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Inquiry-based instruction in geometry: The impact on end of course geometry test scores

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and that any and all revisions required by
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2009

ABSTRACT

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M. Ed., South Carolina State College , 1975
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Doctoral Study Submitted in Partial Fulfillment
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ABSTRACT

Research examining instruction in geometry and standardized tests suggests that students have difficulty grasping geometry concepts and developing problem solving skills. The purpose of this study was to examine the relationship between the use of inquiry-based strategies in a geometry class and achievement on the end of course test (EOCT) and to analyze qualitatively the implementation of inquiry-based instruction. Embedded in the theoretical framework of constructivism, inquiry-based instruction gives students skills to become independent learners. Addressing an issue in mathematics education, the primary research question focused on how to improve scores on a standardized geometry test. This mixed methods study utilized the *t* test to analyze the EOCT scores of 2 groups of geometry students in a Title I school. The results indicated that students taught using inquiry-based instruction scored higher on the EOCT. Lesson plans, field notes, observation notes and other artifacts were analyzed using categorical aggregation. The results indicated that the predominant instructional strategy in the implementation process was guided inquiry and that formal instruction included models of the inquiry process. Social change will be impacted by pointing to instructional strategies that will help students develop positive attitudes to problem solving through inquiry and increased understanding of the mathematical content. The development of critical thinking skills in problem solving will contribute to success in high school, in college and in the workplace.

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SECTION 1: INTRODUCTION TO THE STUDY

Rationale of the Study

Education has always been a means by which a person can advance and reach specific goals. In the United States, the public school system was created to give children opportunities for advancement (Darling-Hammond, 2006; Dewey, 1966). There have been discussions and controversies about how the school system should operate, what should be taught, and how it should be taught. The public school has progressed from the one-room schoolhouse to the magnet school for which students must apply to enter into a specialized area of study. The progression of one teacher teaching all subjects to a certified teacher specializing in one area of study has unfolded over time as the public school system has changed. Instruction has evolved as much as the school system with continuous public discussion and some controversy. But traditional instruction, which placed the teacher as the giver of information and demonstrator of skills and the student as the recipient of the information, still predominates as the primary method. Studies have shown that this approach with an emphasis on drill and practice does not prepare the student for understanding mathematics (Jacobs et al., 2006; Jarrett, 1997; Perkins, 1993).

According to Desimone, Smith, Baker, and Ueno (2005), in addition to the differences in achievement, there was a striking contrast in mathematics instruction between the United States, Japan, and Germany. After examining videotapes from the 1999 Third International Mathematics and Science Study (TIMSS), it was evident that the instruction in the United States relied more on lecture, drill, and practice in mathematics classes. The instruction in Japan and Germany focused on problem solving and investigations to enhance student understanding of a topic and presented challenges to encourage higher order thinking in students. Consequently, there has been debate in the United States regarding a best practice model of instruction in mathematics. One alternative to traditional instruction is inquiry-based instruction.

Inquiry-based instruction is a resourceful and dynamic approach to instruction that involves the student as an active participant in learning. It involves asking questions by the teacher as well as by the student (Bateman, 1990; Commeyras, 1995; Truxaw & DeFranco, 2008). Inquiry-based instruction was defined in this study as instruction in which the students personally construct their knowledge through asking questions, planning investigations, exploring and analyzing basic concepts, and communicating the conclusions to their peers (Jarrett, 1997). Inquiry, which means to search for information by asking questions, is not a new concept. By human nature, a person will question and focus on the unknown. Curiosity is a natural trait, but needs to be cultivated in education (Ciardiello, 2003).

Background of the Study

Recent research has indicated that inquiry-based instruction, which includes questioning techniques and focuses on the role of the student in the learning process, may improve student achievement and understanding of content (Barab & Roth, 2006; Bateman, 1990; Dantonio & Beisenherz, 2001; Hunkins, 1989; Staten, 1998; Whitin & Whitin, 1997). Major changes need to be made in classroom instruction to translate the research into practice and promote achievement in mathematics. The traditional classroom, which is teacher centered, no longer meets the demands of society and industry (Kuhn, 2007; National Commission on Excellence in Education, 1983).

The focus of this study, inquiry-based instruction, was described as instruction in which the students are actively engaged in the construction of their knowledge. This was in contrast to the traditional instruction in which facts and procedures are presented by the teacher and rote memorization, drill, and practice are the norm (Jarrett, 1997).

Nationally, education has been in the spotlight for years. To provide data for research and educational policy, the National Assessment for Education Progress (NAEP), also known as the "Nation's Report Card", was first given in 1969 as a mandate by Congress (National Center for Education Statistics [NCES], 2006). The goal was to compare and track student achievement in the United States. In 1983, the National Commission on Excellence in Education Report, *A Nation at Risk,* raised concerns about education and how students were taught. Further concerns were brought to the nation's attention by the report *Everybody Counts.* The National Research Council (NRC) published this national report that addressed how mathematics education should progress in the future and in particular to the year 2000 (NCR, 1989). In a response to the call for reform, the National Council of Teachers of Mathematics (NCTM) published *Curriculum and Evaluation for School Mathematics* in 1989 (NCTM, 2000). This was just the beginning of a series of reports that focused on the problem of what students should learn in mathematics and how it should be taught.

In 1999, The Third International Mathematics and Science Study made the second of a series of reports to compare students in the United States to students in other countries. This report provided data for fourth, eighth, and twelfth grade students. It was found that the United States did not compare favorably. The scores of students in the United States were among the lowest of the participating countries. The *TIMSS 1999 Video Classroom Study* made several observations based on eighth grade videos. One of the conclusions was that the mathematics courses in the United States did not present as much rigor as in Germany and Japan. The instructional goal for Germany and Japan was to help the student understand the content, whereas in the United States, the goal was to cover content. Emphasis in this report was placed on the problem of putting reform recommendations into practice (Stigler, Gonzales, Kawanaka, Knoll, & Serrano, 1999).

In the executive summary of the report, *Before It's Too Late,* by the National Commission on Mathematics and Science Teaching for the 21st Century, the focus was on the need for reform in mathematics education. The Commission reported "in an age now driven by the relentless necessity of scientific and technological advances, the current preparation that students in the United States receive in mathematics and science is, in a word, unacceptable" (2000, ¶ 1). The report looked closely at the following reasons why this preparation through instruction is so important: (a) the rapid change in the American workplace, (b) the use of mathematics and science in everyday decisions, (c) the links to security in the United States, and (d) the defining influence of mathematics and science in the American culture. The report pointed to the problems in the relationship between student achievement and teaching. The most powerful instrument for change would be within teaching and instructional strategies.

According to Project 2061, “the conditions of one generation limit and shape the range of the possibilities open to the next…” (American Association for the Advancement of Science [AAAS], 1990, p. 93). Positive social change, defined as a “deliberate process”, can advocate actions to address these conditions (Walden University, 2006). With legislation in place to help shape these social changes, helping students succeed in mathematics has become a priority in schools. Because of the No Child Left Behind Act (Learning Point Associates, 2004; No Child Left Behind [NCLB], 2002), school districts, schools, and teachers are being held accountable for achievement in mathematics and language arts. There is a need for further research in teaching practices that employ inquiry and in teacher thought and understanding of inquiry. There is a gap in the literature relating inquiry-based instruction to learning activities (Flick, 1999; Flick, Keys, Westbrook, Crawford, & Cames, 1997; Oscer & Baeriswyl, 2001).

Problem Statement

This study addressed the problem of achievement in mathematics. Nationally, students have scored low on standardized tests (Berry, 2008; Slavin & Lake, 2008). This state is one of 17 states that did not show any significant changes in mathematics from 2005 – 2007 (NAEP, 2007). Schools struggle to assist teachers in improving scores that affect the school accreditation and the school report card (NCTM Research Committee, 2008). Strategies for intervention are still the center of debate and research (McDonald, Keesler, Kauffman, & Schneider, 2006).

Specifically, this study addressed a problem in the achievement of students on the geometry End of Course Test (EOCT). In Georgia, state mandated tests are given at the end of each school year for algebra and geometry. This End of Course Test counted as 15% of the final grade. This problem was accurately described in a statement from the 2006 Southern Association of Colleges and Schools (SACS) Self Study Plan: “The End of Course Tests are in the third year of being administered. From the first year to the second, the percentage of students passing increased in all subjects except Geometry and Economics” (p. 15). This was a problem at this school and throughout the school district.

In this study, the geometry classes were divided into two sections (both were college preparatory classes). Euclidean geometry classes emphasized formal proofs in geometry. The informal geometry class did not emphasize formal proofs. But all students took the same test. In 2006 83% of the students taking the test at this urban high school received a score of D or lower on the test (Georgia Department of Education [GaDOE], 2006). This study contributed to the body of knowledge needed to address this problem by examining inquiry–based instructional strategies in informal geometry as an approach to improve achievement on the EOCT. This study addresses a gap in the literature on inquiry-based instruction in secondary mathematics education.

Purpose of the Study

The purpose of this study was to look for a relationship between the use of inquiry-based strategies in an informal geometry class and achievement on EOCT and analyze the implementation of inquiry-based instruction. One of the greatest American challenges in education for the 21st century is narrowing the performance gap on standardized tests between Title I and urban schools. Title I schools are typically schools that serve minority and low-income students (Kim & Sunderman, 2005). The No Child

Left Behind Act (NCLB) raised the bar for accountability and called for research- based programs. William Tate (2005) noted major findings in the North Central Regional Educational Laboratory (NCREL) study which focused on distinct differences in instruction between higher performing schools and lower performing school. He concluded that higher performing schools deviated from the traditional instructional approach in mathematics instruction. Traditional instruction was defined as teacher centered with lecture, demonstrations and drill. In contrast, instruction in higher performing schools was student centered focused on mathematical understanding and reasoning. Tate called for instructional leadership with specific actions for change in instruction. This study proposed that inquiry-based instruction is the needed change.

The purpose of this mixed methods study was to explore the use of inquiry-based instruction in a 10th grade informal geometry class, to examine strategies that would improve student achievement, and to explore how teachers planned and managed the lessons. The study examined the relationship between inquiry-based instruction and achievement on the End of Course Test with inquiry-based instruction as the independent variable and achievement, as defined by scores on the EOCT, as the dependent variable. Studies have indicated that this approach can prepare the student for understanding content in depth and for transferring in problem solving (Camins, 2001; Commeyras, 1995; Dantonio & Beisenherz, 2001; Flick, 1999; Jarrett, 1997; Perkins, 1993; Staten, 1998; Walshaw & Anthony, 2008). But there is still much debate and discussion on how to make learning meaningful to students and how to help them become problem solvers

(Abrami et al., 2008; Barab & Roth, 2006). Problem solving is important in preparing for goals in life.

Nature of the Study

The study utilized the mixed methods procedure, concurrent transformative strategy. Creswell (2003) stated that “this approach is guided by a specific theoretical perspective” (p. 219). This study was transformative because the driving force was based on a constructivist approach, inquiry-based instruction. The analysis of data was conducted using quantitative and qualitative research methods. The quantitative data were collected and analyzed using “the pre-experimental design, posttest-only with nonequivalent groups” to compare tests scores of an experimental group, which was taught in an inquiry–based instructional environment, with a comparison group which was taught in a traditional classroom setting (Creswell, 2003, p. 168). The qualitative data were collected in a descriptive case study design, to gain a detailed description and analysis of the themes or issues in the implementation of the inquiry–based instructional approach (Creswell, 1998, p. 63). There was no priority in the collection of the data. The data were collected in one phase; therefore it was not a sequential strategy. The collection was multilevel because data were collected from the students and the teacher; therefore the study was nested (Creswell, 2003). There was an in-depth study of inquiry-based instruction with an emphasis on the NCTM process standards.

Instruction was examined during the 2006–2007 school year at an urban high school and 2005–2006 scores were compared with 2006–2007 scores on the End of Course Test. Data were collected from records in the Guidance Office. The researcher was a veteran mathematics teacher and taught all 2006–2007 classes. The students were in ninth through twelfth grade in six different classes of informal geometry. The materials for activities in the study included manipulatives, such as pattern blocks, geoblocks, interlocking cubes, and straight edges. The lessons were designed to incorporate the National Council of Teachers of Mathematics (NCTM) process standards and Georgia Quality Core Curriculum Standards for mathematics**.** A posttest was given after each lesson because students may do well right after a lesson and not do as well on a test at the end of the year. Reflections were recorded on the differences in inquiry-based lessons and traditional lessons in a journal after writing the lesson plan and after teaching the class. Lesson plans documented inquiry-based strategies. Peer review or debriefing and member checks were the procedures used to ensure standards of quality in this research. Detailed descriptions of the lessons provided further verification and interpretations**.**

Research Questions and Hypotheses

The primary research question that guided this study was: What impact will inquiry–based instruction have upon the End of Course Test scores of students in a 10th grade informal geometry class? This question was tested quantitatively. Specifically the following qualitative research questions were answered to support the quantitative question:

1. What part does the student's prior knowledge play in the preparation of the lesson and what activities are needed for scaffolding?
2. What has to be built into a lesson for management of an inquiry-based activity?

3. How are the NCTM process standards embedded in the preparation of a lesson utilizing the inquiry process?

4. What part of the continuum of inquiry does each inquiry instructional strategy represent?

5. How does inquiry-based instruction promote student engagement?

The hypothesis was: If inquiry-based instruction is implemented in an informal geometry class, then there will be a significant difference in understanding the content, as measured by achievement on the End of Course Test. The independent variable was inquiry- based instruction and the dependent variable was the score on the EOCT.

Definition of Terms

The key concepts relating to mathematics education in the context of this study:

Constructivist learning: how students translate their past experiences during the cognitive process into knowledge. Constructing meaning is the focus of the activities for the student. Efforts are made to engage the student in higher order thinking and help them become independent thinkers (Lambert et al., 2002). This is "a change from traditional classrooms that focus on students' acquiring proficiency in reproducing existing solution method to classrooms that support helping students construct personally meaningful conceptions of mathematical topics" (Fraivillig, Murphy, & Fuson, 2002, p. 37).

Differentiation: instructional avenues to address the learner's needs at different levels (Tomlinson, 1999). Supporting the student in the learning process at different levels means providing positive experiences. Scaffolding is a strategy that will lead to differentiation in instruction (Carolan & Guinn, 2007).

> Scaffolding refers to any support system that enables students to succeed with tasks they find genuinely challenging. Goals of scaffolding include helping students be clear about the task's purpose and directions and helping students stay focused, meet the expectations for quality work, find and use appropriate sources of information, and work effectively. (Tomlinson & Eidson, 2003, p. 189)

Lewis and Batts (2005) answered the question of how to differentiate with three words – adapt, adapt, adapt.

End of Course Tests (EOCT): mandated by state legislature as requirements for eight high school courses. It is a ninety minute multiple choice test administered three times during the year. Every student must take the test for each subject to get credit for the class. The test constitutes the final exam for that course and counts 15% of the student's final grade (GaDOE, 2007a).

Inquiry continuum: developed to describe inquiry strategies. The continuum described the amount of student motivation and the amount of direction provided from the teacher or material. "On one end of the continuum of inquiry might be the use of highly structured hands-on activities…; in the middle might be guided inquiry… and at the farthest end, students might be generating their own questions and investigations" (Jarrett, 1997, p. 3). The continuum described lessons that were exploratory and open-ended, beginning with concrete models and moving to the abstract.

Inquiry-based instruction: described as "the creation of a classroom where students are engaged in essentially open-ended, student-centered, hands-on activities" (Colburn, 2004, p. 42). Inquiry-based instruction is centered on asking the right questions and using the answers to guide an investigation (Camin, 2001). Based on the theory of Constructivism, inquiry-based instruction involves many stages in which the teacher and student take on different roles in the learning process (Lambert et al., 2002). The teacher becomes the facilitator and creates a learning environment that will support the inquiry approach. This means that the teacher would not follow the textbook rigidly, but uses sources that are related to student questions. Instructional materials would be provided to start with concrete concepts and then move to more abstract concepts.

Manipulatives: instructional tools that can be used to start with concrete examples that will lead to more abstract ideas. They include, but are not limited to, geoblocks, interlocking cubes, nets, and graphing calculators. ”When manipulatives are used, the senses are brought into learning. Students can touch and move object to make visual representations of mathematical concepts” (Math Forum, 2006, ¶ 1).

Metacognition: refers to “higher order thinking which involves active control over the cognitive processes engaged in learning” (Livingston, 1997, ¶ 1). This is a skill which was addressed at different intervals in the year to help students in the inquiry process. The questioning process in inquiry relies on adequate understanding of one’s thinking. If a student is to become an independent learner, “they need to develop the ability to assess their own progress. Students then become owners of their own learning” (Williams, 2006, p. 18).

Prior knowledge: skills acquired in a previous course. In mathematics, some students will have gaps in their knowledge and need extra instruction in more advanced classes. Instructional priorities have to be defined within these boundaries for student success and mastery (Courtade-Little & Browder, 2005; Pollock, 2007). These gaps in the student’s prior knowledge determine where to start in a lesson.

Standards: directed by content and process standards. According to the NCTM**,** standards are "descriptions of what mathematics instruction should enable students to know and do – statements of what is valued in school mathematics education" (NCTM, 2000, p.7). The NCTM content standards relate to the strands for student learning. They are: (a) number and operations, (b) algebra, (c) geometry, (d) measurement, and (e) data analysis and probability. The process standards are strategies in which the content can be applied. They are: (a) problem solving, (b) reasoning and proof, (c) communication, (d) connections, and (e) representation. The standards are designed to help students think and reason while serving as the foundation for mathematical knowledge and skills (NCTM, 2000). Inquiry is embedded in the process standards. Quality Core Standards are state mandated standards for mathematics based on the NCTM standards (GaDOE, n. d.).

Traditional instruction: built on information being presented by the teacher and learning is based on rote memory and recalling facts (Meece, 2002; Piaget, 1965). "Students generally follow a procedure to solve a problem or follow a procedure to confirm, versus explore a concept or principles…" (Young, 1995, p. 5).

The 4E model: In 1989 the 5E model of instruction was developed by the Biological Science Curriculum Study as a model for constructivism instruction. The components were "engage, explore, explain, evaluate, and elaborate" (Al–Qurashi, 2002, p. 10).

> The 5E cycle 1) focuses on major misconceptions, 2) begins with an 'engage' phase that requires active participation by students, 3) moves to additional phases that develop and expand the information and ideas, 4) but with much of the articulation done by the students, and 5)ends with an evaluate phase that emphasizes student synthesis and/or application, plus self-assessment… (Stamp, 2007, 5E Method of Instruction)

This study utilized a modified version of this cycle. The 4E cycle included engage, explore, explain, and evaluate as components.

Assumptions

This study encompassed informal geometry classes. It involved a mathematics teacher who implemented inquiry-based lessons during the 2006–2007 school year and the study compared scores for 2005–2006 and 2006–2007 on the EOCT. The study examined the impact of the inquiry-based approach rather than the traditional approach and analyzed teacher rationale for inquiry-based instructional strategies. In each unit, there was a lesson taught emphasizing inquiry. During the lessons, the researcher examined student engagement and persistence, as well as interactions within small groups. According to Steward and Brendefur (2005), there are three criteria for instruction that will raise achievement. They are: (a) “construction of knowledge”, which occurs when knowledge is “organized, synthesized, interpreted and evaluated – all higher–order thinking”, (b) “disciplined inquiry”, which results in “in–depth understanding”, and (c) “value beyond school”, which makes connections in the real world (p. 6). The lessons incorporated activities that emphasized these criteria, the process standards, and the inquiry process.

For this study, the following facts were assumed to be true:

1. Students enrolled in the informal geometry class have passed Algebra I, even though placement in the informal geometry class suggests that there are deficits in their prior knowledge.

2. Instruction in previous mathematics classes was the traditional approach, focusing on teacher–centered activities, drill, and practice.

Limitations

The limitations of this study were that the constructivist theory of learning can be very broad and inquiry-based instruction is sometimes not definitive (Bateman, 1990; Camins, 2001). Young (1995) stated, “Learning may take place in a variety of modes (e. g., small groups, hands-on work, whole group discussion… individual projects)” (p. 2). According to Flick et al.(1997), new instructional models have to be designed to “improve the currently fuzzy area of assessing inquiry by making clearer links between hands-on, investigative behavior and specific types of learning outcomes” (p. 7). The criteria for identifying inquiry–based instruction were established around five essential features. These features were: (a) instruction centering on engaging questions, (b) priority given to evidence gathered by the students in which they develop and evaluate their findings, (c) explanations scrutinized to focus on the questions, (d) the examination of alternate explanations for the questions, and (e) both verbal and written communication by students to justify the explanations (Beerer, 2004). These criteria were included in the 4E lesson plan. The delimitations of this study were that the study encompassed a single site and one teacher in an urban community. Further research would be needed to generalize to other populations.

The potential weakness in this study was that test scores may be affected by absenteeism, student prior knowledge, and motivation. Dewey (1910/1991) called for “habits of active inquiry” in describing successful thinking patterns. The problem in training thought stems from a student having no prior knowledge or past experiences in the formation of new knowledge. This was a factor that had to be closely examined.

Significance of the Study

This study was significant to teachers of mathematics, administrators, and program evaluators globally who are in reform efforts to raise achievement test scores in mathematics. Many schools have tried new reform movements and have seen little changes in achievement and classroom instruction. Peer debriefing was utilized to “get to the classroom level … to start conversations about curriculum, instruction and student learning “(Steward & Brendefur, 2005, p. 3). Flick et al. (1997), in their article on conflict and clarification in inquiry–based instruction, stated,

> Our knowledge about inquiry teaching has developed more from the perspective of how students behave and what they experience than from how teachers generate and manage those experiences. Data has accumulated in support of inquiry teaching from a broad range of studies that have focused on classrooms features such as hands-on or laboratory activities, classroom discourse, writing and portfolios, and small group work. However…researchers and teachers must become more explicit about the behaviors and thoughts of teachers engaged in inquiry teaching. (p. 5)

To the mathematics teachers, this study should give insight into the inquiry process and assist in the planning of inquiry-based instruction.

Implications to Social Change

A little over 25 years ago, America was stunned by a commission appointed by President Reagan to examine the public schools and make recommendation. There was a concern that the United States was not preparing students for a global economy in a technical society. Borek (2008) stated it was a beginning of growing concerns as a nation about the educational system. The Commission “urged citizens to see themselves as part of a society in which people develop their potential in school…” (p. 573). Everyone needs a good background in mathematics.

Focusing on the subject of mathematics, the commission recommended that the mathematics graduation requirement should be increased to three units. This requirement was recently increased to four units of mathematics (GaDOE, n. d.). With this increased requirement, more attention should be given to instruction that makes the content more meaningful and prepare students to raise questions and think creatively (Jarre, 2008). Teachers need to act as a catalyst in directing students to productive roles in society. This study looked at the development of strategies that will enable students to pursue knowledge for future goals through inquiry (Berry, 2008; Hargreaves, 2003; Walshaw & Anthony, 2008; Wolk, 2008;).

Summary and Transition

“Determining what works best, for whom, and under what conditions are the central tasks that educational researchers are being asked to address” (McDonald, et al., 2006, p. 15). This research proposed that if inquiry is applied more in the mathematics classroom, there will be deeper understanding of the content. As a result, there will be a significant difference in scores on the End of Course Test for students taught using inquiry-based instruction. An analysis of tests scores of the one group taught using inquiry-based instructional strategies and a comparison group taught using the traditional approach was used to support the hypothesis. Section 2 will present a review of the literature and research relevant to inquiry-based instruction. This will include theorists such as, Dewey, Piaget and Vygotsky. There will also be a look at theorists who examined the teaching of geometry: (a) Piaget and Inhelder, and (b) Pierre and Dina van

Hiele. Section 3 and Section 4 give the details of the methodology and analysis. Section 5 summarizes with conclusions and recommendations.

Through this research, deliberate steps for action to address low achievement in mathematics will impact positive social change. The decisions made by the educational community influence the preparation of students for future endeavors in everyday life. (NCTM, 2000). This will be evident in the workplace as skills become more technical.

SECTION 2: LITERATURE REVIEW

This literature review provides an initial study into the historical background of inquiry-based instruction and the characteristics of this approach. Historical notes of early advocates for inquiry, such as Dewey and Piaget, were given and other theorists who promote active inquiry were examined. The need for a change in the “traditional” approach is noted in the call for reform in mathematics and science. Linked to constructivism, inquiry-based instruction places more responsibility on the student, but it also requires that the teacher’s role change from just presenting facts to facilitating the learning experience through the use of questions. According to Hargreaves (2003),

> For many teachers, the impact of new developments in the science of learning has meant learning to teach differently from how they were taught as students.... Teaching for today’s knowledge society is technically more complex and wide-ranging than teaching has ever been. (p. 24)

Problem Statement

Oser and Baeriswyl (2001) asked the question, “What can we say about the real relationship between the activities of teachers and the operations of learners in a classroom?” (p. 1031). In the research, there is a gap in relating the activities of teachers and student learning in secondary mathematics education. In the science curriculum, there is an abundance of research and information, even though inquiry-based instruction is not clearly defined in all instances (Camins, 2001; Clements, 2007; Flick, 1999; Flick & Dickson, 1997; Flick et al., 1997; Hill, Rowan, & Ball, 2005). This literature review looked at the research and current trends to answer this question in mathematics education. The research variables were inquiry-based instruction and achievement in mathematics. The following section will give a basis for the proposed research and take a look at the methodologies of previous research which give credence to this research.

This study focused on informal geometry instruction. Traditionally, geometry in preschool through the middle school emphasized the vocabulary of geometric shapes. Many elementary teachers spent little time on geometry instruction (Baroody, Feil, & Johnson, 2007; Clement, 2003). The comparison of elementary students and high school students presented a picture of little progress in understanding geometry. Elementary students, as they progress through school, are less likely to distinguish geometric figures and understand their properties (Clements, 2003). This was also noted in student achievement when compared with other nations as evidenced by the TIMSS. The scores of students in the United States were near the bottom in every geometry task (Jacobs et al., 2006; Lappan, 1999 as cited in Clements, 2003). Locally, this problem was addressed in the 2006 SACS Self Study Plan.

Geometry tends to be the weak link in the curriculum. "In summary, U. S. curriculum and teaching in the domain of geometry is generally weak, leading to unacceptably low levels of achievement" (Clements, 2003, p.152). Geometry, as specific content, does not receive the instructional emphasis needed to help students grasp underlying concepts. Critical thinking skills, a crucial element in geometry, were examined by great minds, such as Socrates (Abrami et al., 2008; Brun, 1960). And for many years, the role of critical thinking skills and the learning process dominated philosophical and educations discussions.

Theoretical Framework

The Socratic method, named after Socrates, is a technique by which an individual will discover the answer to a question through a series of questions and answers. This was one of the earliest attempts to describe inquiry. It has been compared to the scientific method (Dye, 1996). In the United States, Dewey, as a researcher and philosopher, influenced education through his books and open forum discussions and laid the foundations for constructivism (Dewey, 1910/1991; Green & Luke, 2006; Lambert et al., 2002). Dewey (1916) emphasized the connections between actively being involved in an experience, thinking, and learning.

> To "learn from experience" is to make a backward and forward connection between what we do to things and what we enjoy or suffer from things in consequence. Under such conditions, doing becomes a trying; an experiment with the world to find out what it is like; the undergoing becomes instruction – discovery of the connection of things. (p. 164)

Avid in his emphasis in critical thinking and in his enthusiasm for education as a tool for the growth for democracy, Dewy advocated methods beyond his time, He addressed the problem of training thought. According to Dewey (1910/1991), the problem stemmed from a student having no prior knowledge or past experiences in the formulation of new knowledge. Without prior knowledge, there could not be any reflection, which is essential in the building of thought. Dewey stated, "to maintain a state of doubt and to carry on systematic and protracted inquiry – these are the essentials of thinking" (p. 13).

The need for training thought laid in the role of the school system. Dewey (1916) defined education as a continuing activity.

> It is that reconstruction or reorganization of experience which adds to the meaning of experience, and which increases ability to direct the course of subsequent experiences. (1) The increment of meaning corresponds to the increased perception of the connections and continuities of the activities in which we are engaged. (pp. 89-90)

Dewey (1910/1991) called for "habits of active inquiry" in describing successful thinking patterns (p. 55). The purpose of education, according to Dewey (1916), was to develop a cognitive process by which a foundation for future training and skills can be built. He concluded "thinking is the accurate and deliberate instituting of connections between what is done and its consequences"(p. 177). Connections were only formed through active participation or doing something. With connections, meaning comes to an experience. With meaning, thinking becomes knowledge.

Dewey (1916) stressed the scientific method in the thought process – seeing the problem, making generalizations based upon observations, forming conclusions, and testing the conclusions for the desired results. He advocated that "thinking is a process of inquiry, of looking into things, of investigating" (p. 173). If the test did not give the desired results, the process began again. He spoke out against certain practices, which he called "overzeal" (p. 231). Overemphasis on correct answers restricted creativity of higher order thinking and connections to real life situations. Dewey (1966) believed that education was a necessity of life, whether it is a conscious effort or an unconscious effort, whether it is for the sake of democracy or for the sake of morality.

There has been much research on the connection between learning and the development of a child's mind. One of the foremost scholars in this area was Piaget. In 1935 Piaget wrote about "new methods" in education that would be based on the development of the child. In his article, he wrote that children were being taught as if they were adults. “The new methods are those that take account of the child’s peculiar nature and make their appeal to the laws of the individual’s psychological constitution and those of his development. Passivity as against activity” (Piaget, 1935, p. 693).

In 1965, Piaget addressed pedagogy and the research in education. He looked closely at instruction in mathematics and called it the “didactics of mathematics” (p. 701). He observed that many students who fail in mathematics excel in other areas of study. Piaget stated that the problem was “ the way in which mathematics is taught” (Piaget, 1965, p. 701) and emphasized the need for teachers to act as facilitators in helping a student discover mathematics and to make sense of the content through the student’s own thoughts. The conclusion reached was to focus on inquiry instead of recall and practice (Piaget, 1965).

Through his research, Piaget (1970) was instrumental in developing a branch in psychology, genetic epistemology. He defined genetic epistemology as an attempt “to explain knowledge, and in particular scientific knowledge, on the bases of its history, its sociogenesis, and especially the psychological origins of the notions and operations upon which it is based” (p.1). According to Piaget (1977), a child’s developmental progress was affected by biological factors, environmental experiences, social factors, and the process of “equilibration”. Knowledge is formed through the cognitive process of equilibration, “nonbalances”, and “reequilibrations”. Piaget (1963) stated, “life is a continuous creation of increasingly complex forms and a progressive balancing of these forms with the environment” (p. 3). The thinking process or cognitive systems in a child go through cycles of reorganization. Nonbalances are caused by disturbances or curiosity. When the reaction leads to equilibration (a stage of equilibrium), it is called a regulation. Adaptation comes from assimilation with new information or accommodation with old information. This reoccurring process results in reequilibration (McVee, Dunsmore, & Gavelek, 2005; Piaget,1963). Berlyn (1960) described this continuing process as ”an eagerness to resolve conflict and therefore making a decision for action” (p. 267). These processes resulted in an endless process of inquiry which directs one’s actions and reactions.

At birth, a child begins to organize his world into knowledge structures such as sensorimotor, perceptive, spatial, and mathematical. Sensorimotor and spatial structures related to the physical aspect. Perceptive related to visual aspects and mathematical knowledge related to the abstract. As the child matured, going through different cognitive developmental stages, he moved from a concrete level to a formal level of thinking (Inhelder & Piaget, 1958; Meece, 2002; Piaget, 1977; Richmond, 1971).

Because Piaget (1965) felt that the cognitive process was one of constructions and reconstructions, he urged that research deal with best practices in teaching and the need for “active methods” (p.712). Active methods may result in activity in lower levels. But at higher levels in school, the activity would be more frequently, discovery of new knowledge through reflection and not in merely copying a process. Piaget (1972) recommended that “representations or models used should correspond to the natural logic of the levels of the pupils in question, and formalization should be kept for a later moment as a type of systematization of the notions already acquired” (p.732). According to Piaget, the problem in teaching mathematics stemmed from the methods used in instruction, not in the subject itself.

Research in the domain of geometry instruction by Piaget and Inhelder suggested that geometric concepts were constructed and developed over time. That is, “ideas about shapes do not come from passive looking” (Clements, 2003, p. 152). Exploration was necessary for complete understanding of shapes and their attributes. There was a need to be active in the investigations of shapes. Traditional approaches relied on the use of pictures linked to the vocabulary. The use of pictures did not produce the contextual meaning that would lead to a full understanding of shapes (Abrami et al., 2008; Clements, 2003; Clements, 2007; Clements, Battista, & Sarama, 2001).

Bruner (1966) also promoted constructivism and believed “instruction is after all, an effort to assist or to shape growth” (p. 1). In his work, he referred to Piaget and his description of a child at different developmental stages. Much of his work looked at how a child is stimulated, used prior knowledge (experiences), and then translated this into something that is useful to him. He stated that it is done by representation. There were three ways to do this: (a) action, (b) visual organization, and (c) language. Language was “at the center of the stage in considering the nature of intellectual development” (p. 20). His concern was how to arrange the learning environment to maximize the translation. He stressed helping the child become a problem solver. “Instruction consists of leading the learner through a sequence of statements and restatements of a problem or body of knowledge that increase the learner’s ability to grasp, transform, and transfer what he is learning" (p. 49). These phases of construction made the learner an active participant in the cognitive process.

In the research of Bruner, Goodnow, and Austin (1961), there were many examples. Thinking, "concept attainment" (p. 233), was characterized by the use of categories. Being able to define or validate attributes so that the process of grouping or categorizing could begin was one of the first steps in the learning process. They stated, "a category is, simply, a range of discriminably different events that are treated 'as if ' equivalent " (p. 231). Categories were constructed and developed in a continual process, which lead to learning.

Later, Bruner (1973) looked at the study of perceptual identification, which can be viewed as a way to categorize. As he stated, "children, as they grow, must acquire ways of representing the recurrent regularities in their environment, and they must transcend the momentary by developing ways of thinking past to present to future – representation and integration"(p. 348). According to Bruner (1971), through discovery and exploration, a child can organize his thinking by contrasting through inquiry to formulate choices.

Vygotsky (1978) another constructivist theorist, began his work as a teacher and moved to research to help in educational reform. In his research, he referred to Piaget's research as a background for his experiments. He stated, "Piaget has shown that cooperation provides the basis for the development of a child's moral judgment" (p. 90). He, then, developed the theory of the zone of proximal development. An important feature of this theory was that the development of a child does not maintain the same growth rate as the cognitive processes in learning. "The two never accomplished in equal measure or in parallel"(p. 91). There is a timeframe in which the child will need assistance from an adult or peer to reach competency in a skill (Gredler & Shields, 2008; Murata & Fuson, 2006; Vasquez, 2006)

According to Vygotsky (1926/1997), "questions of education will have been resolved when questions of life will have been solved" (p. 350). His emphasis was on the social aspect of the student as developed through the use of language. There were three stages: social, egocentric, and inner speech. The social stage was for communicating. The egocentric stage described the child talking to himself and the inner speech was the process a student uses to solve a problem mentally. Knowledge is constructed through social interactions (McVee, Dunsmore, & Gavelek, 2005; Meece, 2002; Vygotsky, 1978).

Vygotsky (1978) wrote,

> …the student's personal experience becomes the fundamental basis of pedagogical work. Strictly speaking, and from the scientific point of view, there is no other way of teaching…. Ultimately, the child teaches himself, in the educational process, the student's individual experience is everything. Education should be structured so that it is not that the student is educated, but that the student educates himself…. The educational process must be based on the student's personal activity. (pp. 47 - 48)

Ernst von Glaserfeld (2001) is a theorist in constructivism. He referred to Piaget in his research and using his theory of schema as he developed his work. He stated his work was to show "every inductive inference involves the spontaneous creation of an idea that may turn out to *fit* the "data" but was not actually inherent in them" (p. 9). Thus, new knowledge is constructed and everything reflects the person's own perception of the world (Raskin, 2002).

One model of teaching geometry is the van Hiele model, introduced to the United States in the late 1970s. In their study, they concluded that there were five learning levels in geometry. They are: (a) visualization, (b) analysis, (c) informal deduction, (d) formal deduction, and (e) rigor. The van Hiele model was based on the following premise: "the levels are sequential; a student progresses from level to level primarily because of the instruction received rather than chronological age of that student, and when the levels on a geometry topic is on one level and the student is operating at another level, the student is usually not able to follow the thought process used, and often very little real learning takes place" (Woodward & Hamel, 1990, p. x). The levels of learning, called van Hiele levels, lead to the phases of learning. The phases are: (a) inquiry/information, (b) directed orientation, (c) exploration, (d) free orientation and (e) integration (Clements, 2003; Clements et al., 2001; van Hiele, 1959/1985).

It has been concluded in several studies that the instruction in most geometry classes in high school are taught at the level of formal deduction and rigor while most students are at the first and second levels. "This mismatch between the level of the learner and the level of instruction is at least a partial explanation for the frustration which often occurs in high school geometry courses" (Woodward & Hamel, 1990, p. x). The overall frustration in mathematics instruction was addressed by government committees and agencies and lead to numerous reports and research.

Reports and Current Research

For many years, national reports centered on mathematics instruction and there is still debate on this issue (Jacobs et al., 2006). The "Nations Report Card" was published by NAEP in 1969 (NCES, 2006). The National Commission on Excellence report, *A Nation at Risk*, was published in 1983. The report, *Everybody Counts*, addressed mathematics education (NRC, 1989). The report, *Adding It Up: Helping Children Learn Mathematics*, raised further concerns about mathematics instruction (Center of Education, 2001). These were just some of the reports examining mathematics instruction.

In the TIMSS report, administrators, teachers and students were surveyed on their perceptions, instructional and school policies. Curriculum guides and textbooks were examined. Observations and interviews were conducted in the United States, Germany, and Japan as well as video tapes of the mathematics instruction in eighth grade classes in these countries. It was found that the United States did not compare favorably. The scores of students in the United States were among the lowest of the participating countries (Desimone, Smith, Baker, & Ueno, 2005; Greene, Herman, & Haury, 2000).

The *TIMSS Video Classroom Study* made several observations based on classroom videos. It was concluded that there was not enough rigor in instruction in the United States. The focus of instruction in Germany and Japan was to help the student understand the content through discovery and explaining multiple ways to get answers. Whereas in the United States, the focus was to cover content and get the answer. Emphasis in this report was placed on putting reform recommendations into practice (Jacobs et al. 2006; Stigler, et al., 1999).

The National Center for Education Statistics (1998) presented some startling results.

> Despite the fact that about one-quarter of the test related to calculus and that one-half of the U. S. advanced mathematics students were actually studying calculus, it was in geometry, not calculus, where U. S students performed worst. This is consistent with performance in grades 4 and 8, but unexpected because these advanced students have all had formal geometry coursework. The results show that both geometry and algebra need to be key subjects of study throughout the curriculum. (p. 7)

In 2000 the NCTM revised standards, which raised expectations: " mathematics can and must be learned by all students" (p. 13). The process standards, problem solving, reasoning and proof, communication, connections, and representation, recommended a move from traditional classroom setting to one that is student centered and flexible for discovery (NCTM). Inquiry-based instruction is one approach that can accomplish these goals.

Inquiry-based instruction is inherent in the science curriculum in many publications, but inquiry can be applied in the instruction for all courses (AAAS, 1990, 1993, 2001; Beerer, 2004; NRC, 2000). "Advocates of whole language approaches to reading and language arts also stress the importance of authentic learning in which students are immersed in a language-rich environment in meaningful and productive ways" (Meece, 2002). The process standards incorporate inquiry in mathematics (NCTM, 2000).

The call for educational reform began years ago, but there has not been evidence that reform has been put into practice. The 2003 TIMSS report indicated positive changes in student achievement for elementary students in mathematics and science (Gonzales et al., 2004). A new report comparing 12 countries instead of 40 countries in TIMSS and PISA confirmed these findings. "The United States does relatively better in data and statistics and relatively worse in measurement in grades 4 and 8 and in geometry in grade 8 and at age 15" (American Institute for Research, 2005). A NRC (2005) report focused on specific strategies that targeted mathematics teachers in content areas. Inquiry is incorporated in these strategies.

Beginning with Dewey (1916) and continuing with the educational studies in the 1990s, debate has been encouraged, data has been collected and content standards formulated to call for changes in the way students are being taught. Teaching for understanding, rather than delivering facts is the focus of the reform movement and different teaching strategies can incorporate inquiry to enhance students' experiences in the classroom (Jarrett, 1997; Colburn, 2004). Research in inquiry-based instruction continued to highlight problems in learning mathematics, more specifically geometry. The following studies focused on inquiry as an instructional strategy and provided the lenses through which this research was directed.

One study by Bastista (2002) examined a fifth grade teacher utilizing inquiry for a geometry instructional unit on the enumeration of cubes in 3–D arrays. The researcher noted that

> fewer than 50% of middle grades students could solve such problems, with about 23% of fifth graders, 40% to 45% of sixth and seventh graders, and 50% of eighth graders answering correctly. The results of the second NAEP showed that fewer than 40% of 17-year-olds solved problems of this type. (Hirstein, 1981 as cited in Battista, 2002, p. 75)

The researcher used a case study design, giving a detailed narrative of the classroom setting describing students' thinking during activities. These details gave rich accounts of the instructional process. He concluded that "powerful mathematics learning can occur in problem-centered inquiry-based instruction" (Battista, 2002, p. 82).

An action research study was conducted by Staten (1998). The study included a literature review, observations, focus group discussions and field notes on professional development sessions. The participants were mathematics and science teachers. From the study, a framework was developed to help teachers implement and sustain inquiry-based instruction in science. This framework developed by Staten helped to guide the formulation of the definition of inquiry-based instruction in mathematics at the beginning of this mixed method research and to clarify the focus in inquiry activities.

Flick (1999) conducted four studies, each lasting at least a year, on inquiry-based instruction. In collaboration with science teachers, several formats of inquiry were investigated. The research was guided by observations, teacher narratives, and lesson plans. The studies, in case study design, focused on how to design and implement instruction that was based in inquiry. Through his study, he added to the literature on inquiry-based instruction and provided guidelines for further research. In Flick's studies, the research emphasized teacher thought and lesson preparation. In the case study design of this mixed methods research, teacher thought and preparation was a focus.

Al-Qurashi (2002) conducted research examining inquiry-based instruction in mathematics. Teachers were trained in professional development sessions and participated in an inquiry-based instruction project. He used videotapes, lesson plans of the participants, observations, and interviews to explore the implementation of inquiry – based instruction. Using the 5 E design, he developed a rubric to evaluate lessons. He concluded that inquiry-based instruction promoted student achievement. This design was useful in describing instructional strategies in an inquiry-based activity. A modified version of the 5 E design is used in this research.

Clements (2003) examined instruction in geometry. He reviewed the literature, summarized the use of instructional tools in geometry, and other issues in geometry instruction. He found given conventional instruction, children were less likely to understand geometric attributes. “Inquiry environments appear to have the potential to serve as catalysts in promoting teachers’ and students’ reconceptualization of what it means to learn and understand geometry…” (p. 160). Citing Klausmeir (1992), Clements found that instructional activities that include exploratory and discovery phases rather than structured discovery are more effective. The researcher stated that the NCTM standards present guidelines that focus on the inquiry phases. Preparation for an inquiry-based lesson required the use of the NCTM process standards.

Harpaz and Lefstein (2000) focused on twelve Israeli schools, examining a questioning pedagogy versus an answering pedagogy. The K–12 model, called Communities of Thinking, was implemented through the Branco Weiss Institute for the Development of Thinking. Instruction was based on “cycles of learning in research teams and discussions within the whole classroom” (p. 56). The study concluded that a questioning pedagogy produced students “who are excited about their research questions and who are developing deep and lasting understanding as they grapple with those questions “(p. 57). The emphasis on questioning in the instructional process leads the teacher into the role of a facilitator of learning.

Helm (2004) examined project-based learning, in which inquiry is embedded, in pre-kindergarten and primary classrooms. He compared teaching strategies that began with instruction on one skill or concept which is not initiated by the student to projects which were initiated by the child and teacher for exploration into the student's question. The researcher stated that "the project approach responds to children's curiosity and makes project work generative and engaging" (p. 59). The author concluded that the single concept or "directive pedagogy" limits student learning. The mastery of one concept at a time can lead to drill and practice which did not promote learning or promote student engagement.

Rasmussen and Marrongelle (2006) examined the continuum of inquiry by looking at what is categorized as pedagogical content tools (PCT) in mathematics instruction. The PCT is a "device such as a graph, diagram, equation, or verbal statement that a teacher intentionally uses to connect to student thinking while moving the mathematical agenda forward" (p. 389). The researchers contended that the recommendations by NCTM require an approach that is different from traditional approaches. PCTs were recommended as a possible component for inquiry-based teaching. Their research was based in the "Realistic Mathematics Education (RME) design heuristics of emergent models and guided reinvention" (p. 388). This model, using generative alternatives, was viewed as in the middle of the strategies that begin with "pure discovery to pure telling" (p. 391). An inquiry continuum was developed in this research to make the structure of inquiry-based lessons comparable.

The data for their research was collected from two classes of differential equation for one semester. Instruction in both classes was inquiry-based. Class A had 12 students enrolled, whereas class B contained 45 students. Class A was taught by a college professor in a public university and Class B was taught by the Marrongello. Data collection included video tapes, interviews, samples of student work and a weekly focus group meeting. A code was developed to identify episodes of generative alternatives. They concluded that this method led students through the learning process in a student-centered environment which emphasized student reasoning and discourse (Rasmussen & Marrongelle, 2006).

Kamina (2005) utilized a case study design to study the implementation of the series, *Investigations*. Examining fifth-grade teachers, the researcher conducted interviews and conferences with the teachers, focused on lesson plans and classroom data, and taped class sessions using a tape recorder and a video recorder. The researcher found that teacher collaboration was necessary to establish successful inquiry-based instructional strategies.

Weaknesses and Strengths

One of the weaknesses in constructivism and inquiry-based instruction is that the instruction stresses prior knowledge. Productive questions cannot be formed without foundational information. Students will have to have an opportunity to reflect. The level of the questions will be determined by past experiences. This weakness will challenge the content knowledge of the teacher. The teacher has to have the knowledge base to help direct student inquiry. Instruction will have to be developmental and this involves time and a sequential curriculum (Barrett, Clements, Klanderman, Pennisi, & Puluki, 2006; Bateman, 1990; Dantanio & Beisenherz, 2001; Jarrett, 1997; Kamina, 2005; Marzano, 2003; Meece, 2002; Rasmussen & Marrongello, 2006; Staten, 1998).

The strength of constructivism and inquiry-based instruction is that the student takes on more responsibility for his learning (Dantanio & Beisenherz, 2001; Bateman, 1990; Jarrett, 1997). The student becomes a self-directed learner, in that the student accepts the challenge to construct meaning through reflection, which involves the process of questioning the information acquired. Errors are taken as stepping stones, rather than setbacks (Bateman, 1990; Beto, 2004; Costa & Kallick, 2004; Dantanio & Beisenherz, 2001; Jarrett, 1997).

Inquiry-based instruction gives the student more responsibility in the learning process. Giving students time to discover has advantages over the traditional approach. When students can ask questions, search for the answers to these questions through their own investigations and analyze and communicate their findings, the student becomes a problem solver and critical thinking skills are developed (Bateman, 1990; Brooks, 2004; Commeyras,, 1995; Ennis, 2000; McQuillan, 2005; Whitin & Whitin, 1997).

Summary

Following the mandates of NCLB, the spotlight is on education and the performance of schools. The performance of schools is directly related to the achievement of students (Hess & Rotherham, 2007; Rothstein & Jacobsen, 2006). Great philosophers and theorists have argued about best practices in the educational process, and emphasized that learning can only be meaningful if the students are actively engaged in the construction of their own learning. According to research, the learner, as just a receptor of knowledge, is not adequately prepared for the transfer of knowledge or problem solving. Inquiry-based instruction does require more planning and thought in the presentation of a lesson then the traditional approach of lecture and rote memory. But the traditional approach often does not prepare the student for applying the knowledge in a new context (Baroody et al., 2007; McTighe, Seif, & Wiggins, 2004; Perkins, 1993). Section 3 describes the methods used in this study to examine an alternative approach at the secondary level.

SECTION 3: METHODOLOGY

The purpose of this study was to examine inquiry-based instruction as an alternative to traditional instruction in an informal geometry class. In the last two decades national reports have argued in favor of educational reform. O'Brien (2007) labeled the discourse the "Math Wars" (p. 664). There was a call for major changes, including a change from teacher-centered (traditional approaches) to student-centered instructional approaches in mathematics education (Kilpatrick, Martin, & Schifter, 2003; NCTM, 2000). Weiss and Pasley (2007) described this as letting the student direct the flow of instruction and "sense-making" or "connect experiences with meaning" (p. 674). The construction of knowledge is dictated by the student.

This study (Walden University IRB approval #05-04-08-292868) examined inquiry–based instruction in mathematics. Inquiry–based instruction is one approach, rooted in constructivism that focuses on the student as an active participant in the learning process. Inquiry-based instruction is defined as instruction in which students personally construct their knowledge through asking questions, conducting investigations, exploring and analyzing basic concepts, and communicating their conclusions to peers (Jarrett, 1997). Inquiry-based instruction encourages explorations, investigations, and problem solving versus the traditional approach which relies on lecture, drill, and practice (Brooks & Brooks, 1999). This study also focused on inquiry-based instruction to add to the literature base on inquiry-based instruction in secondary mathematics education.

Research Design and Approach

The research utilized a mixed methods strategy positioned in a concurrent transformative framework. Creswell (2003) stated that "this approach is guided by a specific theoretical perspective"(p. 219). This research was transformative because the driving force was based on a constructivist approach, inquiry-based instruction. Data were statistically analyzed using quantitative and qualitative research methods. The quantitative data were collected by using the preexperimental design, posttest-only with nonequivalent groups to compare tests scores of an experimental group, which was taught in an inquiry–based instructional environment with a comparison group which was taught in a traditional classroom setting (Creswell, 2003). In a case study design, the qualitative data were collected to gain a detailed description and analysis of the themes or issues in the implementation of the inquiry-based instruction approach (Creswell, 1998; Merriam & Associates, 2002). There was no priority in the collection of this data. The data were collected in one phase; therefore it was not a sequential strategy. The collection was multileveled because data were collected from the students and the teacher; therefore the study was nested (Creswell, 2003).

The mixed methods design explored the use of inquiry-based instruction in mathematics classes and examined strategies that will improve student achievement. Quantitatively, the relationship between inquiry-based instruction (independent variable) and achievement (dependent variable) was analyzed. Qualitatively, through a case study design, the implementation of inquiry-based strategies and teacher use of these strategies was examined. In the case study, a program or event is studied in depth and is bounded by time and activity. There are a variety of procedures used to collect the data (Creswell, 1998; Hatch, 2002; Merriam & Associates, 2002).

The qualitative approach, case study, was used to understand how the lesson plans and implemented lessons reflect inquiry-based instruction (Al–Qurashi, 2002). This case study can also be defined as educational research. This means that it is a "critical enquiry aimed at informing educational judgments and decisions in order to improve educational action… Educational research is more concerned with improving action through theoretical understanding" (Bassey, 2002, pp. 108-109). This research sought to provide an in-depth picture of the implementation of inquiry-based instruction.

Research Questions

The primary research question that guided this study was: What impact will inquiry–based instruction have upon the End of Course Test scores of students in a 10^{th} grade informal geometry class? This question was tested quantitatively. Specifically the following qualitative research questions were answered to support the quantitative question:

1. What part does the student's prior knowledge play in the preparation of the lesson and what activities are needed for scaffolding?
2. What has to be built into a lesson for management of an inquiry-based activity?
3. What are the NCTM process standards embedded in the preparation of a lesson utilizing the inquiry process?

4. What part of the continuum of inquiry does each inquiry instructional strategy represent?

5. How does inquiry-based instruction promote student engagement?

The hypothesis was: If inquiry-based instruction is implemented in an informal geometry class, then there will be a significant difference in understanding the content, as measured by achievement on the End of Course Test. The independent variable was inquiry- based instruction and the dependent variable was the score on the EOCT.

Setting and Sample

The samples were drawn from a population of mathematics students in a high school that was located in a southern, urban community, with approximately 1200 students. In this state, schools that do not meet AYP are placed on a Needs Improvement List. Eleven schools, including three middle schools that were feeder schools to this high school, have been on the list longer than any other school in the state (Gelpi, 2007). For the last two years, the high school, a Title I school, has been rated as unsatisfactory. The school did not meet AYP as prescribed by the State Department in 2007. Approximately 85% of the student body received subsidized meals, and 98% of the school population was African-American. The remaining population was classified as Asian, Indian, or multi-racial. The researcher was a veteran teacher of mathematics at the school and taught all informal geometry classes in 2006-2007. The sample size was 127. The multi-grade classes had no more than twenty-five students. In this state, the End of Course Test in Algebra I and Geometry counts for 15% of the final grade. The EOCT is defined as the standardized tests mandated by the State Department for evaluating students' progress in

Algebra I, Euclidean Geometry, and Informal Geometry. Eighty-three percent of all students taking the geometry test in 2006 received a D or lower (GaDOE, 2006).

In this study, the researcher had the responsibility of ensuring the confidentiality of the participants (Rubin & Rubin, 2005; Hatch, 2002). The following safeguards were carried out to protect the participants. The data were kept in a secure place. EOCT scores were coded to conceal the identity of individual students. Written permission was secured from the principal to proceed with the study. The district and school were not identified. The raw data collected was handled only by the researcher, but the results were shared with the district and the teachers at the school.

A "convenient sample" (Creswell, 2003, p. 164) was used in this study because the students were assigned to me at the beginning of the year and there was no choice in the selection. This sample can also be called a "purposive or purposeful sample" – a sample that meets the criteria for the research (Merriam and Associates, 2002, p. 12). The course, an informal geometry course, was considered college preparatory; but the course did not emphasize formal proofs. Ninety–five percent of the students enrolled in the informal geometry classes failed the EOCT for Algebra I, but passed the course (GaDOE, 2006).

Instructional materials were provided to start with concrete concepts and then move to more abstract concepts. The inquiry-based class instruction started with the examination of the student's prior knowledge and encouraged student participation through questions from students. The discussions in class were student-centered where the students would be given opportunities to formulate their own ideas about the concept presented and given the time for reflection and reconstruction of ideas (Lambert, et al., 2002, p. 14). Learning was made “thinking-centered” with a quest for inquiry and comprehending the content in depth (Perkins, 1993). Students were also introduced to the concept of metacognition to guide them in inquiry activities (Martinez, 2006). Teacher-made activities that focus on inquiry were administered throughout each unit and were used in the qualitative design.

Validity and Reliability

The End of Course Test is created and administered by the State Department of Education. Reliability is “a measure of the extent to which an item, scale, or instrument will yield the same score when administered in different times, locations, populations …” (Garson, 2002, p. 190).The technical quality, reliability and validity of the EOCT test, is established by State Department.

> Establishing the validity of a test is a process that begins with test development and involves expert judgment throughout the entire process. Test items and forms are continually reviewed by content experts.… The reliability of the EOCT is established through a measure of internal consistency called coefficient alpha (α). Coefficients at or above .70 are generally considered evidence of a high level of reliability. The reliability coefficients for the EOCT are well above the criterion. (GaDOE, n. d., p. 5)

According to the Testing Program Newsletter (2007a), the EOCT is developed through the State Department of Education. Committees of teachers from around the state establish what will be assessed from the Quality Core Curriculum. “A test blueprint and test specifications” are determined to direct review committees on “which standards can and will be measured and how they will be represented on the assessment” (p. 1). The test items are written according to domain specifications by committees under the supervision of the GaDOE, curriculum specialists, and assessment contractors. Review committees check alignment with "standards, suitability, and potential bias or sensitivity issues" (p.1). After the items have been field tested, another committee reviews the test items before the test is formulated. In the formulation of the tests, content and statistical data are considered so that each form of the test covers the "same range of content" and carries the "same statistical attributes" (p. 2). When several forms of the test have been developed, they are equated. "Equating refers to a procedure to make sure that the tests are of equal difficulty" (p. 2). The test is administered and standards are set for scoring.

Some student activities are generated through the textbook test data bank and resources. Through various research activities, the publisher presents evidence to validate the test questions and activities. These activities include:

> "(a) a review of educational research and recommendations by groups such as NCTM, (b) mail surveys of mathematical educators, (c) discussion groups involving mathematics educators, (d) face-to-face interviews with mathematics educators, (e) telephone surveys of mathematics educators, (f) in-depth analysis of manuscript, and (g) field tests" (Cummins et al., 2001, p. T12).

One threat to the validity of the research involved adherence to the definition of a random sample. Students were placed in classes by a computer and the researcher had no choice in the selection. This presented a flaw in the final analysis, based upon the definition. This will be addressed in the analysis of the data. Control awareness, another threat, was not an issue because students were aware that different activities would be done in different classes, but the same content will be covered in all classes. There were commonalities to all the classes because all teacher–made tests are generated from the same test bank.

A good construct has a clear operations definition that allows space for indicators to be selected for it. To address construct validity, the definition of inquiry-based instruction was closely adhered to with the construction of the lesson plan. Each inquiry-based lesson was specific enough in the 4E model to identify the indicators. External validity was incorporated through the use of the NCTM Standards and the Quality Core Curriculum Standards of the state (Garson, 2002, 2006).

In the case study design, comparisons were made with all the classes the researcher taught. It is possible that unknowingly there would be a self-fulfilling prophecy in the analysis. In educational psychology, this concept was developed by Merton (year) "to explain how a belief or expectation, whether correct or not, affects the outcome of a situation or the way a person (or a group) will behave" (Waasdorp, 2007). To counter this issue, the Geometry 2006–2007 EOCT scores were compared with the 2005–2006 EOCT scores of students taking informal geometry who were taught by the other geometry teachers. In general, these teachers did not utilize inquiry-based strategies in their classes.

To further address validity and reliability in the qualitative data, four avenues were being employed: (a) prolonged gathering of data, (b) triangulation, (c) documentation of similar research in inquiry, and (d) peer consultation (Becker et al., 2005). The implementation process proceeded over a period of one school year. This presented enough time to look at different activities for changes in lesson design and a variety of inquiry-based strategies. Triangulation involved using a variety of data sources. Data were collected from lesson plans, journals, field notes and student work. Lesson plans were used to answer research question one. The 4E model of instruction in the lesson plan was used to identify inquiry strategies/indicators. The teacher journal was used to answer research question one-b, one-c, and research question two. Field notes from observations were used to answer research question one-c and research question two. Student work was used to answer research question one-b. Similar research is cited such as Batista (2002), Flick (1999), Al-Qurashi (2002) and Clemons (2003) in the literature review. Theoretical research, based in constructivism, was cited by Piaget, Vygotsky, Bruner, and others. Peer consultation with other geometry teachers in Section Five further established validity to the qualitative study through their expert pooled judgment.

Data Collection

The data collection included quantitative and qualitative data. The target group for data collection in this study was high school mathematics students taking informal geometry. The qualitative data were collected in a case study design to gain a detailed description and analysis of the themes or issues in the implementation of the inquiry–based instruction approach (Creswell, 1998). Data for this research were collected from lesson plans, field notes and other artifacts. Student activities were generated through the test data bank and resources for the informal geometry textbook. Mini assessments were made through teacher made inquiry activities (Cummins et al., 2001).

In the quantitative design, the data collected were the EOCT scores from the administrative office of the school. The 2005–2006 scores for informal geometry were compared with 2006–2007 scores. The EOCT scores represented the dependent variables.

The type of instruction, inquiry-based or traditional instruction, was the independent variable. In May, the EOCT in Geometry was administered to all geometry students. These scores were sent to the Guidance Office as a School Summary Report and a Class Report. The Summary was released on the school district website. A System Summary Report was available on the Department of Education websites (GaDOE, 2007b).

Strategies for Analysis

This concurrent, transformative, mixed methods design proposed to examine the implementation of inquiry-based instruction in an informal geometry class by collecting data, conducting a statistical analysis (quantitative research), and presenting a descriptive analysis (qualitative research). In the quantitative data collection, a posttest-only with nonequivalent group design, test scores were used to measure the relationship between the use of inquiry-based instruction and academic performance in two groups (Creswell, 2003). At the same time, through the research strategy of case study, inquiry-based instruction was investigated. A narrative portrayed major events. Through a detailed description, an analysis of "themes and issues" resulted in an interpretation of the implementation and "lessons learned" (Creswell, 1998, p. 63).

Looking at three specific lessons, one at the beginning of the year, one at the end of the first semester, and one at the end of the year, data analysis examined in depth the lessons and the inquiry approaches that were predetermined in the inquiry continuum. From this, specific strategies were identified. A holistic analysis was used to write descriptive narratives (Creswell, 1998).

The case study narrative covered the experience in the school with "rich, thick descriptions" (Creswell, 2003, p. 196). The operational definition of inquiry–based instruction was closely followed. Any researcher bias was explained and clarified at the onset of the case study. Every effort was made to present all themes, both positive and negative. Collaboration with another mathematics teacher at the school was used to review the narrative and assist in a debriefing process. Using observation notes, journal entries, roll books, student work, and lesson plans as sources of information, there was a focus on a coherent justification of the themes that emerged from this collection of data through categorical aggregation (Creswell, 1998).

The independent sample *t* test was used to compare the Geometry EOCT scores for the 2005–2006 school year and 2006–2007 school year. The z statistic was considered for the analysis of the data. But the shortcoming of z scores is that the population standard deviation is needed for the analysis. In this data, the standard deviation for the population was not known. The confidence level was 95% with $\alpha = 0.05$. An effect size was calculated to describe the size of the treatment effect. Cohen's *d* was used to measure the effect size where the mean difference was measured in terms of the standard deviation ($d > 0.8$ indicates a large difference). A one-tail test was used because it will indicate small differences in a specific direction. Equal variances were assumed (Gravetter & Wallnau, 2005). To increase reliability and reduce errors in measurement, the data was entered into the Statistical Package for the Social Sciences (SPSS) program by two different people and the tabular results was compared for discrepancies and verified.

According to Gravetter and Wallnau (2005), there are three conditions that have to be satisfied before a *t* test can be used for the hypothesis testing. They are: (a) the sample data are independent (one measurement is not influenced by another measurement), (b) the population of the samples is normally distributed, and (c) the samples have equal variances (homogeneity of variance). The first condition was satisfied because comparisons will be made with students who are taking different tests. The second condition was satisfied by the Central Limit Theorem. That is, the sample means is almost normal if "the number of scores (*n*) in each sample is relatively large, around 30 or more" (Gravetter & Wallnau, 2005, p. 158). The third condition was verified through the use of F-max test and the effect size was calculated. According to Fink (2006) and Trochim (2002), there should be at least 20 to 30 participants per group of students and the data should be continuous. These conditions were satisfied.

Summary

The focus in this research was on the implementation of inquiry-based instruction in mathematics education. For the quantitative phase of the study, a *t* test was used. A case study design examined specific instructional strategies at the secondary level. Data, lesson plans, and student activities are available in the appendices and comparisons are displayed in tables. Section 4 will discuss the actual data collection and analysis describing the first year of implementing inquiry-based instruction in an informal geometry class.

SECTION 4: RESULTS

This concurrent, transformative, mixed methods study investigated inquiry-based instruction in a 10th grade informal geometry class. This design was selected because it created an opportunity to include personal reflection and data analysis in an effort to improve the achievement of students in geometry. A case study design was used to describe the issues involved in the implementation of a reform instructional strategy. The quantitative design examined the relationship between inquiry-based instruction and achievement on the EOCT in geometry. This chapter discusses the analysis of data used in each design.

For this study, data were collected from lesson plans, teacher field notes, teacher journal, roll books, guidance office records of the EOCT scores, and the web sites of the district and State Department of Education. Using multiple data resources allowed for triangulation. Using categorical aggregation for data analysis (Creswell, 1998), pertinent raw data from teacher field notes, teacher journal, and lesson plans were placed in the appendices.

Description of Informal Geometry Classes

The total number of geometry students taking the EOCT in 2006 was 233 and the total number of geometry students in 2007 was 198. The geometry classes at this high school were divided into two sections. The Euclidean geometry classes consisted of students who passed Algebra I with at least a B average. These students were considered to be students who needed the more rigorous approach to geometry, which included proofs. The informal geometry classes consisted of students who passed Algebra I with a

C or below. The informal geometry student was more likely to cut class or be suspended more than one time during the school year. This study focused on the informal geometry students.

The 2007 informal geometry class (sample 2) was unique in several aspects. This was the class that was taught using inquiry-based instruction, but this class was also the first class to take geometry for a full year before being tested. There was no prerequisite for taking the second semester of the course. The 2006 informal geometry class would be students who passed the first semester (Part A) of the course and entered the second semester (Part B). If they did not pass Part A, they had to repeat the course work before taking Part B. The 2007 informal geometry classes included students who failed Part A or Part B the previous year. Students who failed Part B would take only the second semester of the course. Both groups of students were included in the analysis of the data. This meant that this was the first year of inquiry-based instruction and the first year in which the course would be taught as a one year course with one unit of credit instead of ½ unit for Part A and ½ unit for Part B. There was no prerequisite for taking the second semester of the course.

Typical Classroom Setting

In this study, the textbook with resources was the same textbook used in the 2005-2006 school year. The curriculum and class period were the same. The class period was 50 minutes. The textbook supplied hands-on activities for almost all sections. To reduce the variable of teacher personality and teaching style, all classes were taught by the principle researcher. To implement inquiry-based instruction, emphasis was placed on questions, hands-on activities, and explorations.

A typical mathematics class involved students in cooperative groups or independently using manipulatives to support the lesson. Because geometry is the study of the basic figures of points, lines and planes, an assessment of students' previous knowledge of basic shapes was administered. It indicated that most students had problems identifying basic figures and understanding the detail in a diagram. Drawing the figure to examine detail then became a routine part of the assignment. When a student had a question, my response was "did you draw the figure?' If the answer was no, the student was asked to sketch the figure and identify all parts. In doing so, many times the student answered the posed question. If the answer was yes, the student was asked to give all details in the figure, which assisted in answering the question. Students had to become accustomed to being asked a question when they asked a question and drawing figures. Some initial student responses to this emphasis at the beginning of the year are as follows:

1. I thought this was a geometry class, not an art class.
2. You're the teacher; you're supposed to work the problem.
3. Just show me how to get the answer.
4. You're not like my other teacher. (Journal Entry I, Appendix A)

Throughout the course, the focus was on representation and understanding of the vocabulary through hands-on activities rather than memorization of facts. Mathematics lessons and activities began by engaging the students using directed questions or a problem solving activity. Lessons chosen for examination in this chapter were activities in which students worked independently or in groups, with minimal help from the researcher. Assessing students' prior knowledge revealed that the hands-on activities from the textbook assumed knowledge beyond the scope of the students.

Explorations were created to fill in the gaps and provide differentiation in the lesson so that every student was given a measure of success. According to the students, they had very little previous experience using hands-on or inquiry-based instructional strategies. From this discussion, their responses indicated that their last experience with hands-on activities was in elementary school. Through discussions with the other geometry teachers, traditional instruction was utilized as opposed to inquiry-based instruction.

Because most students were not familiar with inquiry as a routine part of class, the first week of school was spent helping students understand inquiry as a deliberate effort to ask questions, obtain answers, and evaluate answers in the light of the questions. The activities were dedicated to helping students understand themselves in the learning process. A discussion on why do I like or dislike mathematics gave insights on issues that would not show up on a diagnostic test. Metacognition was introduced as the researcher's effort to assist the students in understanding their thinking and to emphasize the role of questioning in this class. Three questions for reflection were discussed and placed on the walls as a reminder.

1. Am I understanding a concept? How well am I understanding?
2. What else do I need to know and do to expand my understanding?

3. Can I pass a test/quiz on this section? (Journal Entry I, Appendix A)

Three lessons were selected for the research questions. Lesson One represents a lesson at the beginning of the year. Lesson Two represents a lesson at the end of the first semester. Lesson Three represents a lesson at the end of the second semester. These lessons should give an accurate discussion on the implementation of inquiry-based instruction.

Research Question #1: What part does the student's prior knowledge play in the preparation of the lesson and what activities are needed for scaffolding?

In Lesson One, exploration 2 was designed in response to student's questions in section 2-1, Real Numbers and Number Lines. At the beginning of the school year, the diagnostic test revealed that there was a weakness in computation with whole numbers, fractions and decimals. Scaffolding refers to activities that are used to help a student succeed in areas that they find challenging. This topic was assumed to have been mastered in Middle School. This lesson presented an excellent opportunity to address these areas of weakness pointed out by the diagnostic test. Used at the beginning of the chapter, this activity focused on prerequisite skills that were essential for understanding number lines and mastering the content in this chapter. The use of the calculator helped focus on the concept being taught rather than errors in arithmetic. It was also noted that students still had problems in reading a ruler or number line. They counted the division lines instead of the units. This was used as a scaffold, an activity to bridge gaps in prior knowledge, for the textbook geometry hands-on activity in this section. (Lesson Plan One, Appendix D; Journal Entry II, Appendix A; Appendix F)

Lesson Two was used in the last part of the first semester (about 15 weeks into the school year). The lesson covered Right Triangles and Congruence. Students were still not familiar enough with inquiry to design an exploration. This lesson relied on the students' understanding of chapter 5 (prior knowledge) which focused on the basic theorems of triangle congruence. This lesson's activity was used as a scaffold to bridge gaps in prior knowledge in this section and to make connections clear. The emphasis continued to be seeing detail in the diagram and being able to label correctly (Lesson Plan Two, Appendix D).

Designed to give students an opportunity to develop spatial sense, Lesson Three was taught during the last grading period. Students struggled with the diagrams in the assignment because the figures were three dimensional (solids).The concept of volume was explained using interlocking cubes, but more practice was needed. This was another activity used to scaffold for the geometry hands-on activity in the textbook (Lesson Plan Three, Appendix D; Journal Entry XII, Appendix A).

Research Question Two: What has to be built into a lesson for management of an inquiry-based activity?

In Lesson One, the activity was designed to be done with minimal assistance from the teacher. The partner routine had to be established with all classes. In these first lessons, students did not want to work in pairs and some refused to work in a pair. These individual students were allowed to work alone, but counseled on the outside of class about working in groups. (Field Notes, Appendix B; Journal Entry II, Appendix A)

Management in Lesson Two began with having established the routines of cooperative groups. By now, students are used to working with a partner. Some students yet refused to work in a pair or a group. This activity required groups of three, where each student would investigate one of the three theorems and then the group would come together to submit one paper (Field Notes, Appendix B).

For Lesson Three, preparation beforehand was essential for management. The right number of interlocking cubes was placed in bags so that each student could participate with a minimum of instructional time being lost. Before the lesson, students were given an opportunity to become familiar with the cubes. One comment was that this activity was for elementary school. But many students had problems making the pictured solid (Field Notes III, Appendix B).

Research Question Three: How are the NCTM process standards embedded in the preparation of a lesson utilizing the inquiry process?

In Lesson One, the NCTM standards of representation, connections, and problem solving were embedded in the lessons. For example, when explaining the relationship between the coordinates and the graph on the number line, the students had to connect the abstract with the concrete representation of a fraction or decimal. This concrete representation was a point on the number line. Students had to decide on the units of measure on the graphs. One example was given in the activity. By applying various strategies and utilizing previous skills, problem solving was a key factor in doing the remaining problems. (Lesson Plan One, Appendix D)

In Lesson Two, all process standards were incorporated into this lesson. (See Appendix E) The emphasis was placed on connections being made from Chapter 5 (Basic triangle congruence theorems and postulates) to Chapter 6 (The right triangle). This exploration used the process of problem solving and reasoning and proof. Representation was the focus in the drawings, labeling, and identifying parts. Cooperative groups helped students communicate with peers.

Lesson Three emphasized the process of representation as essential in understanding the net and the diagram of the solid. Using interlocking blocks helped the students visualize what was on the activity sheet. To make predictions and give the number of cubes in the diagram, the students had to focus on reasoning and problem solving (Lesson Plan Three, Appendix D).

Research Question Four: What part of the continuum of inquiry does each inquiry instructional strategy represent? (See Appendix C for the Inquiry Continuum)

The phases of Lesson One were at Level 3 for all categories. In the task, the teacher provided a list of open-ended questions which directed the students to the analysis of data. This lesson would be classified as a guided inquiry.

For Lesson Two, the levels varied. According to the Inquiry Continuum, the level was A2 for Engage because specific questions were provided. In the second phase of the lesson, Explore, the level was B2 because the activity sheet provided the directions for the exploration. In the third phase of the lesson, Explain, the rating was C4. The teacher guided the students to the data. Evaluate, which was the last phase of the lesson, was rated D4. Students worked more independently in the analysis of the data. This made it difficult to classify the lesson. But with an average of three (2+2+4+4), the lesson was classified as a guided inquiry, level three. (Lesson Plan Two, Appendix D).

In Lesson Three, the Engage phase was rated as A2. Specific questions were provided. In the Explore phase, the rating was B3. Teacher direction was given in the open-ended task. In the third phase, Explain, the rating was C3. Data were provided for student analysis. In the Evaluate phase, the rating was D3. With teacher support, the group completed the analysis. With all categories rated as 3 except Engage, this activity would be classified as a guided inquiry (Lesson Plan Three, Appendix D).

Research Question Five: How does inquiry-based instruction promote student engagement?

After introducing number lines and a discussion on numbers, the assignment in Lesson One presented the material in a different way. This was the first inquiry activity in which the researcher would step back and let the students work independently. Some students did not engage in this activity. Some students hesitated because they were not used to investigating a problem and making independent inferences. When students were instructed to work individually, explain, and compare answers with a partner, some felt more comfortable. Even with probing questions, the students did not begin work on this assignment. Only with the researcher's support did the class, as a whole, complete the assignment. Some student responses were:

1. You didn't show us how to do this.

2. You show me how to do it. I'll do it. (Field Notes, Appendix B; Journal Entry I, Appendix A)

During Lesson Two, students had become accustomed to working in groups and to the questioning strategy used in class. The comfort level was raised. Students became more verbal in their discussions, correcting one another, and engaging in debates over answers. Some students still chose to work individually (Field Notes, Appendix B).

Lesson Three was during the last grading period and students were very comfortable with cooperative group and peer discussions. Reluctant students participated in the activities and other students began to act as experts. Some responses were as follows:

1. We got it right! (Student to student)
2. S1: Let me read the direction… that's 4 and that's 5. S2: That's the way I did it. (Students high five)
3. S: Is this right? T: Why would you think it is right?

   S: There are two in front, and four on the side, and then up two. T: That's correct. Student to another student: I told you so.

Inquiry Project

This activity was given at the end of the first semester to encompass a student centered activity at Level 5 in the Inquiry Continuum. This was in response to questions that were asked from the beginning of the semester. Summarized, the question was "How is geometry going to help me in the future?" The goal was to have students look at different careers so that they could reflect on future goals. The student had total freedom in designing the inquiry process, collecting data, making inferences, and reporting the findings. This activity was offered to all classes as an extra credit assignment so that those who choose not to do it would not be penalized.

Less than 15 percent of the students (21 students) chose to do this assignment. These students did not have clear ideas or understand what their future plans would be or where to go to obtain the data (information). With researcher's support, they completed the assignment. Special discussions were placed in different lessons to target this gap in knowledge. Exercises directed to specific careers were assigned to make connections to everyday life and create discussions about possible careers that use geometry.

Themes Inherent in the Data

In analyzing the three lessons, several themes emerged. In inquiry-based instruction, the teacher had to become the facilitator in the class and had to model the questioning technique in the inquiry process. In the beginning, students had to become accustomed to the teacher assisting in the construction of knowledge as opposed to giving facts for memorization. A training period was necessary to bring students to the point where they were aggressive in formulating their own questions and engaging in an inquiry process. Being in charge of the learning process was new to most of them and many resisted the process at first.

The implementation required intensive planning and creating explorations because of the gaps in the students' prior knowledge. To advance in a lesson, connections had to be made evident through student activities. The NCTM process standards were crucial in all steps to meet the needs of all students. The geometry course relied heavily on these standards.

The inquiry process takes time and the fifty minute period did not lend itself to the completion of a task in one day. Giving students time to reflect and analyze conclusions required the division of a task into manageable units. Sometimes this could be accomplished, but due circumstances beyond the researcher's control (field trips, club meetings, suspensions, etc), the tasks could not be completed by all students. This required reteaching at some point to bridge the gaps in knowledge. The inquiry activities were used to introduce, teach, or reinforce a concept. Time was a factor that influenced the creation, the design, and the implementation of exploration activities. In the three lessons, all students did not complete the exploration activities and in many instances makeup work was not completed by the student.

None of the inquiry activities were totally student centered. The students engaged in an exploration with teacher support and guidance. Time did not permit the examination and reflection needed for a pure inquiry activity. Time management was a skill that had to be emphasized in the student activities. Learning to stay focused and on task was a lesson taught each day. The lesson on metacognition gave the researcher opportunities to emphasize the habits needed to become independent thinkers.

Descriptive Statistics

Table 1 summarizes the statistics for all students in this state, county, and school and looks at the subset of Black students. Examining the data using descriptive statistics revealed subtle changes in the scores of students who were tested. In 2006, over all 45% of all geometry students (n = 1,768) in the county passed the EOCT. Looking at the Black geometry students (n = 1,231) in the county, 37% passed the EOCT. At this school, only 19% of all Black geometry students (*n* = 218) passed in 2006. Focusing on the subset of informal geometry students at this school, 6.9% of these students (*n* = 155) passed the EOCT. Data on informal classes in other schools were not available (GaDOE, 2008).

In 2007, 38% of all geometry students (*n* = 2067) in the county passed the EOCT. Twenty-nine percent of the Black geometry students (*n* =1510) in the county passed. At this school, 22% of all geometry students (*n* = 198) passed the EOCT with 21% of the Black geometry students (*n* = 181) passing. Looking at the informal geometry students (*n* = 121), 11.6% passed the EOCT (GaDOE, 2008).

Table 1

Geometry End of Course Passing Rates

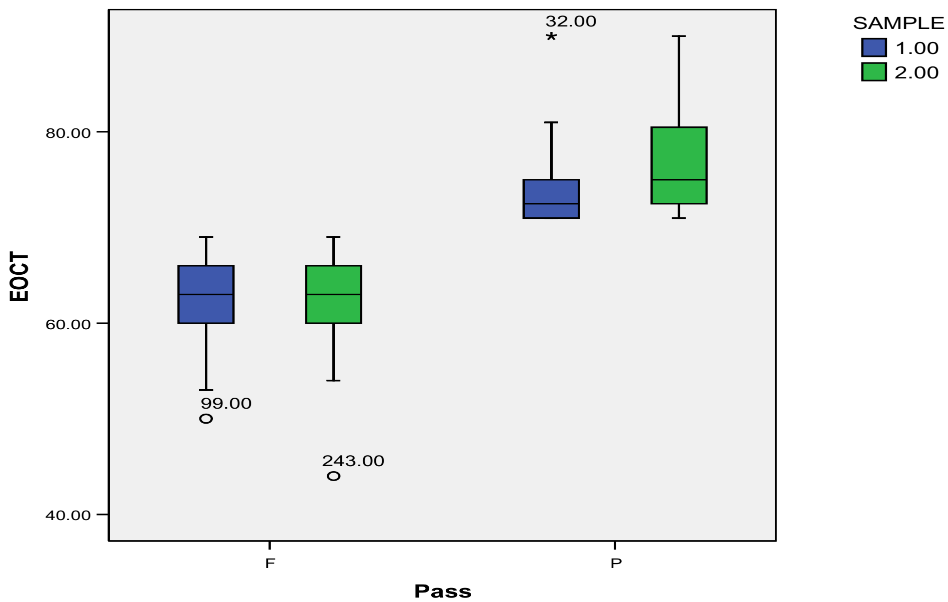
	2005 - 2006		2006 – 2007	
	Passing	# of students	Passing	# of students
Statewide	63%	94,593	63%	99,924
State -Black	40%	37,880	42%	39,062
Countywide	45%	1768	38%	2067
County -Black	37%	1231	29%	1510
School	19%	233	22%	198
School -Black	19%	218	21%	181
IFG*	6.90%	155	11.60%	121

*Informal Geometry

(GaDOE, 2008)

A box-and-whisker plot (See Figure 1) revealed that in the sample 1, there was one outlier and an extreme score which may influence the mean values. The outliers can be described as scores that are 1.5 to 3 interquartile ranges from the top hinge or the bottom hinge of the box. The extreme score is more than 3 interquartile ranges away from the upper and lower hinge of the box (Johnson, 1989). This box-and-whisker plot shows that there was a higher number of passing scores in sample 2 and that the passing scores for sample 2 were higher. This boxplot shows comparisons for all students in sample 2.

Figure 1. Clustered Box - and - Whisker Plot for sample 1 and sample 2.



Analysis using the *t* test

An analysis using sample 1 and sample 2 was the first step in examining the data. Sample 2 (n = 127), who were taught using inquiry-based instruction, had an average M = 64.2 with SD = 6.7. Sample 1 (n = 155), who were taught using the traditional instruction, had an average of M = 63.8 with SD = 4.8. Statistical analysis indicated that even though the mean of sample 2 was greater than sample 1, sample 2 did not score significantly better than sample 1. The analysis was t (223) = 0.455, $p > 0.05$, and therefore fail to reject the null hypothesis. This could result in a Type II error meaning that there was a difference in the scores, but not a significant difference. Since this was the first year of implementation, reexamination of the data was deemed necessary (Gall, Gall, & Borg, 2003).

Examining the data again, a subset of sample 2 was used, sample 2a. This subset did not include the students who failed Part B of the course and therefore came into the class at the beginning of the second semester, students who were sent to the alternative school during the year, but were included in sample 2, and students who missed more than six weeks of instruction (i. e., students who had unexcused absences and various other reasons). Statistical analysis using the *t* test indicated that the mean of sample 2a was greater than the mean of sample 1. Using a one-tail test, t (143) = 1.763, $p < 0.05$, $r^2 = 0.02$ and therefore reject the null hypothesis.

Summary

This chapter explained the analysis of the data. First, the qualitative data was used to answer the research questions in the case study design. A look at the descriptive statistics for this data gave some insight into the analysis of the *t* test. The *t* test was used to examine the data from two perspectives. A closer look was given to students in sample 2 who were in the class most of the school year. The results of the *t* test were two-fold. One, the *t* test for the entire sample indicated that there was no significant difference between sample 1 and sample 2. This was the first year of implementation and sample 2 was a mixed group of students, all of whom were not taught for a whole year. Two, when a one-tailed test was used in the analysis of sample 2a, a subset of sample 2, there was a significant difference; but there was not a strong correlation between passing scores and instruction. Section 5 will give the conclusions and implications found from the analysis.

SECTION 5: SUMMARY, CONCLUSION, AND RECOMMENDATIONS

The purpose of Chapter Five is to report and discuss the findings of this study. The focus was on inquiry-based instruction. This instructional approach was first introduced to the researcher in a science and mathematics seminar in which the majority of the resources focused on science instruction. Inquiry-based instruction was defined in the context of an experiment. In the research during this study, inquiry-based instruction was not clearly defined in mathematics. Grossman and McDonald (2008) quoted Lartie (1975) in discussing this lack of a common vocabulary in teaching which would facilitate describing teaching in all grades and all subjects. Therefore, at the beginning of this study inquiry-based instruction had to be clearly defined and subsequently a continuum developed to describe and categorize the phases of inquiry.

This study was important because the algebra and geometry courses serve as indicators for success in future endeavors. Paek and Center (2008) stated that "83 percent of students taking Algebra and Geometry went to college within two years of graduating from high school… This percentage drops to 36 percent for those who did not take Algebra I and Geometry" (p. 10). The data indicated that students struggle with these courses.

In report after report from research committees and the United States Department of Education, it was pointed out that the traditional instruction did not bring the desired results in achievement in mathematics. Theorists have posited that the learner had to be involved in the construction of knowledge during the learning process. This study was an effort to document the implementation of inquiry-based instruction, as an alternate approach, from a teacher's perspective and examine its relationship to achievement in an informal geometry class.

This study examined one school year, 2006-2007, in which inquiry-based instruction was emphasized as one of the instructional strategies for six classes of informal geometry students at an urban city school located in the southern part of the United States. The school was a predominately Black Title I school and their EOCT scores were included as part of the analysis. Lesson plans, field notes, the researcher's journal, and EOCT scores were sources of data. Research questions for the case study were answered using a narrative format reflecting the classroom climate, student involvement, and the preparation and implementation of lessons.

Brooks and Brooks (1999) found that a lesson plan could indicate a constructivist approach, but the implementation of the lesson did not always follow the constructivist approach. Putting a reform approach into practice takes time for the teacher and the students with administrative support. Paek and Center (2008) addressed this problem and concluded that administrators, teachers, and students have to make changes in their attitudes as well as instructional practices. Raudenbush (2008) examined the "intended" and "enacted" lesson in class instruction. This would be a result of teacher beliefs and prior experiences. The researcher taught all classes; therefore the variable in teacher instruction and interpretation of inquiry-based instruction was put at a minimum. Because this was the first year of implementation, originally there was resistance by students. This was documented in the researcher's journal and field notes.

One limitation of this study was that it involved one teacher and one school. Using a convenience sample, the groups were selected without random assignment. Gall et al. (2003) concluded that random assignment is extremely difficult in an educational setting. Raudenbush (2008) addressed this issue as the measure of the statistical power of a study. He concluded that to conduct a carefully controlled study, the number of studies examining alternative instructional approaches and their impact on achievement would be large and require a substantial funding. He stated "experienced instruction is measured with error and not amenable to randomization" (p. 206). This was considered in the interpretation of the data.

Based on the researcher's journal and lesson plans, the case study reflected the researcher's bias in reporting instances in instruction, but it reveals the issues and challenges involved in the daily planning and implementation of a "new" instructional strategy. The case study was designed for an in depth examination of inquiry-based instruction through personal lens. With this examination through personal interpretation with a statistical analysis, the bias of one method could "neutralize" the biases of the other method (Creswell, 2003, p. 15.)

Recommendations for Action

The 2006-2007 School Improvement Plan addressed two strategies for intervention. One of these strategies was to use hands-on activities in all mathematics classes. According to research, geometry is the weak link in the curriculum. It should be taught at all levels, but it is most likely to be the least emphasized (American Institute of Research, 2005). The implementation of inquiry-based instruction on a larger scale would require professional development and support for administrators and teachers (Wayne, et al., 2008). An activity can be hands-on, but not include inquiry. According to Raudenbush (2008), educational policy should be driven by research.

Reflecting on journal entries and field notes, the study suggests that students are motivated to participate when the assignment included segments that require actual handling (hands-on) or creation of geometric figures. Drawing the figure was considered a hands-on strategy to help students construct new knowledge. To many of these students, most of the geometry content seemed unrelated to prior knowledge. In the first six weeks, one student asked when will we do some figuring [math operations].

Examination of the data suggests that student attendance may be a reason for low achievement on the EOCT. A rigorous course of action may be needed to respond to this problem. The consequences of not meeting adequate yearly progress mandate that avenues to monitor students' attendance be reviewed and an aggressive support program be put in place, especially for juniors.

When examining the students in each sample, it would seem that sample 1 would have done much better than sample 2. The students in sample 1 passed part A and were recommended for part B. These findings suggest that in the first year of an implemented program significant progress may not be evident in a statistical analysis. And it may be that the EOCT may not be the test to show these changes. Another goal in inquiry-based instruction was to make students more responsible for their learning by becoming independent learners. This urban high school did not met AYP in mathematics for two years. One of the indicators for meeting AYP depended on the eleventh grade students taking the Georgia High School Graduation Mathematics Test for the first time. In 2008, the mathematics department made AYP under Safe Harbor. Fewer students passed but a larger percentage of students passed with a proficient ranking (GaDOE, 2008). The content of the mathematics test could be 32%–34% geometry (GaDOE, 1999). I would hypothesize that the informal geometry students made the difference in this percentage. Further study would have to provide proof for this statement. Further study would compare EOCT scores during the second year in which more students passed. This study opens other questions that would look into self-regulated learning (SRL), which is essential to inquiry-based instruction. This would address the student's "initiative, perseverance and adaptive skill" (Zimmerman, 2008, p.167). Motivation is a key element in the pursuit of the answer to a question.

The Impact on Social Change

When this study was begun, the challenge was what question was worth asking concerning instruction and curriculum. In mathematics, Piaget (1965) stated that the problem in excelling in mathematics was not in the content, but the way it was being taught. Dewey (1916) emphasized that if there was going to be constructive change in a society, it would be through the educational system. With this in mind, this study focused on inquiry-based instruction as an alternative strategy and it was directed to geometry students because this is a pivotal point in the mathematics curriculum.

The content in a geometry class is usually taught in high school. In this class, the foundations are laid for every advanced mathematics class in high school and college. One-third of the test that will be required for graduation is geometry (GaDOE, 1999). The

Scholastic Assessment Test (SAT), which covers three years of high school mathematics can be a factor in going to college (Black & Anestis, 2007). After acceptance, the college entrance exams, which will include geometry, determine the freshman mathematics course. Teaching critical thinking skills should be a primary goal in instruction (Abrami, et al., 2008). Doors will open or close depending on the mathematical ability to think and reason logically. Inquiry-based instruction will promote self correction, which develops an adaptive attitude toward learning, and influences creativity (Jarre, 2008)

This research was relevant in this area of study because it also focused on teacher thought and lesson design. There is a reform movement and there are needed changes in instruction. The demand for improvements comes from industry and the national scene. (Noffke, 2008). To be successful, students need more than the content as information.

Summary

At this school, conversations regarding inquiry began among the teachers and sharing. These activities need to continue to sustain change. Students became participants in the process of learning and began to develop into independent learners with a quest for knowledge. The NCTM process standards, when incorporated on a regular basis, provided the guide for activities. These standards need to be emphasized as well as the content standards. Statistical analysis did not provide a strong correlation between inquiry-based instruction and achievement on the EOCT even though the average EOCT score for sample 2 was greater than sample 1. But the impact on student learning was evident through conversations with these students as they took advanced mathematics courses. As a recommendation from this study, the implementation of inquiry-based instruction, as an alternative to traditional instruction, will require specific professional development for teachers to insure the command of content and a full understanding of the cognitive skills needed for inquiry.

In retrospect, this study provided a professional development experience that will impact every facet of the researcher's teaching career. Inquiry-based instruction is a dynamic strategy that can carry students to another level in thinking. It will also impact their success in future mathematics courses and their role in social change. The implications for social change are evident in the fact that students become confident, engaged learners. The problem solving skills that are learned provide a foundation for meeting challenges they will face in the future in school and in the workplace.

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APPENDIX A: SELECTED JOURNAL ENTRIES

I. First Week – August 14, 2006

I introduced the term, metcognition, to all of my classes. The discussion centered around three questions.

1. Am I understanding a concept? How well am I understanding? Would I be able to pass a test on this?

2. What else do I need to know and do to expand my understanding?

3. Can I demonstrate my understanding on a test/quiz?

I hope this will help them "think" or question their thoughts. Students are not used to doing work on their own. Comments were "You are the teacher. You are supposed to work the problem". "Just show me how to get the answer". Some have refused to do an assignment because they felt I was not teaching "right". One student said, "You are not like my other teacher". This week has been a rough week.

Activities –

1. Do I like Math?
2. Pretest
3. Discussion on how to study math
4. Metacognition discussion

The pretest revealed weaknesses in the basic operations of addition, subtraction, multiplication, and division, and the basic operations in fraction and decimals. Most of the students cannot do the basic operations correctly without a calculator.

II. August 29, 2006

First "Inquiry" activity

I have got to make some connections to the algebra in this chapter. I described this course as another approach to mathematics. Students are still looking for more computation and this course is more a "thinking" course. I selected this activity because of the weaknesses in basic operations in fractions and decimals and we discussed number lines in this section. The textbook activity was above the students' reading level. I have to scaffold to get there. I felt that it was an easy assignment. This was an opportunity to work totally on their own.

Directions: With a partner, read the directions and graph the sets of numbers. Answer each question and discuss your answer with your partner. Compare answers and write one answer for each exercise.

This was a challenging point in the lesson. My goal was to give as much freedom in solving this problem as possible. Students did the first problem and stared at the sheet (They were quiet though). Some did not want to work in pairs. My directions were what are you thinking now? Put what you think it should look like. Most did not try to do it. Comments:

- I don't know how to do it.
- You didn't show us how to do this.
- You show me how to do it, I'll do it.

I found that some of the textbook activities were above students' reading level. I have to scaffold to get there. Teacher support was necessary to begin and complete this activity. Students are still counting lines instead of spaces on the number line.

III. August 31, 2006

I used a word problem as the warm up activity. It could be classified as inquiry because we had not discussed this problem. Students did have the background for the activity. I gave directions – Begin with a question on how do I begin this problem? If you do not know how to do it, put something down, start with another question, and we can go from there.

Students put down anything, wrong answers. (Really frustrating) The problem dealt with a picture frame. Even though we always draw a figure, no one drew a figure to get started.

IV. September 22, 2006

The textbook activities, even though hands-on, are still above student. I don't know if it's the reading comprehension. Vocabulary will have to be stressed more. Example: Draw two lines and their point of intersection. Students have a problem visualizing a point of intersection. I will need to work on visual sense. Scaffolding will include visual sense. Students have problems copying diagrams accurately.

Pure inquiry activities are too frustrating for students. They want to do it right the first time. I am working on a "safe" environment – not afraid to be wrong and start over. But not enough time.

V. Week of October 3, 2006

I used a “semi” inquiry lesson for the section 3-4. Students were asked to choose a study buddy. Some did and some didn’t. They eventually worked in groups of four or more.

As long as the work was easy, there were lively discussions. When a problem was hard, they wanted me to work instead of trying different ways (inquiry) to get the answer. First period worked in groups. Second period worked together (but did not choose a study buddy), but shared answers in class. Third period worked with study buddies and then in small groups. Fifth period was too large, but some worked together. Sixth period and seventh period worked independently.

In each class, there were students who finished and helped explain the work to other students individually. The problem – how to manage noise level. Sometimes it was alright and other times almost too loud. Students seemed to enjoy the activity.

VI. October 9, 2006

Another activity for “semi” inquiry. First period: Students did not respond, because they said they did not know how to do it. But they solved equation yesterday?!! They got mad because I said, let’s think back. On yesterday, we did equations. I know you can do It. (Frustrated)

I did not do this activity in groups with the other classes.

VII. November 15, 2008

This exploration for 5.1 was easy. But students mixed angles measures with the lengths of the sides of a triangle. Another opportunity to reteach the ruler and the protractor.

VIII. November 29, 2006

The textbook used constructions for hands-on. Students are still having difficulty understanding constructions. Time is so short. This would be “semi” inquiry. Changed to proving triangles congruent by cutting out and placing on top for correspondences. (5-5 Practice)

We had to spend two days on this, but students enjoyed it. Class was not boring. All students participated, but 7^{th} period.

IX. December 12, 2006

I tried constructions again in introducing median. It was not successful. There is not enough time to help slower students. Each student wants my attention individually and refused to work until I come. Students still do not understand the use of the compass. I used a paper folding activity instead for the other classes.

X. January 25, 2007

The 7-2 hands-on geometry activity requires the use of the protractor. Some students just drew triangles. Others just looked and stared. Some discussed the assignment explaining to others. My constant directive was to focus. Students are still having difficulty using the protractor, even though it has been taught several times with different lessons. Also difficulty in making conjectures.

XI. March 9, 2007

Students were asked to transfer work done with (n-2)180 to a word problem. My question was how would you begin this problem? I will have to work on generating a discussion...

- I can't do this.
- Why don't you show just us how to do this?

Students do not want to read the problem. If they read the problem, they do not apply the definition. When a problem is worked (regular polygons), it may not apply to a polygon that is not regular. When they are taught one way, they want to do all of the problems the same way.

XII. March 19, 2007

As a teacher, I have to learn to let them explore and ask their own questions. I have mastered asking them questions instead of just answering their question. By now, they are used to me asking them a question to answer their question. Many times they answer their own question.

XIII. Week of May 9, 2007

Students are having difficulty in working with solids. I had to go to another book for the hands-on for this section. Then it will make the regular activity easier.

The assessment on volume was not a good one. Back to the drawing board. We will focus on the drawings of a solid and identify top, bottom, etc.

APPENDIX B: SELECTED FIELD NOTES

I. Investigation – Polygon Exploration

Student to Student Discussion

That's not right!
Yes, it is!
It's not right!
Oh, Ohhhh, I see.

Yours doesn't look like mine.
Yes, they do. Turn it.

Student to Teacher Discussion

S: What is this?
T: How many sides are there?
S: You can't just tell me?
T: No, let's try this again, Look at the number of sides.
S: They don't look like the ones on the bulletin board.
T: No, those are quadrilaterals. Go to section 10-1 for the names.

Student Comment

This exercise makes you think. I don't want to think.

III. Transformations – February 27, 2007

Students were directed to work in pairs or individually.

T: Find the trapezoid.
S: Which one is a trapezoid?
T: I'll let you figure this one out.
S: It doesn't look like that one on the wall… (Pointing to a rectangle), But it does look like that one. (Then pointing to the trapezoid on the bulletin board)
T: Let's make the translation.
S: 1, 2, 3… (Counting lines instead of spaces for translation)
T: Cut out the trapezoid and slide it.
S: (After sliding the figure,) Oh, you count spaces instead of lines.

III. Volume Exploration - May 8, 2007

Student to Student

S1: How did you get that like that? S2: I counted the blocks like this… (Looking at the finished solid.) We got it right!

S1: That's wrong. 1, 2, 3… (Counting blocks)
S2: No, it's not. Hold up 1, 2, 3, 4… (counting cubes in a solid)
S1: I think we have it right now.

S1: Oh, it's in layers. It's a cube!
S2: Yea, We need one more layer.

S1: No, It's 36. (Explaining to partner). This is the way you do it.

S1: Let me read the directions… That's 4 and that's 5.
S2: That's the way I did it. (High five)

Student to teacher

S: Is this right?
T: (Seeing it is wrong.) Did you read your directions?
S: No.
T: Read the directions for me.
S: (Reads directions) Ohhh… I need to …

S: One answer for #1 is 2.
T: How did you get 2?
S: They show me a box like this picture with…. (Student explains problem)

S Ms. L. is this right?
T: Why would you think it is right?
S: There are two in front, and four on the side, and then up two.
T: That's correct.
S: I told you so. (To partner)

S: How do you do this?
T: What does this say?
S: Five X four
T: How many do you have [in this row]
S Five
T: Then what do you need?
S: Four rows.
T: Very good.

APPENDIX C: INQUIRY-BASED INSTRUCTION CONTINUUM

	Level	A	B	C	D
Student centered Inquiry	5	Students pose questions.	Students design inquiry based on prior knowledge.	Students collect data and make deductions based on the data.	Students analyze data, report results and apply to a new problem.
	4	Topics are suggested with samples to formulate questions.	Teacher provides support to help the student design the activity and scaffolds.	Teacher directs students to data.	Students analyze data and report results.
Guided Inquiry	3	A list of open ended questions is provided.	Teacher provides open ended task with choices that direct the student through questions.	Data are provided and students are asked to analyze.	With teacher support, the analysis is the result of a group effort.
	2	Specific questions are provided.	Activity sheet provides direction for the exploration.	Data are provided with directions on how to analyze.	Teacher directs the student's attention to pre-determined conclusions.
Teacher centered Inquiry	1	The teacher poses all questions.	Demonstration is done by the teacher.	Teacher directs analysis with questions to the student.	Lecture with facts presented by teacher.

A - Problem identification with questions

B - Procedural design of the inquiry

C - Investigational design, inferences, analysis

D - Communication, Application

Open-ended question – The question may have more than one correct answer. This approach to solving problems means that students will focus on the different ways to solve a problem, rather than just arriving at an answer (Shimada, 1997)

(Beerer & Bodzin, 2004; Flick, 1999)

APPENDIX D: LESSON PLANS

Lesson Plan One – Chapter Two Exploration

Quality Core Curriculum Standards

- 9 -12.10: Identifies and defines or describes properties associated with points (distance, between, collinear)

NCTM Content Standards

- Geometry – Specify locations and describe spatial relationships using coordinate geometry and other representational systems; use visualization, spatial reasoning and geometric modeling to solve problems
- Algebra – Use mathematical models to represent and understand quantitative relationships.

NCTM Process Standards

- Problem Solving – Monitor and reflect on the process of mathematical problem solving.
- Reasoning and Proof – Make ad investigate mathematical conjectures.
- Communication – Communicate their mathematic thinking coherently and clearly to peers, teachers and others.
- Connections – Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.
- Representation – Create and use representations to organize, record, and communicate mathematical ideas

Directed Questions:

1. Give me a definition of a whole number, a fraction, a decimal.
2. What is the relationship between a whole number, fraction, and decimal?
3. Give me an example of how each is used in everyday life?
4. How is each represented symbolically, graphically?

Essential Question: How are the subsets of real numbers related?

Time	Activities	Materials
Engage 5 minutes	Directed Questions, Discussion to assess prior knowledge	Overhead projector, transparency
Explore 15 minutes	Chapter 2 Exploration	Paper, Pencil, Calculator
Explain 15 minutes	Work with a partner, discuss answers, class discussion of answers	Overhead projector, transparency
Evaluate 10 minutes	Number line assignments	Paper, pencil, ruler, textbook

Lesson Plan Two – Chapter Six Exploration

Quality Core Curriculum Standards –

- 9 – 12.17: Identify congruent triangles and right triangles using basic congruence postulates and theorems.

NCTM Content Standards –

- Geometry: Explore relationships (congruence) among two dimensional geometry objects, make and test conjectures about them.

NCTM Process Standards –

- Reasoning and proof: make and investigate mathematics conjectures
- Connections: understand how mathematical ideas interconnect and build on one another to produce coherent wholes.
- Representation: create and use representations to organize, record, and communicate mathematical ideas.
- Problem Solving: Monitor and reflect on the process of mathematical problem solving; apply and adapt a variety of strategies to solve problems.
- Connections: Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.
-

Essential Question: How can you use SAS, ASA, and AAS to prove right triangles congruent? Explain using the correct mathematical terminology.

Time	Activities	Materials
Engage 5 minutes	Review congruence theorems. Discussion to assess prior knowledge	Overhead projector, transparency
Explore 15 minutes	Chapter 6 Exploration	Paper, Pencil, Calculator
Explain 15 minutes	Explain to your partner how you used the terms hypotenuse, and leg to rename SAS, ASA, AAS.	Handout
Evaluate 10 minutes	Discuss answers with your group to come to a common answer. Class discussion.	Overhead, transparency

Lesson Plan Three – Chapter Twelve Exploration

Quality Core Curriculum Standards

- 9 – 12.3: Uses visualization skills to explore and interpret both two- and three- dimensional geometric shapes
- 9 – 12.32: Defines and differentiates area and volume.

NCTM Content Standards

- Geometry – analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships; use visualization, spatial reasoning and geometric modeling to solve problems

NCTM Process Standards

- Problem Solving: Monitor and reflect on the process of mathematical problem solving; apply and adapt a variety of strategies to solve problems.
- Reasoning and Proof: Make and investigate mathematical conjectures.
- Communication: Communicate their mathematic thinking coherently and clearly to peers, teachers and others.
- Connections: Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.
- Representation: Create and use representations to organize, record, and communicate mathematical ideas.

Essential Question: How is a net related to the diagram of a box? Explain how you would relate surface area to volume.

Time	Activities	Materials
Engage 5 minutes	Introduction to geoblocks; Activity – Building 3 – D Solids	Geoblocks for each student Overhead projector, transparency
Explore 15 minutes	Review definition of a net; Inquiry: Make a box from a net	Paper, Pencil, Geoblocks
Explain 15 minutes	Work with a partner to make a box from a net, and then draw the box. Explain your diagram to your partner.	Activity Sheet
Evaluate 10 minutes	With your partner, write an answer to the essential question	

APPENDIX E: NCTM PROCESS STANDARDS

NCTM Process Standards

- Problem Solving
  - Build new mathematical knowledge through problem solving.
  - Solve problems that arise in mathematics and in other contexts.
  - Apply and adept a variety of appropriate strategies to solve problems.
  - Monitor and reflect on the process of mathematical problem solving.

- Reasoning and Proof
  - Make and investigate mathematical conjectures.
  - Recognize reasoning and proof as fundamental aspects of mathematics.
  - Develop and evaluate mathematical arguments and proofs.
  - Select and use various types of reasoning and methods of proofs.

- Communication
  - Communicate their mathematic thinking coherently and clearly to peers, teachers and others.
  - Organize and consolidate their mathematical thinking through communication.
  - Analyze and evaluate the mathematical thinking and strategies of others.
  - Use the language of mathematics to express mathematical ideas precisely.

- Connections
  - Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.
  - Recognize and use connections among mathematical ideas.
  - Recognize and apply mathematics in contexts outside of mathematics.

- Representation
  - Create and use representations to organize, record, and communicate mathematical ideas.
  - Select, apply, and translate among mathematical representations to solve problems.
  - Use representations to model and interpret physical, social, and mathematical phenomena.

(NCTM, 2000)

APPENDIX F: SAMPLE EXPLORATION

Name:__________________
Period __________________
Date_____________________

Chapter 2 Exploration.

I. Graph 3, 6, and 4 on the number line.

____

What do you notice about the location of the numbers?

II. Graph -1, ,-3, -5, +1, and +4 on the number line.

____

What do you notice about these numbers? What are these numbers called?

III. Change the 5/8, 0/6, and 1/4 to decimals. Graph each fraction on the number line.

____

5/8 = __________ 0/6 = _____________ 1/4 = ____________

Explain how you graphed each fraction to your partner.

IV. Change 1/3, - 2/11, and 4/15 to decimals. Graph them on the number line.

____

V. Change 5/13, 4/21, and - 5/7 to decimals. Graph them on the number line.

____

How are the fractions in Section IV different from these fractions?
Compare your answer with your partner. Combine your answers and write one paragraph to answer this question.

VITAE

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Mrs. Lewis holds a bachelor’s degree in mathematics from Bennett College and a master’s degree from South Carolina State University. She holds state certification in secondary mathematics and advanced placement calculus. She has received additional training from the SERVE Technical Assistance Academy for Mathematics and Science.

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