model	90.517	3	30.	.28	.833	.005	.105
Intercept	40998.263	1	40998.26	392.369	.000	.676	1.000
Years of Experience	43.461	1	43.461	.416	.520	.002	.098
Teacher Score	61.181	188	30.590	.293	.747	.003	.096
Error	19643.963	188	104.804				
Total	292592.000	192					
Corrected Total	19734.479	191					

This indicated that there was no linear and statistically significant relationship between years of experience teaching chemistry and students attitude scores therefore it is not likely that including this variable in the model would reduce the error variance. Therefore, the covariate was removed from the model and the analysis of variance (ANOVA) test might be the better test to answer the research question.

Analysis of Variance (ANOVA)

To determine if there were mean differences between the high, medium and low level of inquiry based instruction and the student attitude scores an ANOVA test was conducted. First, the following three assumptions were tested for the ANOVA model: independence, normality, and equal variances (Gall, Gall & Borg, 2007). The assumption of independence was satisfied due to the lack of dependence or relationship among the participants. The mean and median of the dependent variable (*student attitude score*) ($M = 37.70$ and $Mdn = 36.50$) were approximately equal. Normality was also examined based on the criteria that the skewness and kurtosis of the dependent variable fell within the range from -1.0 to +1.0. Both of these test supported the assumption of normality for the roles variable. The Levene's test revealed $F(2, 189) = 1.093$, $p = .337$. These finding supports equal variances between the two groups.

The *student attitude score* in all three groups were approximately the same; high inquiry based group ($M = 37.84$, $SD = 9.42$), medium inquiry-based group ($M = 37.99$, $SD = 10.36$), and low inquiry-based group ($M = 36.58$, $SD = 11.681$). The results of the ANOVA test indicate $F(2, 188) = .226$, $p = .798$. Table 8 shows the results of the ANOVA test.

Table 8

ANOVA Table

	SS	df	MS	F	Sig	Eta Squared	Observed Power
Between Groups	47.056	2	23.528	.226	.798	.002	.085
Within Groups	19687.424	189	104.166				
Total	19734.479	191					

The results indicated that there was no difference in the student attitude in chemistry score based on their teacher's level of inquiry-based instruction (low, medium, high) as

measured by the Teacher Inquiry Chemistry Teacher Self-Assessment. These findings support, at alpha .05, there is no statistically significant differences between student attitude scores and the level of inquiry-based instruction their teacher may use. The effect size, eta squared, revealed .002, which is indicative of a very small effect size based on the Cohn's guidelines (Hinkle, Wiersma, & Jurs, 2003). This value indicates that less than one percent of the variance in student attitudes, .2%, can be explained by the teacher's level of inquiry-based instruction.

Research Question 3

This research question explores a high school chemistry teacher's willingness to use the inquiry-based approach to instruction in their classroom, as indicated by open-ended Chemistry Teacher Interview questions during an interview that corresponded to the Chemistry Teacher Self-Assessment.

This section will include a positionality statement from the researcher. It is important to understand the background of the researcher and how that may influence the way he reads and interprets the data. Next this section will include a brief biography of each of the nine teacher participants so that the reader can understand each teacher's background. The participants have been given a pseudonym to protect their identity and to conform to confidentiality policies. Following the biography will be a section on the themes and codes from the interviews.

Positionality

As the researcher in this study, I am currently a chemistry teacher in one of the school districts that was used in the study. I have taught in this school system for ten years and have taught chemistry for a total of fifteen years. I also have participated in Alabama Science in Motion (ASIM) summer training program and as the teacher facilitator of the Chemistry Professional Learning Group. As a chemistry teacher, I was introduced to the idea of inquiry-

based learning at an ASIM seminar and my interest grew in classes that discussed inquiry. My interest in inquiry-based learning increased when I realized that little research in the field of chemistry and inquiry-based learning existed. The research conducted on chemistry and inquiry-based instruction has allowed me to (a) fulfill my degree obligations (b) improve my own teaching practice and (c) add to the gap in the literature for chemistry instruction.

Participant Biography

Participant 1 – Mr. Edwards

Mr. Edwards is a teacher within a city school district in the southeast United States. The high school where he teaches has 1383 total students and is 65.76% free and reduced lunch. This school is a 9th -12th grade high school that is on an alternating block schedule. He has 14 years of experience teaching chemistry and physical science. During his time teaching, he has taught multiple levels that include: special education students, English as Second Language (EL) students, regular education students, honors students, and Advanced Placement (AP) Chemistry. During the 2013-14 school year, Mr. Edwards taught three classes of chemistry, two classes of honors chemistry, and one in physical science. His score on the Chemistry Teacher Self-Assessment was 86 and has been identified as a high inquiry-based instruction teacher. In addition to teaching, Mr. Edwards has administrative duties on a myriad of committees and initiatives that are in the school.

Participant 2 – Mrs. Flowers

Mrs. Flowers is a teacher within a city school district in the southeast United States. The high school where she teaches has 1383 total students and is 65.76% free and reduced lunch. This school is a 9th -12th grade high school that is on an alternating block schedule. She has 25 years of experience teaching, 20 of which she has taught only chemistry and physics. During her

time teaching, she has taught only regular education students or honors students. It was only this year that Mrs. Flowers had EL students in her chemistry classes and this was a challenge for her teaching practice. During the 2013-14 school year, 2 of her 6 courses were chemistry, three physics courses, and one period for athletics. Mrs. Flowers has been a volleyball coach for 20 of her 25 years. Her score on the Chemistry Teacher Self-Assessment was 72 and has been identified as a medium inquiry-based instruction teacher.

Participant 3 – Mrs. Coffee

Mrs. Coffee is a teacher within a city school district in the southeast United States. The high school where she teaches has 956 students and is 59.52% free and reduced lunch. This school is a 9th-12th high school that is on an alternating block schedule. She has 17 years of experience teaching chemistry, physical science, and earth and space science. She has taught special education students, EL students, and regular education students. During the 2013-14 school year, 3 of her 6 courses taught were chemistry, while the other classes were earth and space. Her score on the Chemistry Teacher Self-Assessment was 71 and has been identified as a medium inquiry-based instruction teacher.

Participant 4 – Mr. White

Mr. White is a teacher within a city school district in the southeast United States. The high school has 1383 total students and is 65.76% free and reduced lunch. This school is a 9th-12th school that is on an alternating block schedule. He has 15 years of experience teaching chemistry, physical science, and environmental science. He has taught special education students, EL students, and regular education students, honors students, and Advanced Placement chemistry. Mr. White has teaching experience in the United States and also in the United Kingdom. During the 2013-14 school year, 2 of his 6 courses taught were chemistry, 3 were

physical science, and 1 was AP chemistry. On the Chemistry Teacher Self-Assessment, Mr. White scored an 80 and has been identified as a high inquiry-based instruction teacher.

Participant 5 – Mrs. Delano

Mrs. Delano is a teacher within a county school district in the southeast United States. The high school where she teaches has 424 students and is 46.93% free and reduced lunch. This school is a 9th-12th grade school that is on an alternating block schedule. She has 9 years of experience teaching biology, chemistry, physical science, and marine science. She has taught special education students, EL students, and regular education students. During the 2013-14 school year, 1 of her 6 courses taught were chemistry, 2 were physical science, 1 biology, and 1 was marine science. On the Chemistry Teacher Self-Assessment, Mrs. Delano scored a 56 has been identified as a low inquiry-based instruction teacher. Mrs. Delano stays busy outside of school with two very active middle school boys who participate in fall and spring sports.

Participant 6 – Mrs. Brewer

Mrs. Brewer is a teacher within a city school district in the southeast United States. The high school where she teaches has 956 total students and is 59.52% free and reduced lunch. This school is a 9th-12th school that is on an alternating block schedule. She has 34 years of experience teaching chemistry, physical science, and physics. She has taught special education students, EL students, and regular education students, honors students, International Baccalaureate (IB) and AP Chemistry. During the 2013-14 school year, 3 of her 6 courses taught were chemistry, 2 were physics, and she was assigned one class period for administrative duties as the department chair. On the Chemistry Teacher Self-Assessment, Mrs. Brewer scored an 86 has been identified as a high inquiry-based instruction teacher. Mrs. Brewer plans to teach one more year and then retire.

Participant 7 – Mr. Mickle

Mr. Mickle is a teacher within a county school district in the southeast United States. The high school where he teaches has 901 total students and is 53.11% free and reduced lunch. This school 9th -12th grade school that is on a 7-period day. He has 28 years of experience teaching biology, chemistry, physical science and middle school science. He has taught special education students, EL students, and regular education students, honors students, AP Chemistry. During the 2013-14 school year, 3 of his 6 courses taught were chemistry, 1 was physics and 1 class of biology. He is the science department chair at his school. On the Chemistry Teacher Self-Assessment, Mr. Mickle scored a 54 has been identified as a low inquiry-based instruction teacher.

Participant 8 – Mrs. Essmon

Mrs. Essmon is a teacher within a county school district in the southeast United States. The high school where she teaches is 366 students and is 49.18% free and reduced lunch. This school is a 7th-12th grade school that is on a 7-period day. She has 21 years of experience teaching biology, chemistry, physical science and middle school science. Mrs. Essmon started out as a middle school teacher and 11 of her 21 years was in 7th grade. She has taught special education students, EL students, and regular education students. During the 2013-14 school year, 4 of her 6 courses taught were chemistry and the other 2 are biology. She is also the science department chair at her school. On the Chemistry Teacher Self-Assessment, Mrs. Essmon scored a 96 has been identified as a high inquiry-based instruction teacher. Her score may need to be examined with caution because with such a high score the researcher speculates that Mrs. Essmon did not read the questions thoroughly and/or was trying to please the researcher. Nonetheless, her interview and scores will be used in this data.

Participant 9 – Mrs. Morgan

Mrs. Morgan is a teacher within a county school district southeast United States. The high school where she teaches is 431 total students and is 57.18% free and reduced lunch. This school is a 7th-12th grade school that is on a 7-period day. She has 10 years of experience teaching biology, chemistry, physical science, and middle school science. She has taught special education students, EL students, and regular education students. During the 2013-14 school year, she taught 1 course of chemistry, 1 marine science, 2 biology, and 2 classes of 7th grade science courses. She is 1 of 2 science teachers at her 7-12 high school. On the Chemistry Teacher Self-Assessment Mrs. Morgan scored a 79 has been identified as a medium inquiry-based instruction teacher. Mrs. Morgan spends a lot of time planning for her numerous classes that she teaches daily.

Interview Analysis

After the interviews were conducted, they were transcribed into written format. All interviews were read numerous times to ensure that the researcher understood exactly what the participants were expressing in the interview. Open coding was used to code the interviews (2007). For example, if the participants talked about seminars or training, the words were coded for that question. Similarly, when the participants talked about ‘science in motion’ the words ‘resources’ were coded for this theme. Four major themes appear from the interview data: available resources, the teacher’s prior experiences, teacher initiative, and chemistry specific topics. These themes will be discussed in detail below.

Available Resources

The first theme that was evident from the data was resources. Any science teacher will assert that having adequate money and time is a necessary component of teaching science effectively. This section will outline what the participants report about resources.

Alabama Science in Motion (ASIM). Many of the participants indicated that the Alabama Science in Motion (ASIM) program was a huge benefit to doing lab and demonstrations in chemistry. ASIM was started in 1994 and is a state-funded program that will deliver labs to the teacher upon request. ASIM has over 100 labs and demonstration kits available to the chemistry teacher on every topic in the Alabama course of study (ALSDE, 2014). Any chemistry teacher who has been through ASIM training can request the kits any time during the school year. ASIM does not cost the school system anything to participate and any person who is a science teacher may participate in ASIM.

All of the participants mention ASIM in some form during the interview. A number of participants indicate that they like ASIM but it is not always convenient. Whereas you can order a kit at any time in the school year, it may require up to two weeks to receive the lab. Therefore, planning is essential to use this resource to its fullest. “I love ASIM, but you must be on your toes with planning,” said one teacher in the high inquiry-based instruction group. A teacher in the low group stated, “sometimes I do not bother ordering the labs because I do not like to do the labs when I am on another topic.” Because of the nature of how chemistry is taught, all the chemistry teachers in the program are going to request to the same lab kits at the same time. Luckily, there are 2-3 kits for the same lab, but planning is essential. Another teacher stated, “I really do not like using the kits after I have taught the lesson but I will use it whenever it comes. It is good review for the kids, I guess, if I use it after the unit is over.” The teachers who were

identified as using high and middle inquiry-based instruction were positive about the ASIM program; however, the low inquiry-based instruction teachers did not mention ASIM.

Money. The next code that was labeled for resources was “money, teacher allocation, and personal money.” Money is essential for doing chemistry labs. Most, if not all labs performed in chemistry, are one-time only labs – little, if anything, can be re-used. Chemicals are costly and with limited money come limited number of labs. Many of the teachers indicated teacher allocation should to be more for science teachers than other teachers because of this reason. As one participant stated, he was, “tired of using personal money to buy household items” from the grocery store while another teacher stated, “it really adds up when I am spending \$20-\$40 a month on supplies to do labs and activities out of my own pocket.”

Demonstrations. Demonstrations and money seem to be tied together as well. Six of the teachers indicated that many times it is more cost effective to do a demonstration with the class when the experiment is costly. One middle inquiry-based participant indicated that demos are “not as expensive and not as time consuming as a lab.” Both high inquiry-based teachers indicated that they enjoy doing demos for the students. One teacher responded, “doing a demo is fun because it can get the students excited about the lesson.”

Time. Coded also under resources was the idea of “time.” Any teacher will tell you that time is essential to doing their job effectively. The teachers interviewed thought that time was important part of whether or not to use 5E inquiry-based instruction because they believed that it required more time to teach using this model. Also, some teachers thought the time required to go through the entire 5E cycle was too time consuming and it was not necessary to do the entire 5E model. All 9 participants mentioned time. “Inquiry just seems to take up a lot of that we do not have,” stated one participant in the low group.

The student's prior experiences. Teachers mentioned “the student’s prior experiences” that was labeled as resources. All the teacher participants were concerned about how little experience their students had in the lab setting. One teacher low inquiry-based teachers felt that “I should not have to teach them how to do lab, they should know.” Four of the teachers were concerned with student’s prior lab experiences. Also, teachers were concerned about the grade level of the students reading and math and believe this is a factor in whether or not to use 5E inquiry-based instruction. It appears that the low and middle inquiry-based teachers were using the kids prior knowledge and experiences as an excuse to not use the model.

Technology. Lastly, under resources, nine of the teachers indicated that “technology or computers” was a factor in whether or not to use the 5E inquiry-based instructional model. It seems that the schools that were in the study are lacking technology. One teacher indicated that the computer labs are “always in use for English classes or for standardized testing.” The teachers seem to have a desire to use more technology in their lessons but are unable to do so because of the lack of computers. “If we had more computers I would allow the students to do more research on their own about the topic we are studying, but we don’t have the computers and even if we did the Internet would probably not work on the day I need it to!”

The teacher's prior experiences. The participants were asked how they learned chemistry as a student; their prior experiences may open up a new insight into how they may teach chemistry. All nine of the participants indicated their chemistry class was purely “lecture” based. Only three of the participants indicated that they remembered having demonstrations in their chemistry class. The idea that the teacher was difficult to understand because of the language barrier was common among most of the teachers interviewed. Two participants mentioned that their chemistry teacher was Asian and this made instruction challenging to

understand. The teachers who mentioned lab reports referred to them as “awful,” “tedious,” and “dreaded.” These feelings were used by teachers in all three levels of inquiry-based instruction (high, medium, and low).

Teacher Initiative

Teaching with inquiry-based instruction means a teacher must take initiative to make the lessons meaningful, fun, and address the learning objective (Cheung, 2009). Several ideas around this theme of initiative were present in the data from the interviews.

Training/professional development. First, the words “training” and/or “professional development” were coded under initiative. When it comes to 5E inquiry-based training, all the teachers mentioned ASIM. ASIM must be the only mode of delivery for this type of training. ASIM is a great tool for all chemistry teachers because not only do they deliver the lab/demo kits they also do professional development for 5E inquiry-based instruction.

One teacher indicated that teaching 5E was a struggle. “I am not sure you can do that whole 5E cycle thingy because of time,” stated one participant. Interestingly, this participant did not feel that he needed more professional development when it came to 5E instruction. Another participant indicated they could use more training and asserted that they are not very comfortable with the 5E method of instruction. She stated that she has been to training but does not get much out of it because the training is very fast and technical. Five of the teachers interviewed stated they would like “make and take” seminars. These are seminars whereby you make a lesson, lab, or manipulative to take back to your classroom and use.

Six of the nine teachers interviewed reported they do not feel like they need more professional development on the topic of 5E inquiry-based instruction. It appears from the interviews that the low inquiry-based teachers do not have a desire to learn more about best

practices for teaching inquiry-based chemistry. However, the other three teachers (one middle and two high inquiry-based teachers) seemed eager to learn and are eager to see what new idea or lesson they can take back to the classroom. The middle inquiry teacher's score was very close to being in the high range. One high inquiry-based participant is involved with a Professional Learning Group through ASIM; this is a group that gets together to discuss best practices in chemistry. "It is nice to have a group where we can get together and talk about professional issues and work on building lessons and share what works in our practice."

In addition to professional development, the idea of "time" was also coded and placed into the initiative theme. It may require additional time to set up and take down the labs that are associated with 5E inquiry-based instruction. As one participant reported, "a lot of time goes into prepping, setting up, taking down, and grading the lab, not to mention the time necessary for the students to actually perform the lab." Many of the teachers felt "crunched" for time to finish the course of study due to a myriad of reasons: weather related absences, field trips, sports playoffs, and daily high school interruptions.

Chemistry Specific Topics

The last theme that will be discussed is chemistry specific topics. The teachers were asked if a specific topic influenced them to teach using the 5E inquiry-based instruction model. Interestingly, all the teachers, high, medium, and low, reported the same topics: gas laws, stoichiometry, and metric conversions. Perhaps this is from their ASIM training or perhaps these are just the best topics for inquiry-based instruction in chemistry. To support this one participant said, "I really enjoy doing the limiting/excess reactants lab with the kids to start my stoichiometry unit." While another participant said, "gases are easy to teach through inquiry

because there are a lot of readily available materials and the kids already know a little about gasses.”

Most of the teachers interviewed reported that enlisting background knowledge prior to a lesson was an important part of the way they teach chemistry. The teachers seemed to believe that teaching stoichiometry through the 5E inquiry-based model is the best way to teach this topic as well as the concepts of limiting and excess reactants. Also, it seems that teaching gas laws and the concepts of gases are best delivered through 5E inquiry-based instruction.

Summary

Chapter IV provided a detailed analysis of the data collected from the Chemistry Teacher Self-Assessment, Chemistry Teacher Interview Questions, and Chemistry Student Attitude Survey. The teacher interviews revealed findings similar to that of Cheung (2009). Teachers were categorized into three groups of inquiry-based teaching (high, medium, low) from the Chemistry Teacher Self-Assessment. The teachers were also interviewed and based on their level of inquiry-based instruction their interview responses were analyzed and grouped into their respective group of high, medium or low. Teachers in the high and medium groups indicated they are interested in learning more about the 5E inquiry-based instruction model however, they desire professional development that is meaningful and that can be quickly implemented into the classroom. Students were also interviewed and revealed that they prefer instruction that is hands-on and has applicability into everyday life. Chapter V will offer a conclusion of the research and recommendations for further research in addition to any limitations of the study and recommendations for future researchers.

CHAPTER V:

DISCUSSION

The purpose of this study was to explore the relationship between a high school chemistry teacher's inquiry-based approach to instruction and their student's attitudes about chemistry. Chemistry is important in the field of science because it is central to understanding all of the branches of science (Brown & Lemay, 1977). Since chemistry was first introduced into the secondary classroom, little has changed with the instructional practices since the early 19th century (Cooper, 2010; Johnstone, 2009; Shepard & Robbins, 2005). The National Science Foundation (1996) and the Next Generation Science Standards (2013) as well as numerous researchers want to move away from lecture type learning and "cookbook" type labs to a place of inquiry-based teaching and learning. A focus on inquiry-based teaching to address both teaching and learning will hopefully have a positive impact on chemistry students.

This study explored how a teacher's attitude of chemistry is related to the use of inquiry-based instruction. This study was designed to provide insight on the experience of a chemistry teacher and explore factors that affect a high school chemistry teacher's willingness and ability to use the inquiry-based approach to instruction in their classroom. Implications drawn from the data and acknowledgement of previous research are discussed in order to understand the teacher's perspectives. Limitations of the study are identified and recommendations for further study are proposed.

Findings and Conclusions

Three original research questions were constructed to guide this study. This section will discuss results from each of the questions.

Sample

In this study, there were nine chemistry teacher participants and 192 chemistry student participants. The sample was from two school systems in the southeast United States: one city school system and the other a county school system. The city school system had two high schools in the study and the county school system had four schools in the study.

Teachers were given a survey to self-assess their level of inquiry-based instruction. The teacher's scores from the Chemistry Teacher Self-Assessment ranged from 54-96. There were four teachers who were identified as having a high level of inquiry-based instruction, three teachers who were identified as having a medium level of inquiry-based instruction, and two who were identified as having a low level of inquiry-based instruction. These scores will be used to evaluate the research questions and for grouping.

Research Question 1

“What are the characteristics of a high school chemistry teacher based on their level of inquiry (high, medium, or low) from the Chemistry Teacher Self-Assessment and their responses to the Chemistry Teacher Interview Questions?”

The data from the interview questions were separated into the three groups (high, medium, or low) according to their self-assessment score and the groups were examined for characteristics. There were four themes that emerged from the data: experiences and use of the 5E inquiry-based model, professional development, Alabama Science in Motion, and time.

According to Cheung (2009), more years of experience can influence whether teachers use inquiry-based instruction. It did not appear that years of experience influence the teacher's level of inquiry-based instruction in this study given that each group had varying amounts of experience. The years of experience from the low inquiry group ranged from 9-28 years of experience, medium group ranged from 10-20 years of experience and the high group ranged from 9 to 34 years of experience. Gender also did not play an important role.

From the interview questions, there were some common threads among the groups. All nine of the teachers reported that their chemistry class was primarily lecture based. However, the low group reported that they did not enjoy their college lab experiences whereas the high group reported that lab was more of an enjoyable experience. Breslyn and McGinnis (2011) reported that a chemistry teacher's personal perceptions and attitudes are more likely than curriculum to play a role in whether or not inquiry is used in their chemistry class. The findings in this study confirmed those of Breslyn and McGinnis (2011).

All teachers agreed that time was an important factor in whether or not they used the 5E model of inquiry-based instruction. Most teachers asserted that they use the 5E model of inquiry-based instruction but not think about it in their lesson plans. Chemistry teachers, like all other secondary teachers, feel a crunch for time in the school year. The teachers reported that it is important to consider the time necessary to prepare, set up, and take down the lab. These findings were not surprising given that Cheung (2009) indicated that time was an important factor in whether or not a teacher may choose inquiry-based instruction.

As for professional development, the three groups held different opinions. Rushton, Lotter, and Singer (2011) reported that teachers with traditional, lecture chemistry lessons are less likely and least interested in learning about inquiry and how to implement inquiry in the

science classroom. As it would turn out, the low inquiry-based group of teachers reported that they do not need any additional professional development with the 5E model of inquiry-based instruction. However the medium and high groups reported that they would like more professional development with 5E. The high group seemed open to learning new strategies to take to the classroom. Their attitudes were more open to learning and focused on how they could ensure student success. The low group felt they had the years of experience and know-how to effectively teach using inquiry-based methods and had no interest in further professional development. These findings seem to corroborate previous research (Rushton, Lotter, & Singer, 2011) that inquiry can be seen as confusing for teachers (Wee, Shepardson, Fast, & Harbor, 2007; Wheeler, Maeng, & Bell, 2013), and teachers have to be open to change in order to be a good teacher of inquiry-based chemistry.

Lastly, seven of the nine teachers mentioned that they had training in 5E instruction in Alabama Science in Motion (ASIM) trainings. Three of teachers believe that the workshops should be focused more on “make and take activities” and this would make the training more desirable. The teachers report they are not interested in attending any more workshops where they are given a binder of labs and activities. Seven of the participants pointed to these folders during the interview. “I am tired of getting a binder at each workshop that I do not use. It comes back to school and sits on the shelf.” As reported by Luft (2001), meaningful and effective professional development may enable teachers to understand the true meaning of inquiry through modeling lessons, activities, and labs. The teachers indicated that making the ASIM trainings more hands on and/or “make and take” would draw more teachers to the trainings and make it more desirable for them to attend professional development.

Research Question 2

“What is the relationship between a high school chemistry teacher’s inquiry-based approach to instruction, as measured by the Chemistry Teacher Self-Assessment, and their student’s attitudes about chemistry, as measured by the Chemistry Student Opinion Survey?”

In this study there was no significant relationship between the student’s attitude and the teachers level of inquiry-based instruction. The overall sample fell short of the 237 estimated sample size with only 192 total student participants. Additionally, the 11th and 12th grade subgroup did not have enough student participants with 70 students in the 11th grade, and only 19 students in the 12th grade and an estimated 79 needed for each group. More teacher participants may have made the sample size larger for the 11th and 12th grade group however it must be taken into consideration it is common for students to take chemistry their 10th grade year.

Another variable to take into consideration was that the teacher information was a self-assessment of their level of inquiry-based instruction. As Banchi and Bell (2008) reported, a teacher may assume their instruction is inquiry-based when in fact, it is not. Researcher observations of the teacher’s practice would provide more insight into the teacher’s level of inquiry-based instruction. However, this research design did not allow for teacher observations.

Whereas the ANCOVA data did not yield significant results, much can be learned from the survey data. It can paint a picture of both the student attitudes as well as how the teachers envision their own practice. The next section highlights some important findings of the Chemistry Student Attitude Survey and its relationship to previous research and the other findings in this study.

Chemistry Student Attitude Survey

The Chemistry Student Attitude Survey data indicated that prior knowledge was an important aspect of chemistry class. Prior knowledge is an essential part of the 5E learning cycle (Bybee, 2006). Sixty-six percent of the teachers reported that they begin their lesson by drawing out prior knowledge. Eighty-seven percent of the students strongly agreed or agreed that they like it when the teacher connects what they know to what they are about to learn. This data indicates that prior knowledge should be an important aspect of the daily chemistry lessons.

Also the Chemistry Student Attitude Survey data indicated that real life application was an important aspect of chemistry class. Dewey advocated for learning based on real-world experiences and reflective thinking (Dewey, 1933). Since Dewey, other science educators have encouraged connecting real-life experiences in the science lessons (Ali & Awan, 2013; Bybee, 2013; Gibson & Chase, 2002; Hofstein & Mamlok-Naaman, 2011). Eighty-eight percent of the teachers reported that they give activities that encourage students to find real life application. Sixty percent of the student strongly agreed or agreed that they like it when the teacher connects the content to everyday thoughts and ideas. This data indicates that real world connections are crucial for students to be engaged in learning chemistry.

Dewey believed that learning should be a hands-on experience (Bybee, 2013). From the survey data, students agree with Dewey. Eighty-three percent of the students surveyed agreed or strongly agreed that they enjoy chemistry lab and 83% wished that chemistry was more hands-on and/or lab experiences. It has been shown that students performed 40% higher in science on standardized testing when they were taught by educators who intergrade hands-on learning and critical thinking into their lesson (Wenglinsky, 2000). Chemistry labs can help students understand the material (Cheung, 2009; Gibson & Chase, 2002) and 79% of the students

surveyed agreed that labs were helpful for learning chemistry. Similar results from Gibson and Chase (2002) also confirmed that hands-on activities are what keep students engaged in the science classroom. From the Chemistry Students Attitude Survey, it can be deduced that hands-on activities through inquiry-based instruction is important for the student's experience in chemistry class.

Research Question 3

“What are some of the factors that affect a high school chemistry teacher's willingness to use the inquiry-based approach to instruction in their classroom, as measured by open ended, qualitative survey?”

From the data there were four major themes that were identified: available resources, the teacher's prior experiences, teacher initiative, and chemistry specific topics. These themes line up parallel to the work that Cheung (2009) who reports the teacher's prior experiences (in the chemistry classroom and lab) as well as resourcefulness was critical to an effective inquiry-based teacher in chemistry. It is important for administrators to understand that barriers exist with chemistry teachers implementing inquiry-based instruction and they must support their faculty in teaching with inquiry-based instruction (Cheung, 2009).

Teachers reported that they were tired of spending their own money on lab supplies. One teacher stated, “it really adds up when I am spending \$20-\$40 a month on supplies to do labs and activities out of my own pocket.” In the state where this research took place, the science teachers receive \$300 a year for supplies for lab and for the classroom. This does not go very far when you consider the cost of chemicals and lab supplies not to mention the cost of everyday teacher expenses (printer cartridge, paper, staples, etc.). Teachers reported that demonstrations were one way to cut the cost of doing lab because of the lack of money necessary for lab; it is less

expensive to do a demo for the class than to have twelve to fifteen lab stations using chemicals. Demonstrations can be less expensive but not as hands-on as the actual lab experience. Also, teachers reported the lack of technology available to the students was a barrier to inquiry-based instruction. Inquiry-based learning can take place on the computer; however, students need access to computers. The teachers saw Alabama Science in Motion as a resource since they deliver the kits with chemicals and lab set ups to the school free of charge. However, what can be frustrating is scheduling for delivery. There are only 1-3 kits for schools in 8 counties. Since chemistry must be taught in a sequence, the kit may not always be readily available when needed. Advanced planning is crucial to receiving the materials when you need them to correlate with the lesson. One teacher reported, “I really do not like using the kits after I have taught the lesson but I will use it whenever it comes. It is good review for the kids, I guess, if I use it after the unit is over.” A teacher in the low group added, “sometimes I do not bother ordering the labs because I do not like to do the labs when I am on another topic.” ASIM is a great resource but it can also be a hindrance because for teachers who rely on this program they must plan ahead and be flexible with their lesson planning.

The teacher’s prior experiences also emerged as a theme from the interviews. Only three participants indicated that they remembered having demonstrations in their college chemistry classes. Two of the participants indicated that they had a difficult time understanding their college chemistry instructor because of a language barrier. At the college level, this may often be the case as the instructors often speak English as their second language. Teachers in all three inquiry-based instruction levels (high, medium, or low) did not have positive memories of lab reports from college and referred to them as “dreaded,” “awful,” or “tedious.” A teacher’s prior classroom experiences as students are how they teach their own classes. Ruston, Lotter, and

Singer (2011) reported that prior experiences are ultimately how science teachers teach. It is imperative that chemistry classes at the college level also adopt inquiry-based practices so ensure these practices are being utilized in at the secondary level.

One of the most important barriers may be professional development. Knight (2013) stated that poorly-designed professional learning can actually inhibit professional growth. The NSF (2013) has called for middle and high school science teachers to have professional development centered on inquiry-based instruction. It is extremely important that the training is designed to address the teacher's professional knowledge and resources rather than simply giving them a notebook of recipe-like teaching procedures (NSF, 2013). Teachers truly feel respected when their ideas and experiences are valued and therefore will engage in meaningful, supportive conversations that can lead to improvements in their teaching practice (Knight, 2013).

It is essential that teachers have the supplies, resources, time, and professional development needed in order to teach chemistry effectively. From the interviews, it appears that the participants want to implement inquiry-based instruction in chemistry however there are just so many hurdles to overcome it is not always possible. Cheung (2009) reported that his teacher participants also wanted to implement inquiry-based instruction however the teachers felt inhibited by the barriers just as the teachers in this study reported.

Implications of Study

This study establishes that the teachers surveyed believe there are barriers to teaching chemistry through inquiry-based instruction. Whereas the statistical significance of this study was not present, this study opens a conversation for the need for studies in high school chemistry classes. The literature gap proves that the need is there for more studies and the willingness of the small sample of teachers indicates that the teachers are willing to provide data. This study

will hopefully facilitate conversations among science education researchers to consider further investigations in high school chemistry as well as in inquiry-based instruction. As the Next Generation Science Standards are implemented 5E inquiry-based instruction will be the focal point of the conversations among science educators.

Limitations of Study

The results of this study should be interpreted after the consideration of the following limitations. First, data collection for this study was limited to two school districts in the southeast United States. One school district was a city school district and the other a county school district. A total of nine teachers participated in the study. All nine teachers had some knowledge of the 5E inquiry-based instruction model through Alabama Science in Motion training. Therefore, the teacher's attitudes concerning inquiry-based instruction may not reflect all chemistry teachers.

Next, even though there was a confidentiality safeguard in the study, the fear of admitting deficiencies in teaching practices may have caused some of the chemistry teachers to not report their experiences accurately on the self-assessment survey or in the interview. Additionally, the students who were interviewed may have not accurately answered the questions to the Chemistry Student Attitude Survey for either fear the teacher would read the surveys or may have simply not taken the time to read the surveys completely.

Lastly, because of the nature of this work, the surveys were given at the end of the school year. By nature of the data needed to be gathered this is the only appropriate time to gather such data. However, the end of the school year is a hectic time with many interruptions to instruction and excitement of the end of school.

Researcher Reflections

A researcher who wishes to replicate this study should be advised of the logistics that goes into personally visiting chemistry classes at the end of the school year. First, you have to ensure the teacher receives the letters to send home to the parents to sign and return. The student must return the signed permission form before taking place in the study. Next, you must schedule times with the teachers which can be daunting because of assemblies, end of year testing, sporting play offs, etc. Also, some teachers may teach a morning and an afternoon class making it difficult to be at any other location that particular day. Only students who returned the signed permission form can participate in the study leaving the other curious about what is on the survey.

Interviewing the teachers can also require some logistics. Finding time during a teacher's planning period to interview them may prove difficult. Many teachers had reservations about being audio recorded but took comfort in the fact that it would be destroyed after transcription.

A research design such as this one is feasible. However, the researcher who wishes to replicate the study needs to have a clear understanding of how an American high school operates and be prepared for many scheduling conflicts.

Recommendation for Further Research

This study has opened a much-needed conversation about inquiry-based instruction in high school chemistry. Replicating this research with more teacher participants may yield different results and warrants further investigation. Whereas this study used nine teachers and Cheung (2009) study used seven teachers, more teacher participants would result in more student participation. Instead of placing the teachers into three levels of inquiry (high, medium, or low) future researchers may wish to place teachers into two levels (high or low) to examine the effects

between two groups instead of three groups. A future researcher may also wish to examine the gender of the teachers and students to see if gender makes a difference in the attitudes of students or teachers, as gender was not examined in the statistical analysis. Lastly, it could be of interest to assess how teacher certification affects the teacher's level of inquiry. Science teachers may be traditionally certified in a college of education or they may possess a degree in chemistry and then be alternately certified through other means. Investigating these prior experiences may make a difference in the level of inquiry-based instruction and should be further investigated.

Conclusion

With the push for more student-centered, inquiry-based instruction in the forefront of science education, especially with the implementation of the Next Generation Science Standards (NGSS), it is important to understand how inquiry-based instruction in chemistry affects students and teachers alike. One of the reasons so many teachers do not teach using inquiry-based instruction is because of the preconceived ideas they hold regarding inquiry-based instruction (National Science Standards, 2000; Cheung, 2007; Cheung, 2009). The NGSS has called for a move away from the word "inquiry" and will be using the word "practices" to try and clarify the best practices for teaching science through inquiry. Research has indicated that the teacher's attitude toward chemistry as well as a teacher's attitude toward inquiry-based instruction may influence a student's attitude of chemistry (Breslyn & McGinnis 2011). With the decline in the number of students interested in science it is imperative that teachers do everything possible to excite students about science, namely chemistry (Chapman, 1997).

With the implementation of the Next Generation Science Standards (NGSS) that calls for a move to inquiry-based instruction and student centered instruction it is important to understand how inquiry-based instruction is used in the field of chemistry. Administrators must encourage

teachers to teach using inquiry-based methods. Teachers must become comfortable with this method of teaching chemistry and understand that the old model of lecturing in chemistry is not the model needed to enhance chemistry instruction. Moreover, teachers must never be satisfied with their ability; constant improvement and refinement of their teaching methods must be the goal of all professional chemistry educators.

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APPENDIX A

Cover Letter for Teacher Participants

Dear Teacher:

You are being asked to take part in a research study. This study is called “How Does a Teachers Instruction Influence a Student's Attitude about Chemistry?”. The study is being done by Charles Holloway, who is a graduate student at the University of Alabama. Mr. Holloway is being supervised by Professor Jamie Mills, PhD who is an Associate Professor of Statistical Methods at the University of Alabama.

This study will investigate the way that chemistry teachers teach chemistry. You have been asked to be in this study because you teach a high school chemistry class this year. There are 7 different schools in this study and approximately 1500 students are being asked to participate. In this study you will be asked to complete a 20-question survey about teaching chemistry. It should take you no more than 5 minutes to answer these questions. Afterwards, you will be asked to take part in a brief interview session that will be recorded. It should take no more than 10 minutes to answer the interview questions.

Being a part of this study will not cost anything and you will not be compensated for being part of this study. No risk is foreseen as when non-sensitive surveys or interviews are used. Although you will not benefit personally from being in the study, you may feel good about knowing that you have helped shape future instruction in high school chemistry. This study will help high school chemistry teachers in effectively delivering chemistry instruction.

You will not be asked to identify yourself on the survey – it will be completely anonymous. You will be asked to complete the survey however they do not have to answer any questions they do not want to. Also, you make choose to not take part in the interview portion of the study.

The alternative to being in this study is not to participate. Taking part in this study is voluntary. It is your free choice. You can refuse to be in it at all. If you start the study, you can stop at any time. There will be no effect on your relations with the University of Alabama.

If you have questions, concerns, or complaints about the study right now, please ask them. If you have questions, concerns, or complaints about the study later on, please call the investigator Charles Holloway at (256) 226-0068. If you have questions about your rights as a person in a research study, call Ms. Tanta Myles, the Research Compliance Officer of the University, at 205-348-8461 or toll-free at 1-877-820-3066. You may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach website at http://osp.ua.edu/site/PRCO_Welcome.html or email the Research Compliance office at participantoutreach@bama.ua.edu.

I have read this consent form. I have had a chance to ask questions. I agree to take part in it. I will receive a copy of this consent form to keep.

As mentioned above, the individual qualitative interview will be audio recorded for research purposes to further understand teacher perspectives with teaching chemistry. These tapes will be stored in a locked file cabinet in a locked room and only available to the research staff. These tapes for no more than 2 months and will destroy them after they have been transcribed.

I understand that part of my participation in this research study will be audiotaped and I give my permission to the research team to record the interview.

Yes, my participation in _____ can be audiotaped.

No, I do not want my participation in _____ to be audiotaped.

Signature of Teacher Participant

Date

Signature of Investigator

Date

APPENDIX B

Chemistry Teacher Self-Assessment

Dear Teacher,

Below are a few questions about your chemistry class. Please indicate what *Percentage of the Time You may Do* the following items in your chemistry teaching practice. Please answer the questions to the best of your ability. There are no right or wrong answers. Your responses are totally anonymous and confidential no one will see your response. Your answers will be used for statistical and research purposes only.

	0-20%	21-40%	41-60%	61-80%	81-100%
1. I often begin lessons that draw out prior knowledge from my students.					
2. When I conduct my lessons, I encourage students to seek alternative modes of investigation or problem solving (such as allowing students to write their own procedures for experimentation).					
3. I try to pose various levels of questions to students. (Explain, define, compare/contrast, draw conclusions, etc.).					
4. When I plan my lessons, I give activities that encourage students to find real life applications to new concepts or skills.					
5. When I teach, I use a variety of methods (models, drawings, graphs, manipulatives, etc.) to evaluate understanding of my lessons.					
6. When I teach I provide resources and manipulatives to my students to stimulate curiosity, provide concrete examples, and thinking skills.					
7. There is often a high proportion of student discussion (on task, about the topic) and a significant amount of it occurs among students.					
8. I consistently ask students to explain findings and draw conclusions to encourage them to think at higher levels.					
9. My lessons provide students with the opportunity to apply and extend new concepts or skills into other areas.					
10. I often assess students through the use of					

both closed and open-ended questions.					
11. The focus and direction of my lessons are often determined by ideas originating with the students prior knowledge.					
12. My lessons provide opportunities for students to answer questions through investigation.					
	0-20%	21-40%	41-60%	61-80%	80-100%
13. My students are asked questions in interactive discussions (either teacher or student lead) that focus on what they have experienced/explored.					
14. I collaborate with other teachers so that I can help students understand cross-curricular connections to chemistry.					
15. I evaluate student progress usually with multiple choice/matching questions.					
16. The content of my lessons are structured around learning concepts that are relevant and based on student's personal experiences.					
17. Classroom activities are student centered and involve hands-on/minds-on activities.					
18. During the time I am teaching my lesson, students are asked to explain concepts in their own words.					
19. I have students keep their science work (interactive notebooks, portfolios, etc.) for reflection and discussion.					
20. I provide opportunities for students to reflect and share their ideas with one another.					

What is your gender? Circle One.

Female Male

How many years of chemistry teaching experience do you have? _____.

How many Chemistry courses do you teach this year? _____

APPENDIX C

Chemistry Teacher Interview Questions

The following questions will be asked in individual interviews with the chemistry teachers.

1. How long have you taught chemistry? Do you choose to teach chemistry here at (fill in the blank) High School or is it a requirement to fill your teaching schedule?
2. Tell me about your experiences in chemistry class in college. Tell me about how they were taught and which classes you remember most.
3. What topics do you look forward to each year when teaching chemistry?
4. What do you enjoy about doing lab work with your students in chemistry? What about demos? Why or why not?
5. Are you familiar with the 5E model of instruction? (If Yes proceed, if not stop). When considering whether or not to use the 5E model instructions in your lessons, what factors figure in your decision to do so?
6. How does time factor into your decision?
7. When considering whether or not to use the 5E model in your lessons, how does access to adequate resources (e.g. equipment, internet access, chemicals, etc...) factor into your decision?
8. When considering whether or not to use the 5E model in your lessons, do you think you have the knowledge and skills needed to implement the 5E model in your teaching practice?
9. When considering whether or not to use the 5E model in your lessons, how important are the specific topics being taught in your decision to use the 5E model in your lessons?
10. What type of professional development have you had regarding the 5E model instruction in chemistry? Do you feel more professional development on the topic of the 5E model chemistry is necessary? Why or why not?

APPENDIX D

Survey Cover Letter for Students

Dear Parent:

You are being asked to give permission for your child, adult relative/person for whom you are a guardian/legal representative to take part in a research study. This study is called “How Does a Teachers Instruction Influence a Student's Attitude about Chemistry?”. The study is being done by Charles Holloway, who is a graduate student at the University of Alabama. Mr. Holloway is being supervised by Professor Jamie Mills, PhD who is an Associate Professor of Statistical Methods at the University of Alabama.

This study will investigate the way that chemistry teachers teach chemistry. Your child has been asked to be in this study because he/she is a student in a high school chemistry class this year. There are 7 different schools in this study and approximately 1500 students are being asked to participate. In this study your student will be asked to complete a 17-question survey about the field of chemistry. It should take you no more than 5 minutes to answer these questions.

Being a part of this study will not cost anything and you will not be compensated for being part of this study. No risk is foreseen as when non-sensitive surveys or interviews are used. Although you will not benefit personally from being in the study, you may feel good about knowing that you have helped shape future instruction in high school chemistry. This study will help high school chemistry teachers in effectively delivering chemistry instruction.

Your child will not be asked to identify themselves on the survey – it will be completely anonymous. The student will be asked to complete the survey however they do not have to answer any questions they do not want to.

The alternative to being in this study is not to participate. Taking part in this study is voluntary. It is your free choice. You can refuse to be in it at all. If you start the study, you can stop at any time. There will be no effect on your relations with the University of Alabama.

If you have questions, concerns, or complaints about the study right now, please ask them. If you have questions, concerns, or complaints about the study later on, please call the investigator Charles Holloway at (256) 226-0068. If you have questions about your rights as a person in a research study, call Ms. Tanta Myles, the Research Compliance Officer of the University, at 205-348-8461 or toll-free at 1-877-820-3066. You may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach website at http://osp.ua.edu/site/PRCO_Welcome.html or email the Research Compliance office at participantoutreach@bama.ua.edu.

I have read this consent form. I have had a chance to ask questions. I agree to take part in it.
I will receive a copy of this consent form to keep.

Signature of Student Participant Parent/ Legal Guardian Date

Signature of Student Participant Date

Signature of Investigator Date

APPENDIX E

Chemistry Student Attitude Survey

Dear Chemistry Student,

Below are some questions about your chemistry class. Place a check mark in the box that best describes how you feel about the question. Answer the questions to the best of your ability and answer honestly. There is no right or wrong answer. Your answers will be used for statistical and research purposes only. It should take you no more than 5 minutes to answer these questions.

	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
1. Chemistry lessons are boring.					
2. I would like to learn more about chemistry.					
3. I look forward to going to chemistry class.					
4. I do not enjoy chemistry labs.					
5. I wish we did more labs and hands-on activities in chemistry class.					
6. A career as a chemist would be interesting to me.					
7. Chemistry classes I take in the future will be interesting to me.					
8. Choosing a career that required chemistry courses would make me reconsider my career choice.					
10. Chemistry labs help me to understand the material covered in class.					
11. I enjoy sharing my data from experiments with other students					
12. My thoughts and ideas are valued in my chemistry class.					
13. I believe there is more					

than one way to answer a question.					
14. I enjoy chemistry lab when I have to make my own procedures.					
15. I like it when I can extend what I have learned in chemistry class to real world ideas.					
16. I like it when my teacher connects what I know to what we are about to learn.					
17. Chemistry can be useful for solving everyday problems.					

What is your gender? Circle ONE.

Female Male

What grade are you in? Circle ONE.

10th 11th 12th

APPENDIX F

Data Management Plan

1. What are the characteristics of a high school chemistry teacher based on their level of inquiry (high, medium, low) from the Chemistry Teacher Self-Assessment and their responses to the Chemistry Teacher Interview Questions?
2. What are the differences in student attitude about chemistry based on their high school chemistry teacher's level of inquiry instruction (high medium, low), as measured by the Chemistry Teacher Self-Assessment, and the Chemistry Student Attitude Survey?
3. How do high school chemistry teachers describe their willingness to use the inquiry-based approach to instruction in their classroom, as indicated by open-ended questions during an interview that correspond to the Chemistry Teacher Self-Assessment?

Question	Measure	Independent or Grouping Variable	Dependent Variable	Projected Analysis
1	Chemistry Teacher Self-Assessment Chemistry Teacher Interviews Question	Teachers level of Inquiry (high, medium, low) Years of Experience	Average scores on Teacher Inquiry Self-Assessment	Categories and grouping of data
2	Teacher Inquiry Self-Assessment Survey Chemistry Student Attitude Survey	Teachers level of Inquiry	Student attitude scores	Regression
3	Qualitative questions that correspond to the Teacher Inquiry Self-Assessment Survey	Teachers level of Inquiry	Teachers responses	Qualitative themes and coding

APPENDIX G

Teacher Self-Assessment Frequency and Percentages

	0-20%	21-40%	41-60%	61-80%	81-100%
1. I often begin lessons that draw out prior knowledge from my students.	0 (0%)	0 (0%)	1 (11.1%)	2 (22.2%)	6 (66.7%)
2. When I conduct my lessons, I encourage students to seek alternative modes of investigation or problem solving (such as allowing students to write their own procedures for experimentation).	0 (0%)	1 (11.1%)	2 (22.2%)	5 (55.6%)	1 (11.1%)
3. I try to pose various levels of questions to students. (Explain, define, compare/contrast, draw conclusions, etc.).	0 (0%)	0 (0%)	0 (0%)	3 (33.3%)	6 (66.7%)
4. When I plan my lessons, I give activities that encourage students to find real life applications to new concepts or skills.	0 (0%)	0 (0%)	1 (11.1%)	5 (55.6%)	3 (33.3%)
5. When I teach, I use a variety of methods (models, drawings, graphs, manipulatives, etc.) to evaluate understanding of my lessons.	0 (0%)	0 (0%)	2 (22.2%)	2 (22.2%)	5 (55.6%)
6. When I teach I provide resources and manipulatives to my students to stimulate curiosity, provide concrete examples, and thinking skills.	0 (0%)	0 (0%)	3 (33.3%)	3 (33.3%)	3 (33.3%)
7. There is often a high proportion of student discussion (on task, about the topic) and a significant amount of it occurs among students.	0 (0%)	2 (22.2%)	2 (22.2%)	4 (44.4%)	1 (11.1%)
8. I consistently ask students to explain findings and draw conclusions to encourage them to think at higher levels.	0 (0%)	1 (11.1%)	2 (22.2%)	3 (33.3%)	3 (33.3%)
9. My lessons provide students with the opportunity to apply and extend new concepts or skills into other areas.	0 (0%)	2 (22.2%)	4 (44.4%)	1 (11.1%)	2 (22.2%)
10. I often assess students through the use of both closed and open-ended questions.	0 (0%)	2 (22.2%)	2 (22.2%)	2 (22.2%)	3 (33.3%)

	0-20%	21-40%	41-60%	61-80%	81-100%
11. The focus and direction of my lessons are often determined by ideas originating with the students prior knowledge.	0 (0%)	1 (11.1%)	2 (22.2%)	6 (66.7%)	0 (0%)
12. My lessons provide opportunities for students to answer questions through investigation.	0 (0%)	3 (33.3%)	1 (11.1%)	5 (55.6%)	0 (0%)
13. My students are asked questions in interactive discussions (either teacher or student lead) that focus on what they have experienced/explored.	0 (0%)	2 (22.2%)	1 (11.1%)	5 (55.6%)	1 (11.1%)
14. I collaborate with other teachers so that I can help students understand cross-curricular connections to chemistry.	0 (0%)	2 (22.2%)	2 (22.2%)	2 (22.2%)	3 (33.3%)
15. I evaluate student progress usually with multiple choice/matching questions.	4 (44.4%)	1 (11.1%)	0 (0%)	1 (11.1%)	3 (33.3%)
16. The content of my lessons are structured around learning concepts that are relevant and based on student's personal experiences.	0 (0%)	0 (0%)	2 (22.2%)	4 (44.4%)	3 (33.3%)
17. Classroom activities are student centered and involve hands-on/minds-on activities.	0 (0%)	2 (22.2%)	2 (22.2%)	1 (11.1%)	4 (44.4%)
18. During the time I am teaching my lesson, students are asked to explain concepts in their own words.	0 (0%)	4 (44.4%)	0 (0%)	1 (11.1%)	4 (44.4%)
19. I have students keep their science work (interactive notebooks, portfolios, etc.) for reflection and discussion.	2 (22.2%)	0 (0%)	0 (0%)	0 (0%)	7 (77.8%)
20. I provide opportunities for students to reflect and share their ideas with one another.	1 (11.1%)	1 (11.1%)	2 (22.2%)	3 (33.3%)	2 (22.2%)

APPENDIX H

Chemistry Student Attitude Survey Frequency and Percentages

	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
1. *Chemistry lessons are boring.	20 (10.4%)	35 (18.2%)	30 (15.6%)	74 (38.5%)	33 (17.2%)
2. I would like to learn more about chemistry.	35 (18.2%)	64 (33.3%)	54 (28.1%)	29 (15.1%)	10 (5.2%)
3. I look forward to going to chemistry class.	35 (18.2%)	64 (33.3%)	32 (16.7%)	35 (18.2%)	26 (13.5%)
4. *I do not enjoy chemistry labs.	13 (6.8%)	10 (5.2%)	9 (4.7%)	72 (37.5%)	88 (45.8%)
5. I wish we did more labs and hands-on activities in chemistry class.	118 (61.5%)	42 (21.9%)	16 (8.3%)	14 (7.3%)	2 (1.0%)
6. A career as a chemist would be interesting to me.	17 (8.9%)	32 (16.7%)	54 (28.1%)	55 (28.6%)	34 (17.7%)
7. Chemistry classes I take in the future will be interesting to me.	24 (12.5%)	48 (25.0%)	74 (38.5%)	32 (16.7%)	14 (7.3%)
8. *Choosing a career that required chemistry courses would make me reconsider my career choice.	11 (5.7%)	34 (17.7%)	46 (24.0%)	60 (31.3%)	41 (21.4%)
9. Chemistry labs help me to understand the material covered in class.	82 (42.7%)	69 (35.9%)	19 (9.9%)	14 (7.3%)	8 (4.2%)
10. I enjoy sharing my data from experiments with other students	31 (16.1%)	79 (41.1%)	51 (26.6%)	23 (12.0%)	8 (4.2%)
11. My thoughts and ideas are valued in my chemistry class.	44 (22.9%)	62 (32.3%)	49 (25.5%)	20 (10.4%)	17 (8.9%)
12. I believe there is more than one way to answer a question.	75 (39.1%)	80 (41.7%)	29 (15.1%)	6 (3.1%)	2 (1.0%)
13. I enjoy chemistry lab when I have to make my own procedures.	33 (17.2%)	57 (29.7%)	59 (30.7%)	28 (14.6%)	15 (7.8%)
14. I like it when I can extend what I have learned in chemistry class to real world ideas.	81 (42.2%)	69 (35.9%)	27 (14.1%)	10 (5.2%)	5 (2.6%)
15. I like it when my teacher connects what I know to what we are about to learn.	90 (46.9%)	78 (40.6%)	19 (9.9%)	4 (2.1%)	1 (0.5%)
16. Chemistry can be useful for solving everyday problems.	42 (21.9%)	74 (38.5%)	44 (22.9%)	22 (11.5%)	10 (5.2%)

*Indicates recoded questions

APPENDIX I

IRB Approval Letter

April 14, 2014

Office for Research
Institutional Review Board for the
Protection of Human Subjects

THE UNIVERSITY OF
ALABAMA
R E S E A R C H

Charles Holloway
ESPRMC
College of Education
The University of Alabama

Re: IRB # EX-14-CM-053 "How Does Teacher Level of Inquiry-Based Instruction Influence a Student's Attitude about Chemistry?"

Dear Mr. Holloway:

The University of Alabama Institutional Review Board has granted approval for your proposed research.

Your protocol has been given exempt approval according to 45 CFR part 46.101(b)(1) as outlined below:

(1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Your application will expire on April 13, 2015. If your research will continue beyond this date, complete the relevant portions of Continuing Review and Closure Form. If you wish to modify the application, complete the Modification of an Approved Protocol Form. When the study closes, complete the appropriate portions of FORM: Continuing Review and Closure.

Should you need to submit any further correspondence regarding this proposal, please include the assigned IRB application number.

Good luck with your research.

Sincerely,

