2010

Inquiry Based Mathematics Instruction Versus Traditional Mathematics Instruction: The Effect on Student Understanding and Comprehension in an Eighth Grade Pre-Algebra Classroom

Kyle Ferguson
Cedarville University

Inquiry Based Mathematics Instruction Verses Traditional Mathematics Instruction: The Effect on Student Understanding and Comprehension in an Eighth Grade Pre-algebra Classroom

A thesis submitted in partial fulfillment

of the requirements for the degree of

Masters of Education

By

KYLE L. FERGUSON

B.A. Middle Childhood Education, Cedarville University, 2006

2010

Cedarville University

CEDARVILLE UNIVERSITY
SCHOOL OF GRADUATE STUDIES

March 16, 2010

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Kyle Lawrence Ferguson ENTITLED Inquiry Based Mathematics Instruction Verses Traditional Mathematics Instruction: The effect on student understanding and comprehension in an 8^{th} grade pre-algebra classroom BE ACCEPTED IN PARTIAL FUFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Education.

William E. Brown, Ph.D.
President

Mr. John Hess
Director of Student Teaching and Licensure

Timothy Heaton, Ph.D.
Professor of Education

Stephen S. Gruber, Ed.D.
Education Department Chair
Director M.Ed. Program

Chien Hwang, Ph.D.
Professor of Psychology
Thesis Advisor

Dr. Pamela Johnson, Ph.D.
Dean, School of Social Sciences
and Human Performance

Acknowledgments

I give thanks to God for giving me the ability and opportunity to complete my M. Ed. I would like to thank Dr. Hwang, Dr. Heaton, Mr. Hess and Dr. Gruber for their input and guidance in helping me through this thesis project. Finally, I would like to thank my wife for her support and encouragement to push on to the end.

ABSTRACT

Ferguson, Kyle L. M.Ed., Education Department, Cedarville University, 2010. *Inquiry Based Verses Traditional Mathematics Instruction: The Effect on Student Understanding and Comprehension in an Eighth Grade Pre-Algebra Classroom.*

This quantitative study provides information obtained through the use of inquiry-based mathematics instruction verses traditional mathematics instruction. The use of each curriculum was implemented into two classrooms of eighth grade pre-algebra students. The study was based on data collected before and after each of the two units of study. Fifty-two suburban eighth grade students represented the sample population. Results of the SPSS analysis showed that both classes made improvement from their pre-test to their post-test for both units but students receiving instruction through inquiry-based instruction showed significantly more improvement on the second unit. These results can be useful for educators considering the adoption of an updated or new mathematics curriculum in their school district.

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Chapter 1

Introduction

If most people were asked to recall how they were taught mathematics they would most likely recall engaging in rote memorization of mathematical concepts as the teacher demonstrated the procedures to solve certain problems on the board. Following the lesson the teacher would give a “drill and kill” homework assignment over the same concepts that were covered in class. The next day would consist of the same procedures but over a different concept. This method of mathematics instruction would continue on day after day. Over the past several years, however, debate has taken place over how to effectively teach math and whether the traditional method is as effective as it once was. Skills students were required to have in order to function in society in the 20^{th} century are different than the skills required of students in the 21^{st} century. With this change in skill requirement comes a need for change in how students are taught (Chapko & Buchko, 2004).

Students today find it difficult to understand what it is they need to know and many times why they need to know it. A common question asked in a mathematics classroom is “why do I need to know this?” or “When will I ever use this?” Answering this “need to know” question has been coined the term *inquiry.* Inquiry goes much deeper than asking simple questions such as, “is it going to rain today?” Inquiry is a process of learning that is driven by questioning, thoughtful investigating, making sense of information and developing new understandings (Diggs, 2009). Traditional methods of math instruction do not allow for much questioning, investigating or individual development of understanding. Inquiry based mathematics instruction allows for all of this to take place in the classroom and opens up the doors for students to answer their own questions by exploring meaningful real-life problems that incorporate several mathematical concepts into one problem. What might this inquiry based mathematics instruction look like in a mathematics classroom?

> We all know there is only one right answer for a math problem, but there is obviously more than one way to obtain that right answer. Inquiry math is different from traditional math in that students work with partners and whole-group instruction to construct mathematical explanations that make sense to them. Students are presented with opportunities to verbally explain their thinking processes to the teacher and class, and it is this exchange of ideas that provides the foundation for true understanding of mathematical concepts (Chapko & Buchko, 2004, p. 33).

Traditional math works in the short term, but students who cannot remember what the teacher did on a certain step or do not understand why the teacher used a particular procedure will inevitably forget. Inquiry math focuses on conceptual development as opposed to procedural development in traditional math. A teacher using inquiry math will establish the problem on which the students are going to be working. Once students understand what the problem is, they begin working on coming up with a solution while working with partners or small groups. Inquiry math allows students more opportunity to think about and explain their mathematical thinking. Communicating math is done in many ways using inquiry math but the predominant one is through written communication.

Writing in mathematics courses is a concept that many mathematics educators would agree needs to be incorporated more into mathematics instruction. Writing allows individuals to think about their reasoning, express ideas and concepts that make better sense to them in their own words and share their ideas with others (Burns, 2004). Writing is an assessment that gives teachers valuable insight into a child’s thinking that can be used for intervention and future planning (McCarthy, 2008). Unfortunately, the pressures of high stakes testing and the reliance on multiple choice tests have limited mathematics instructors in the venues in which they can teach.

Writing is a powerful tool that not only helps to improve students' writing abilities, but also helps students clarify and extend their knowledge in the area of mathematics (Manning and Manning, 1996). Outside of the classroom, students do not typically use mathematical terminology in their everyday language. In fact, most students do not even talk about mathematics naturally outside of the classroom. Because of this, math teachers are challenged to help students learn how to write and communicate their mathematical understanding of concepts and give them opportunities to do so inside and outside of the classroom.

As students academically progress, the mathematics that they encounter should become more complex and abstract. Likewise, students' abilities to communicate in written form should become more sophisticated allowing for richer thought and understanding (National Council of Teachers of Mathematics, 2000). The principles and standards for school mathematics promulgated by NCTM make it clear that writing in mathematics should play a vital role in helping student understanding of mathematical concepts from primary grades to secondary grades and they encourage mathematics educators to increase writing opportunities for students in this content area.

Research has linked writing to improved learning of mathematical content (Meel, 1999) and to the development of important mathematical skills and abilities (Bagley & Gallenberger, 1992). Although there has been increased attention given to writing in mathematics, evidence in the classroom indicates that not all students can write well about their thinking in relation to mathematical concepts (Stonewater, 2002). Some students have mastered the ability to express their knowledge of mathematics in written form and go beyond re-iterating what was heard in class or simply memorized. True understanding is observed when students base their responses on appropriate and accurate mathematical concepts and coherently tie everything together in a clear and insightful explanation of their understanding of mathematics. Students who struggle with mathematical concepts generally generate vague or unclear explanations when describing their mathematical reasoning. Their responses fail to give deep explanations of their mathematical cognition and are typically hard for the teacher to understand students' logic behind their problem-solving strategies. This leads to confusion about what the student really knows and understands (Stonewater, 2002).

A common mistake that some mathematics teachers make when assessing student performance is believing that if a student can "do" a problem, then the student "understands" math. Most mathematics students (and some teachers) seem to interpret the students' role as essentially acquiring (i.e., memorizing) facts and algorithms that can be immediately applied to the solution of given exercises; few students expect mathematics to be meaningful and fewer still see mathematics as a creative undertaking. Consequently, students are too often content with externally manipulating symbols and doing routine problems, without ever reaching a deep and personal understanding of the material (Borasi & Rose, 1989). Inquiry based mathematics incorporates writing in mathematics which highlights this misconception and provides a natural teaching opportunity for developing students' mathematical reasoning skills. Traditional mathematics instruction consists of learning a concept by watching the teacher "do" problems at the board and copying down the steps during note taking (Fleener, Craven & Dupree, 1997). Students are then given homework consisting of several similar problems that assess whether or not those students can follow the procedures they recently observed. By doing this, understanding the concepts behind the problems is not achieved and memorization that took place in class, in most cases, will be forgotten over the next couple of days. A significant challenge for contemporary mathematics instruction (Inquiry based instruction) is the number of students showing an inability to make connections between what they have previously learned to their current learning (Mayer, 2002). Most students often see their roles primarily as acquirers who memorize facts and apply them repeatedly to problems. Many are content with doing routine problems and never having an apt understanding of the principles behind why the math they are doing works. It is fair to say that students can be successful in the short-term, as far as testing is concerned but, without a deeper understanding and problem-solving skills required in mathematics, they will never be successful in the long run (Borasi & Rose, 1989).

Ntenza (2006) interviewed six teachers concerning writing in their classrooms, showing that they believed good mathematical performance by students on a test or examination demonstrates evidence of whether the teaching was successful and whether or not students understood the topic or concepts taught. Unfortunately, this seemingly is how many mathematics teachers and students view the effectiveness of teaching methods and how many gauge students' understanding of the mathematics they are "learning" (Fleener, Craven & Dupree, 1997).

A common type of writing activity utilized in the content areas other than language arts and English classes is reflective journaling (Cicero, 2006). There are many benefits for both student and teacher regarding journal writing in mathematics courses. One such benefit for the student is an improvement in learning and problem-solving skills that results from the articulation of and reflection on their process of doing mathematics (Barosi & Rose, 1989). As appealing as journal writing can be to many mathematics educators, students' perceptions of the task may be a different story. Studies have shown that while students themselves see some benefit in reflective journaling, they generally felt that journaling was not necessary for them to think critically or reflectively (Mills, 2008). With differing attitudes towards reflective journaling between educators and students, Cicero (2006) conducted a study that investigated whether journal writing enhanced students' overall mathematical performance. The results indicated that journal writing had an impact on the lower percentage of C and D grades and little impact on the A and B grades. This study may suggest that journal writing mostly impacts the average student, but it may not adequately take into account student effort to engage in reflective thinking.

A major hindrance for incorporating writing into any classroom, especially mathematics, is the issue of time. Mathematics teachers are pressured to cover a large amount of information while, at the same time, assessing each student's understanding of the topics covered. Journal writing and dialogue between teacher and student is very valuable because it allows for a new mode of communication: private dialogue with each student that otherwise a teacher would not have time for (Barosi & Rose, 1989). As teachers and students become more familiar with journal dialogue, an increased mutual respect and positive rapport between them may grow and develop. This may provide students added motivation to learn mathematical concepts and take control of their learning, prompting the teachers with new sense of motivation to deepen the learning process.

Definition of Terms

504- A civil rights statute that prohibits schools from discriminating against children with disabilities and requires that they provide "reasonable accommodations" (Answers to parent questions about ADD/ADHD, 2000).

Communication- Transfer of information from one person to another. This is done through speech, writing or signs. Communication allows for ideas to become objects of reflection, refinement, discussion and amendment (McCarthy, 2008).

Content Knowledge – Refers to the amount and organization of knowledge in the mind of the teacher (Shulman, 1986).

Curricicular Knowledge – Knowledge of the curriculum materials available for teaching (Shulman, 1986).

Declarative Knowledge- Knowledge that is factual and conceptual and is simply memorized by an individual (Shavelson, Ruiz-Primo & Wiley, 2005).

Dialogue-A form of communication in which two or more people share information both ways. Dialogue involves both student and teacher in bidirectional communication and allows for private interaction where the focus is on the content (Meel, 1999).

Individual Education Plan (IEP)- Plan set forth for students with disabilities and required by the Individuals with Disabilities Education Act (Hammond, Casteneda & Ortega, 2006).

Inquiry- Process of learning that is driven by questioning, thoughtful investigating, making sense of information, and developing new understandings (Diggs, 2009).

Inquiry Based Mathematics- Instruction method where the teacher sets up a problem making sure that everyone understands it. The students are then paired or grouped according to their ability level. They work together to come up with a solution by thinking out the problem, 'questioning and correcting one another (Chapko & Buchko, 2004).

Journal-The keeping of a log or personal notebook, where students can write down any thought related to their mathematics learning, throughout the whole course (Borasi & Rose, 1989).

Journal Writing- A writing to learn activity in which students go beyond the recording of events and personal thoughts. Journal writing in mathematics class consists of reflections on material learned in class, reactions to readings or lectures, or responses to open-ended assignments (Borasi & Rose, 1989).

Junior High- A school designed to bridge the gap between the elementary and secondary grades that houses grades seven and eight. In a typical American junior high school, students' ages range from thirteen to fifteen years old (Ntenza, 2006).

Metacognition- The knowledge about and regulation of one's cognitive activities in learning processes (Veenman, Afflerbach & Van Hout-Wolters, 2006).

Mathematics Standards- The mathematical understanding, knowledge, and skills that students should acquire from Pre-K through grade 12 set forth by the United States Department of Education (NCTM, 2000).

NAT- An examination given annually in March or April to assess the competency of both public and private school students (http://en.wikipilipinas.org).

NCTM- The National Council of Teachers of Mathematics is a public voice of mathematics education, providing vision, leadership and professional development to support teachers in ensuring equitable mathematics learning of the highest quality for all students (NCTM, 2000).

Pedagogical Knowledge –Knowledge that goes beyond subject matter knowledge and includes knowledge necessary for teaching (Shulman, 1986).

PISA- The Program for International Student Assessment (PISA) is a system of international assessments that measures 15-year-olds' performance in reading literacy, mathematics literacy, and science literacy every 3 years (National Center for Educational Statistics, 2006).

Procedural Knowledge- The type of knowledge that requires the individual to know how to do something such as solve and graph a linear equation (Shavelson, Ruiz-Primo & Wiley, 2005).

Schematic Knowledge- Knowledge that allows the individual to understand "why" something happens, not simply "that" it happens (Shavelson, Ruiz-Primo & Wiley, 2005).

Self Reflection- An opportunity for students to look at what they are doing and have a set-apartness from themselves that allows them to effectively critique what they are doing and think about what they know and understand as well as what they still need to learn (Bulpitt & Martin, 2005).

Traditional Math- Method of instruction where the teacher presents a mathematical concept, reviews the procedures required to find the solution, and then has students practice these procedures with additional problems (Chapko & Buchko, 2004).

Writing in Math (WIM)- Students elaborate their knowledge and clarify for themselves what they know about mathematical concepts as they express their thoughts through writing (Manning & Manning, 1996).

Statement of Issue

In today's mathematics classrooms, students sometimes reflect their frustration with the mathematics they are required to learn. A failure to see the importance or applicability of content in subject matter tends to foster a poor attitude and lack of motivation. Students can feel disconnected from their math instruction and perceive it as irrelevant to their lives, impacting their levels of interest and achievement. Some may blame the content these students are required to learn while others blame the instructional approach taken by teachers (White-Clark, DiCarlo & Gilchriest, 2008).

Studies have shown that performance of American students lags behind their international peers in numerous subjects, including math (National Center for Educational Statistics, 2006). Various theories exist to explain why this is happening and exploration is occurring regarding how instruction is carried out in other countries that perform well on national standardized tests. To date, there are no agreed-upon explanations as to why American students perform well below the average in math when compared to other countries. Consequently, more research is needed in order to further investigate the effectiveness of the type of mathematics instruction students' encounter in the classroom. Making math relevant to students' lives is not always an easy task to accomplish as a teacher and, unfortunately, this may be an underlying reason for poor math performance and motivation. Teachers often teach the way they were taught during their own educational experiences. Some veteran teachers still believe that the role of the teacher, especially in the secondary grades, is to give information to their students and hope they retain it for future use (White-Clark, DiCarlo & Gilchriest, 2008).

The particular math class where I focused my study was eighth grade pre-algebra. Students taking this course have accrued a wealth of knowledge of arithmetic through their elementary years. This particular math course challenges students to synthesize many of the previously learned mathematical concepts and apply them to new situations as they think about mathematical contexts on a deeper level.

Reports have been given by those touting traditional mathematics instruction and those touting inquiry based mathematics instruction as the most effective way to teach math. In order for teachers, school districts, states and even the country to make better decisions, further studies need to be done on comparing the two approaches to mathematics instruction. The best way to do this is to perform straight forward comparisons looking at hard student data. In order to better assess the effectiveness of traditional or inquiry based mathematics, quantitative comparisons of the two approaches need to be studied further.

Scope of the Study and Delimitations

In this study I collected quantitative data on students' pre-test and post-test scores for two sections of a particular unit of study. The study was performed in a rural, public junior high with an enrollment of 611 seventh and eighth graders. The student population consisted of approximately 91% Caucasian, 13% economically disadvantaged, and 14% diagnosed as learning disabled. The project focused on eighth grade students in two sections of pre-algebra. Students taking pre-algebra in the eighth grade are on track with what is nationally expected by the time students reach the eighth grade. Due to the scope of this study, the reported results will be reasonably generalizable to other populations of public eighth grade pre-algebra students with demographics similar to the study's sample.

The subjects involved in the study were under my instruction. However, many of my students had different teachers in the seventh grade. Because of this, the phenomenon of interactive effects may influence their scores on both pre and post tests. Since the purpose of this study was to understand the effectiveness of instructional approaches with regards to student performances, specific student perceptions were not tracked.

Significance of the Study

With increased pressure from the federal government on mathematics instruction in the United States, math educators are constantly adjusting their methods of teaching to help improve student understanding of mathematics (Fleener, Craven & Dupree, 1997). There are many factors to consider when looking at how students are taught and learn mathematics. The goal of high school mathematics is for teachers to create a learning environment that is conducive to teaching students the necessary concepts for academic achievement. For some teachers this focus on academic achievement does not extend beyond the walls of the classroom and the quizzes and tests given to students. High stakes testing has created a millieu that prevents students from seeing and understanding the applicability of mathematics in the real world. The US Department of Education reported that the 2003 Program for International Student Assessment found that fifteen year old students from the United States ranked twenty-fourth out of twenty-nine countries in math literacy and problem solving. Because of the poor math performance of U.S. high school students, the National Mathematics Advisory Panel emphasized that "instructional practices, programs and materials have proven to be effective in improving math learning," and "research needs in support of math education" must be addressed "to strengthen math education in order to give our students the skills to succeed in the 21st century" (U.S. Department of Education, 2007, p. 2). The gravity of the educational situation should cause educators to take into more careful account the instructional methods they are using in their classrooms and be willing to change and adapt as the needs of their students change.

The effectiveness of any mathematics instructional approach must be investigated. If students do not perform well on assessments after being taught, then the use of such instructional methods in mathematics should be questioned and/or altered. On the other hand, if students do perform well, then their use should be encouraged by teachers and administrators. There is research that has been conducted regarding the effectiveness of traditional and inquiry based instruction methods but most has been conducted by looking at standardized state test scores (Riordan & Noyce, 2001). Few studies have been done by comparing both instructional methods using curricula that foster them in the same school building used by the same teacher.

Methods of Procedure

Research question:

1. Is traditional mathematics instruction or inquiry based mathematics instruction more effective with regards to student understanding and comprehension?

This experimental research project focuses on my students' academic performance on a pre-test and post-test when taught using a traditional textbook and an inquiry based textbook. The traditional method was carried out by using the 2003 Glencoe Mathematics Pre-algebra textbook. The inquiry based method was carried out by using the CMP2 (Connected Mathematics Project 2) curriculum. The research was conducted using quantitative research protocol. The data was collected through student test scores on a pre-test given before the unit was taught and a post-test given after the unit was taught. The design was a between subjects design with curriculum being the control variable (traditional or inquiry textbook). The statistical analysis was repeated measures ANOVA. Using this analysis, the differences between pre- and post-tests for each group was compared as well as the overall comparison between the two groups. The pre-test served as a baseline measure. In analyzing the data, I looked for statistically significant differences between the two approaches to instruction. The research was conducted in the natural environment of the students' Pre-algebra classroom.

The sample consisted of two Pre-algebra classes that contained both male and female eighth graders. These students have been assigned to my classroom by the Junior High administrators by random selection. Class A contained 23 students of which 14 are male and 9 were female. Class B contained 30 students of which 19 were male and 11 were female.

The study lasted for the duration of 1 unit. Because of the nature of the CMP books, the concepts taken from the Glencoe textbook aligned with what was being taught out of the CMP books to control for differences in content. Class A was taught using the CMP curriculum and Class B was taught using the Glencoe textbook. Each Class was taught with their respective methods of instruction for the duration of the unit.

Before each assessment, students in both classes took the same pre-test. The scores were kept and instruction began. Students met daily for sixty minutes. Each class was taught the same content but with different methods. Upon completion of the instructional units, students took the same post-test.

Student scores were analyzed for each part of the unit using the computer software program SPSS. Since there was only one quantitative dependent variable (student test scores) and a dichotomous independent variable (2 methods of instruction), the repeated measures ANOVA using SPSS was best to use to see whether the difference between the means of the test scores between both groups was statistically significant (Johnson & Christensen).

Chapter 2

Plenary Literature Review

The importance of mathematics cannot be emphasized enough. The National Curriculum for Mathematics (2009) summarizes the importance of math this way:

> "Mathematical thinking is important for all members of a modern society as a habit of mind for its use in the workplace, business and finance; and for personal decision-making. Mathematics is fundamental to national prosperity in providing tools for understanding science, engineering, technology and economics. It is essential in public decision-making and for participation in the knowledge economy. Mathematics equips pupils with uniquely powerful ways to describe, analyze and change the world. It can stimulate moments of pleasure and wonder for all pupils when they solve a problem for the first time, discover a more elegant solution, or notice hidden connections. Pupils who are functional in mathematics and financially capable are able to think independently in applied and abstract ways, and can reason, solve problems and assess risk. Mathematics is a creative discipline. The language of mathematics is international. The subject transcends cultural boundaries and its importance is universally recognized. Mathematics has developed over time as a means of solving problems and also for its own sake."

The importance that is placed on mathematics today was not the case prior to 1957. A historical perspective gives context to the development of mathematics education today and why such importance is placed on this academic discipline.

A Brief History of Mathematics Education

A particular moment in our world's history that had a direct impact on the direction of mathematics was the launching of Sputnik 1 by the Soviet Union on October 4, 1957 (Garrett, 2008). This event marked the space age and race between the United States and the Soviet

Union. Because the United States was not the first to send a spaceship into space, concern that the U.S. was not competing with other industrialized nations was growing. New reforms were put into place to get America “caught up” or “back on track” and many of these reforms dealt with math and science curriculum. “New Math” was brought about in the 1960s and 1970s which put more of an emphasis on set language and properties, proof and abstraction (Education.com, 2009). When the New Math curriculum did not increase the nation’s mathematical performance, educators returned to the Back-to-Basics approach in the late 1970s and early 1980s. With this curriculum an emphasis was put on arithmetic computation and rote memorization of algorithms as well as basic arithmetic facts (Education.com, 2009).

Secretary of Education T. H. Bell created the National Commission on Excellence in Education on August 26, 1981, directing it to examine the quality of education in the United States and to make a report on their findings. This report made public by the U.S. Department of Education (1983) entitled *A Nation at Risk* gave recommendations in the areas of content, standards and expectations, time, teaching, and leadership and fiscal support of schools. The report offered the following “indicators of risk” on page twelve of the document that relate to academic achievement specifically in mathematics: 1) “International comparisons of student achievement, completed a decade ago, reveal that on 19 academic tests American students were never first or second and, in comparison with other industrialized nations, were last seven times.” 2). “The College Board’s Scholastic Aptitude Tests (SAT) demonstrate virtually unbroken decline from 1963-1980. Average verbal scores fell over 50 points and average mathematics scores dropped nearly 40 points.” 3) “One-third of 17-year olds cannot solve a mathematics problem involving several steps.” The report goes on to quote Paul Copperman, an analyst of education reform during this time who noted,

> “Each generation of Americans has outstripped its parents in education, in literacy, and in economic attainment. For the first time in the history of our country, the educational skills of one generation will not surpass, will not equal, will not even approach, those of their parents. It is important, of course, to recognize that *the average citizen* today is better educated and more knowledgeable than the average citizen of a generation ago—more literate, and exposed to more mathematics, literature and science. The positive impact of this fact on the well-being of our country and the lives of our people cannot be overstated. Nevertheless, *the average graduate* of our schools and colleges today is not as well educated as the average of 25 or 35 years ago, when a much smaller proportion of our population completed high school and college. The negative impact of this fact likewise cannot be overstated.” (p. 12-13).

In the late 1980s, the focused shifted from the Back-to-Basics mathematics to critical thinking. In 1989, the *National Council of Teachers of Mathematics* (NCTM) released a document titled *Curriculum and Evaluation Standards for School Mathematics.* This document stresses problem solving, communication, connections, and reasoning (Suydam, 1990). The section of the document titled *What is the Rational for the Standards* goes on to state that

> the mathematics a person needs to know has shifted and new mathematics is being created as technological applications emerge. However, the teaching of mathematics has remained relatively unchanged. As it has for centuries, mathematics often relies on rote memorization. The objectives of mathematics education must be transformed to meet the critical needs of our society: an informed electorate, mathematically literate workers, opportunity for all students, and problem-solving skills that serve lifelong learning. Both the content that is being taught and the way it is being taught need to be reconsidered and, in many cases, transformed. (P. 1).

The standards put out by NCTM were a framework for mathematics curriculum development. In the 1990s, the focused shifted to teaching pedagogy. Using manipulatives and hands-on activities became a common part of the mathematics curriculum (Malloy, 2003).

The need for reform did not go unnoticed by legislation. On January 8, 2002, President Bush signed into law the No Child Left Behind Act of 2001. These laws mandate that all states implement accountability systems and that teachers and schools are held accountable for the education of all students (Crum, 2009). Today, nearly every state in the United States has developed its own set of content standards, performance standards, and assessment measures.

Implementing Inquiry Based Mathematics curriculums

With the focus on standards based instruction and the implementation of standardized tests, the role of the teacher has changed in the last twenty-five years. In the past, teachers were to give students mathematical knowledge but the role of the teacher in the present is to help their students experience mathematics through active participation (Herrera & Owens, 2001). The shift in mindset regarding how to most effectively teach math has gone from rote memorization of math facts and algorithms to inquiry based mathematics instruction. When students can make connections and relate it to their previous learning or a real-life experience of their own they understand and remember the concepts discussed in the education setting (Wilenski, 1993). Inquiry based mathematics allows for teachers to have deeper insight into their students' thinking processes and have a better understanding of their misconceptions about various mathematical concepts (Burns, 2004).

Although implementing new instructional practices is easy to talk about doing, getting principals, teachers, administrators and parents on board and willing to put their full effort into implementing a new program is often a big challenge for school districts. Teachers are directly impacted because they are the individuals having to adapt the most since they are delivering the instruction. Many teachers teach the way they were taught and most teachers today were taught from a traditional “basic math” approach (Malloy, 2003). In order for teachers, in most cases veteran teachers, to effectively implement a new math curriculum they must break away from the traditional approach they are accustomed to. Principals need to be in full support of a new math curriculum as well. Altering the way they approach teacher observations is important because what principles would see in a traditional mathematics classroom is much different than what they will observe in a classroom incorporating inquiry-based activities and group participation (Malloy, 2003). Direct instruction from the teacher would not be observed; therefore different criteria for the observation must be made before an observation is to take place. School districts that choose to implement “new math” often fight an ongoing battle with parents who do not support the switch in instructional methods. The reason for parent disapproval of inquiry based curriculums is because they struggle to help their child at home when they don’t understand what was covered in class that day or how the information was presented by the teacher (West, 1995).

Use of Traditional Mathematics Textbooks

Sava (1997) explains in his report that “in the spring of 1995, more than 500,000 students in 41 countries sat down for three hours of testing for TIMSS--the Third International Mathematics and Science Study, the largest, most expensive ($50 million) appraisal of educational achievement ever undertaken” (p. 64). In math, U.S. eighth graders scored 500, slightly below the 41-nation average of 513, and in science, they scored 534, slightly above the average of 516. Out of all of the countries, the Asians did best: Singapore, Korea, and Japan ranked in the top five on both math and science. It should be noted that even though the performance of American students was not at the top it was not at the bottom either. Performing similar to the American students were students from Israel, Germany, England, Norway, the Russian Federation, Sweden, and Switzerland (Sava, 1997).The data used from TIMSS included more than just the paper-pencil tests. Textbooks, interviews with principals, teachers, and students, and videotapes of Japanese, German, and U.S. teachers presenting typical math lessons were also included. The question that needs to be asked is "what accounts for the success of the superior performance in math of the top five countries?" As the TIMSS researchers studied these countries and their mathematics instruction, the findings pointed out an undeniable fact; the math curriculum, especially in Japan, demands more of students than America's does (Sava, 1997).

An interesting way to summarize U.S. mathematics textbooks is that they are too inclusive. The focus is hard to determine and they pay some (not much) attention to demanding more of students. U.S. textbooks still emphasize simpler, less demanding "basic" tasks. They are less challenging than in some other nations, particularly Germany and Japan. U.S. mathematics textbooks tend to cover many concepts, but only on a surface level. A study done by Schmidt, McKnight and Raizen (1997) investigated different grade-level textbooks and found that among the fourth grade mathematics textbooks investigated, the five topics receiving the most print accounted for 60 percent of the textbook space while those same topics accounted for over 85 percent textbook space internationally. Among the 8^{th} grade mathematics textbooks investigated, the five topics receiving the most textbook space accounted for only 50 percent while internally they accounted for an average of 75 percent.

Richard Riley, the 1996 U.S. Secretary of Education noted at a TIMSS briefing that

> we have bright, dedicated, well-educated teachers, but compared to Japan and Germany, they get little practical training or mentoring, and little opportunity to work closely with other teachers to improve teaching. But changing these or other factors will be of little use if teachers are forced to teach using textbooks that are outdated, lack focus, and do not reflect the tougher standards (cited by Zucker, 1998, p. 16).

It is obvious if one looks down the hall of a U.S. public school that students use textbooks. Lockers are opened and shut as textbooks are exchanged and students switch classes. Students taking any of the four content areas of math, science, social studies and language arts most likely will be accompanied by a textbook as they enter the classroom. The textbook is described as the core of the curriculum in most schools (Duffey et al, 1989). Lester (1997) surveyed forty-four high school 9^{th}, 10^{th}, 11^{th} and 12^{th} graders asking various questions relating to the use of textbooks in their classes. One question in the survey pertained to how often students used their textbooks in the classroom for different subject areas. The participants listed all of their classes and whether or not a textbook was used. The results indicated that the math textbook was used most frequently with 77 percent of the students stating that it was used almost every day of the week.

Teachers' Beliefs and Conceptions about Mathematics Instruction

When teachers plan their instruction for a mathematics course, they have to think about the desired outcomes they want from their students. As Sullivan and Mousley point out, teachers are limited by constraints limited to their "beliefs about mathematics and about mathematics teaching" (as cited by Cha´vez–Lo´pez, 2003, p. 28). With no clear national consensus on what mathematics concepts should be taught in each grade level or how they should be taught, it is up to teachers to ultimately decide how and what to teach. There is no direct connection to a teacher's beliefs about mathematics instruction and the way they teach as mentioned by Thompson (cited by Cha´vez–Lo´pez, 2003) but there is evidence that what a teacher believes to be true about mathematics instruction influences how they teach (Garrett, 2008). Since the release of its Curriculum and Evaluation Standards for School Mathematics (1990), NCTM spawned a major reform movement in school mathematics. This movement has called for the abandoning of instruction that promotes mathematics as a set of rules governed by standards of accuracy and replacing it with instruction that allows students to have numerous and various experiences with complex problems while at the same time giving students the opportunity to read, write and communicate math both orally and verbally. This reform encourages teachers to help students appreciate the mathematics they use and gain confidence as they explore, guess and even make errors as they work towards a solution for a given problem. Before the reform movement, mathematics focused heavily on computational math (Battista, 1994). Over the past decade technology has allowed for computation to take place much quicker and with fewer errors both in the classroom via high tech calculators and outside the classroom via cell phones and blackberries. This fact has called for a shift in the belief that math-is-computation to having a better conceptual understanding of the math that is done and why it works. Even with this new belief about mathematics instruction, researchers have investigated teacher's beliefs and found that there are still teachers that believe math is learned through rote memory and step-by-step procedures. Battista (1994) describes two elementary teachers, Mary and Jack, who's beliefs suggest math "consists of set procedures and that teaching means telling students how to perform those procedures" (p. 462). Cobb, Wood, Yachel, and McNeal (1992) report similar findings in a study done on the beliefs of an elementary school teacher. Their study focused on a third grade teacher that was teaching place value. In one activity the students looked at pictures of tens and ones blocks and answered a series of questions, "How many tens? How many ones? What number is that?" The responses from the students seemed almost memorized and there was never a discussion about why their responses were correct. This is just one example that sheds a lot of light into student "learning" of math in American schools. Students know whether they are right or wrong but most of the time have no clue why they are right or why their work (mathematical thought process) leads them to a correct solution.

It is fair to say that teachers are more comfortable with teaching the way they were taught (Malloy, 2003) but the question needs to be asked, "what type of instruction were current teachers exposed to when they were in school." Handal (2003) points out in her study that most mathematics lessons in American mathematics classrooms "follow a pattern of whole-class lecturing and show and tell style of teaching." (p. 50). Even with the new movement started by NCTM, many teachers still believe that teaching and learning mathematics is more effective with traditional instruction, which as Handal (2003) explains, suggests a historical correspondence between teachers' mathematical beliefs and the teaching practices characteristic of rote memorization of procedural problem solving.

Teachers' Knowledge of Mathematics

In her book *Knowing and Teaching Elementary Mathematics,* Ma (1999) presents evidence that American elementary school teachers do not know mathematics with the depth and flexibility needed to teach it. Ma compares Chinese elementary teachers and American

Elementary teachers and makes the case that American elementary teachers, for the most part, do not have the fundamental understanding of mathematics like their Chinese counterparts. Ma points out that "a good vehicle, however, does not guarantee the right destination. The direction that students go with manipulatives depends largely on the steering of their teacher" (p. 5). In the end, knowing how and why is more important. Today, a lot of focus is spent on using best practices and incorporating more hands-on activities into our mathematics instruction. While it is beneficial to make various mathematical concepts more concrete, it is important to understand that ultimately it is not the curriculum, but the teacher that will correctly guide students to a deeper understanding of the mathematics they are doing. Ma sums up her argument by saying that "the real mathematical thinking going on in a classroom, in fact, depends heavily on the teacher's understanding of mathematics" (p. 153).

A study by Hill, Ball & Rowan (2005) was done on the effect of teachers' knowledge and student achievement. The study was done with both first and third grade teachers and their classrooms. Many factors were taken into account including family background and support before the data was analyzed. The results showed a positive correlation between teacher preparation and content knowledge and how the students in their classrooms tested. In classrooms where teachers had a better understanding of mathematics, the students performed better than those classrooms whose teachers did not show as good of an understanding of their content.

In his article, Shulman (1986) distinguishes between three types of knowledge: *Content Knowledge, Pedagogical Knowledge* and *Curricular Knowledge.* Shulman explains that

> teachers must not only be capable of defining for students the accepted truths in a domain. They must also be able to explain why a particular proposition is deemed

> warranted, why it is worth knowing, and how it relates to other propositions, both within the discipline and without, both in theory and in practice (p. 9).

Content knowledge alone is not enough for a teacher to have in order to effectively teach so that their students understand. Pedagogical knowledge goes beyond knowledge of subject matter to subject matter knowledge needed for teaching. Pedagogical knowledge empowers the teacher to "use the most useful forms of representation for a given concept, the most powerful analogies, illustrations, examples, explanations and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9). Pedagogical knowledge also allows a teacher to understand what makes the learning of specific concepts easy or difficult for students to understand (Shulman, 1986).

Benefits of Traditional Mathematics Instruction

With the push for different approaches of mathematics instruction in American schools one might think it would be hard to find an advocate for continuing with traditional mathematics instruction. In a study done by Alsup (2003), two different forms of mathematics curriculums were put to the test and compared using students' SAT scores over a three year period. The traditional curriculum used was Houghton-Mifflin while the reform (or inquiry) curriculum was Cord Applied Math. Results showed that the reform method of instruction did not appear to improve significantly over the traditional method. The results also showed that the traditional approach had a positive impact on procedural tasks such as computation and equation solving. After viewing the results, the teacher (name unknown) in whose classroom the test was administered questioned the time and money spent to implement a reform curriculum and cautioned any mathematics departments from jumping right in. The teacher responded by saying

“A reform mathematics curriculum is expensive to implement; teachers must be trained and supplementary' kits must be purchased. Such expenses, in his opinion, are questionable, since a reform mathematics curriculum did not promote an increase in student achievement” (Alsup, 2003, p. 694). In his closing remarks Alsup echoes the opinion of many current mathematics teachers today by saying, “Over the decades educators have tried to develop more effective methods to teach mathematics. Though most educators agree that mathematics achievement needs to improve, the current reform trend does not appear to be the answer. Further, it appears to be detrimental to procedural knowledge” (p. 694).

A major concept in traditional mathematics instruction is the idea of spiraling. In traditional math, spiraling is the idea of revisiting a specific mathematical concept several times over a period of time. It is based on research of spaced learning which explains that learning is enhanced through stronger memory retention if learning is spaced out over a period of time (Wartonic, 2005). With the use of spiraling in traditional mathematics instruction, learner stress is reduced since students are not pressured into fully understanding the mathematical concept being studied the first time they are introduced to it. With reminders along the way, students can start to assimilate concepts and apply their knowledge to new concepts they will see in the future, progressively getting better at applying the concept and using it.

Limitations of Traditional Mathematics Instruction

The scene Marshall (2006) depicts of a mother and daughter working together on her math sums up what inquiry based mathematics advocates say is wrong with traditional math. When the mother tells her daughter what the numbers are and has her repeat them back to her it is much like the traditional approach to mathematics instruction. Students learn best when they can make connections, organize, clarify and reflect on their thinking (Burns, 2004) and with traditional mathematics instruction this does not happen. The problem with traditional instruction is the concept of *rote* learning. Marshall (2006) takes the definition of "rote" from the Oxford English Dictionary which defines rote as, "in a mechanical manner, by routine; especially by the mere exercise of memory without proper understanding of, or reflection upon, the matter in question." Through traditional mathematics instruction, children are expected to use a mathematical concept before they have been able to experience it primarily focusing on how the teacher "told" them how to use it. This style of teaching is what Michael Battista says is common in American schools, is "ineffective" and "seriously stunts the growth of students' reasoning and problem-solving skills" (as cited by Marshall, 2006, p. 357).

Benefits of Inquiry-Based Mathematics Instruction

For teachers to have a proper understanding of students' mathematical knowledge and know-how, there must be tangible ways teachers can gain insight into their students' thought processes. Inquiry based mathematics instruction does just that. The teacher's role has evolved from concept deliverer to concept facilitator where questions are posed to get students thinking and experiencing the mathematical concepts at hand. Students are encourage to "show what they mean" and "explain" their thinking either orally or in written form. Bonner (2006) reported findings in an action research study on two fifth grade teachers that both incorporated inquiry based lessons into their teaching. In one instance, the teachers introduced a four-step problem solving strategy 1) write out the original problem 2) cross out unimportant information 3) draw the problem and 4) solve the problem. The teachers did not provide any specific strategies for solving word problems which allowed students to explore possible solutions to solving them. Students applied the mathematical knowledge they already had to the general guidelines and constructed their own process for solving the word problem. Students were then able to share how they got their solution with the class which gave them the opportunity to orally communicate their mathematical understanding. This allowed the teachers to gain insight into students' thinking and point out misconceptions students had. A quasi-experimental study carried out by Riordan and Noyce (2001) compared two inquiry based mathematics programs; an elementary program called *Everyday Mathematics* and a middle school program entitled *Connected Mathematics.* The study compared statewide standardized test scores for students using these curriculums to demographically similar students using a mix of traditional instruction methods. The results of this study showed "that students in schools using either of these inquiry-based programs as their primary mathematics curriculum performed significantly better on the 1999 statewide mathematics test than did students in traditional programs" (p. 368). Another study showing the effectiveness of inquiry-based instruction when compared to traditional instruction was a two-year study performed by Crawford and Snider (2000). Research was conducted in two fourth grade classrooms to test the effectiveness of *Connected Math Concepts (CMC)*, an inquiry-based program, and a traditional program utilizing the textbook published by Scott, Foresman. During the first year the CMC group scored significantly higher than did the group using the traditional textbook on the computation subtest of the National Achievement Test as well as curriculum-based tests constructed from the CMC and traditional programs. In year two, both groups used the CMC program and the group using the traditional textbook the previous year showed significant improvement.

Many mathematics teachers fear that if the level of difficulty is increased by way of inquiry based instruction even the slightest bit they will cause their students to become disinterested and perform poorly. Turner, Daggs & Styers (1997) discuss through examples taken from junior high classrooms that just the opposite happens when students are challenged more in the classroom. One example depicts how a teacher runs an inquiry based lesson on "what is a fraction?" The teacher started the lesson by drawing seven equivalent squares on the chalkboard. She then proceeded to ask students to show her seven-fourteenths of the squares. The teacher did not give the students any procedures or "teacher-done" examples of how to "show seven-fourteenths" and left the challenge up to the students. Through thought provoking questions, the teacher was able to guide students inductively to an understanding of the meaning of seven-fourteenths by having students "show" the fraction rather than following traditional procedures of watching her do the example and copy it down into their notes.

Limitations of Inquiry Based Mathematics Instruction

There are limitations of any curriculum adopted by a school district. Inquiry based mathematics, although highly revered by many, has its limitations. R. James Milgram (n.d.), professor of mathematics at Stanford University, gave a report on his review of the Connected Mathematics Program. In his report he states that the "philosophy of this program is that the students should entirely construct their own knowledge and that calculators are to always be available for calculation" (p. 2). Milgram goes on to discuss the program's failure to implement "repetitive practice" and "basic manipulative skills" that are crucial for students to master before moving on to another concept. Essential in mathematics is the development of skills necessary for later work in more advanced mathematics and possible technical careers. Training in proving algorithms correct mathematically is a must if students are to construct their own methods of solving problems and “CMP does not do this” (p. 2).

As with CMP, many inquiry based mathematics programs often require supplementation with additional materials that give students extra practice with procedural and computational skills (Wartonic, 2005). There are many reviews of empirical studies that have established a solid defense against the use of inquiry based instruction. Mayer (2004) reviewed evidence from studies conducted from 1950 through the 1980s comparing inquiry based learning with guided forms of instruction (traditional instruction). He suggested that in each decade since the mid-1950s, when empirical studies provided solid evidence that the popular method of inquiry based instruction did not work, a similar approach came about under a different name and the cycle repeated itself. This process continued and many new names came about that dealt with the method of unguided or inquiry based instruction. Mayer (2004) concluded that the “debate about discovery learning has been replayed many times in education but each time, the evidence has favored a guided approach to learning” (p. 18). Many teachers who implement inquiry based instruction end up giving students a great amount of guidance because students oftentimes fail to meet the learning goals of the teacher. This can be seen in studies conducted by Aulls (2002), who observed a number of teachers as they implemented inquiry-based activities in their classrooms. He described the scaffolding that the most effective teachers introduced when students failed to make learning progress in this type of setting. He reported that the teacher whose students achieved all of their learning goals spent a great deal of time in instructional interactions with students by “simultaneously teaching content and scaffolding-relevant procedures…by (a) modeling procedures for identifying and self-checking important information…(b) showing students how to reduce that information to paraphrases…(c) having students use notes to construct collaborations and routines, and (d) promoting collaborative dialogue within problems" (p. 533).

*Mathematically Correct is a*n advocacy group for the improvement of mathematics education in America's schools. The group was founded in Southern California in 1995 by parents concerned about the weakness of the mathematics programs available to students in California. Clopton, McKeown, McKeown, and Clopton (1999) conducted a study in which different mathematics programs were reviewed that focused on instruction in grades 2, 5 and 7. The programs were evaluated based on the group's premise that k-7 mathematics instruction should prepare students well enough to study algebra in the eighth grade. The rating criteria that was used consisted of the following: depth of content, quality of presentation and quality of student work. These aspects were used to assess how well students would learn the mathematical concepts needed to succeed in an eighth grade algebra course as they progressed through the younger grades. It is important to note that an overall rating of F was given to the three inquiry based mathematics programs, of which CMP was one of them.

Need for the Present Study

With the continued scrutiny of mathematics education in America, it is crucial to evaluate the effectiveness of mathematics curriculums as they become available to school districts. There is plenty of research on using an inquiry approach in the sciences, but little in the discipline of mathematics. Research that has been conducted on using inquiry in mathematics tends to focus more on achievement tests scores in the elementary grades or perceptions of the use of inquiry in college level courses. Few studies have been done that focus on the middle school grades using pre and post tests for individual units. Making a direct comparison between two instructional approaches (inquiry and traditional) that focus on a specific unit of study that is taught in the same building will give a glimpse of the effectiveness of each approach.

While research has been done on inquiry based mathematics instruction in general, research analyzing concrete data when comparing the Connected Mathematics Project 2 and Glenco/McGraw-Hill program is minimal. If school districts are considering adopting a new curriculum, it is important that there be extensive research from unbiased groups so that administrators and teachers can make the best decision based on evidence that is available. Each mathematics curriculum has its own approach to presenting the mathematical concepts it contains whether it be inquiry based or traditionally based. Therefore, this present study focuses on the inquiry approach of Connected Mathematics Project 2 and the traditional approach of the Glencoe Pre-algebra series.

Chapter 3

Methodology

For this research project, a quantitative study using a between subjects design was performed using ANOVA as the statistical analysis instrument. The goal was to determine whether traditional mathematics instruction or inquiry based mathematics instruction was more effective with regards to students' understanding and comprehension. In order to achieve this goal, I taught two different classes using the different instructional methods. Each class was taught the same concepts, but through the different methods as mentioned above.

The unit was broken up into two parts. To establish a baseline for statistical analysis, a pre-test and post-test was given before and after both parts of the unit to both classes. Each class completed the same questions on each pre and post test. Scores were entered into SPSS for statistical analysis. The entire study lasted four weeks, with each part (excluding time for pre and post tests) lasting about two weeks. The following pattern shows the outline for each class:

Class A: 2 weeks on rational/irrational numbers, roots and square roots with inquiry instruction. (Unit 1)

2 weeks on Pythagorean Theorem with inquiry instruction (Unit 2)

Class B: 2 weeks on rational/irrational numbers, roots and square roots with traditional instruction. (Unit 1)

2 weeks on Pythagorean Theorem with traditional instruction. (Unit 2)

Dates of the study:

October 19- 30 10 school days (part 1)

November 2-12 10 school days (part 2)

The classes met daily for 60 minutes. The lesson covered during the first two weeks of pre-algebra included rational and irrational numbers, roots and square roots. Class A received instruction on these topics through inquiry which allowed for students to recognize patterns and rules by engaging in discussion about problems from the Connected Mathematics Project 2 curriculum. Class B received instruction through the traditional approach in which students took notes as I performed practice problems on the board and completed homework problems from the Glencoe text.

Rational for the Method

Quantitative studies are commonly completed by educators that wish to use numerical data to help describe, explain or predict results (Johnson & Christensen, 2008). The educational issue on which I focused was the effectiveness of two different approaches to mathematics instruction. This was gauged by collecting pre and post test numerical data before and after instruction was carried out. The results are able to help mathematics teachers and school districts decide on curriculum adoption as they research the possibilities that are available and the effectiveness of them.

As previously mentioned, a plethora of research has been conducted on inquiry and traditional instruction approaches to mathematics over the years but new curriculums are being produced. As a result, the research needs to stay up to date as well and be conducted by many parties to eliminate bias. I sought to test my hypothesis that students under inquiry instruction tend to understand and comprehend better than students under traditional instruction. The best way to test this hypothesis was through quantitative research with a two-group pre- and post-test using repeated measures ANOVA as the statistical analysis procedure.

Population of the Study

The population of the study consisted of eighth grade pre-algebra students. Particularly, the results have some degree of external validity for rural, middle school students. The results of the study are most applicable to Caucasian students in the Midwest and of average socioeconomic status.

Sample

Sample criteria. The students used in this research were the students assigned by normal scheduling to my pre-algebra class. I collected data on all students in my classes. Class A contained 22 students and Class B contained 30 students. Pre-algebra is the regular mathematics class eighth grade students take at this grade level.

Rational for Sample. I used my assigned pre-algebra classes because that is the most realistic population for this study. As a teacher, it is impractical to achieve a random assignment of students due to the nature of the middle school setting. Since I only studied two classes, I collected data on all of my students to attain a reasonable *n* of 22-30 students for each class. The total number of students achieved enough data collection to provide adequate external validity for the study's intended purpose.

Methods of sampling. Sampling from the population occurred through class assignment. This was determined by the student selection and assignment of classes by the guidance office. No sampling occurred in the data collection process since data was collected from all students. My classes constituted a sample from all rural public, Midwest 8^{th} grade pre-algebra students.

Procedure

Instruments. The instruments used for data collection involved student pre- and post-test scores from part one and part two of the unit of study. The pre-tests were given to every student in both classes before each part was taught. The post-tests were given to every student in both classes after each part was taught. The testing instruments for parts one and two can be found in the Appendix section of this report.

Data Collection Methods. The data collection took place by way of student scores on the pre-tests and post-tests. Each test was completed in the classroom without the aid of notes, textbooks or peers. Pre-tests were scored based on how many points were earned out of the total possible. The exact same questions were then given on the post test and scored in the same way. The process was repeated for part two of the unit.

Relevant ethical considerations. This quantitative study posed no harm to the students involved. I taught in a normal manner. The only change included different instructional techniques (inquiry/traditional). Although students involved were minors, an active informed consent from students' parents was unnecessary. This is due to the fact that classroom instruction would have been carried out similarly had the research element not existed.

Variables. The independent variable in my study was the instructional approach. This was tested to see if it had an impact on students' understanding and comprehension (test scores) which is the dependent variable.

Method of data analysis. Student scores were analyzed for each part using the computer software program SPSS. Since there was only one quantitative dependent variable (student test scores) and a dichotomous independent variable (2 methods of instruction), the repeated measures ANOVA using SPSS was best to use to see whether the difference between the means of the test scores between both groups was statistically significant for each unit of study (Johnson & Christensen, 2008).

Safeguards to internal and external validity. To best control for confounding variables, measures were taken to best control them if possible. The students assigned to my pre-algebra classes represented a range of abilities and attitudes towards school. This could have affected their motivation to learn and do well on the pre-tests and post-tests. To maintain validity, incentives were offered for improved scores such as candy and extra credit towards students' quarter grades.

The level of support outside of the classroom is different for all of my students. To help control this variable, statistical analysis was done on each student to test individual improvement from pre-test to post-test.

The results of this study are not generalizable to a large population because random sampling did not occur. This negatively affects the external validity of the research. However, generalization was not the main goal. The greater purpose was to describe the effectiveness of two different instructional approaches and to give mathematics teachers and school districts more data as they consider new curriculum adoption. In spite of the fact that the results cannot be completely generalized to a greater population, the results can, to some degree, be generalized to similar groups of students with teachers who possess comparable characteristics to the individuals in the present study.

Chapter 4

Results: Quantitative Analysis

Overview

This study analyzed the effectiveness of two different mathematics instruction models in an 8^{th} grade pre-algebra classroom setting. To compare the two curriculums, a unit of study was broken into two smaller units (unit 1 and unit 2) in which both sections of pre-algebra students were given an identical pre-test and post-test before and after each unit. Class A was taught using an inquiry-based instruction model while class B was taught using a traditional instruction model. Each class received instruction covering the same concepts. The only differences between the groups were the manner in which the information was presented or explored and the style of homework that was given. Each class' homework related to the style of the instruction model used with the respective classes.

The pre-test scores were used as a baseline for each class so that the post-test scores could be analyzed for individual improvement as well as overall classroom improvement. The means for each class were analyzed and checked for statistical significance for both units 1 and 2. Examining the students' scores of class A compared to students' scores from class B resulted in greater improvement for class A between pre-test and post-test scores for both units 1 and 2. By doing this study, I found that the inquiry model increased the interest level in the classroom compared to the traditional approach. The inquiry model encouraged more engaging problems and fostered mathematical discussion on a deeper level than did the traditional approach that was used.

Results of Unit 1

As shown in Table 1, class A had a sample size of n= 22. The baseline mean for class A was 9.27 with a standard deviation of 5.10. Class B had a sample size of n= 30. The baseline mean for class B was 7.67 with a standard deviation of 4.97. The post-test mean for class A was 18.27 with a standard deviation of 3.98. Class B had a post-test mean of 14.67 with a standard deviation of 4.37.

Table 1

Mean Scores and Standard Deviations for Unit 1 Pre-test and Post-test

Pre-test			
Class	Mean	Std. Deviation	Sample Size
A	9.27	5.10	22
B	7.67	4.97	30
Post-test			
Class	Mean	Standard Deviation	Sample Size
A	18.27	3.98	22
B	14.67	4.37	30

Results of repeated measures ANOVA showed a significant main effect of the test with $F(1,50) = 166.12$, and Wilk's Lambda = .23, $p < .001$. This means that the performance on the post-test was better than the performance on the pre-test for both class A and class B. The significant results of the tests of between-subjects effects, with $F(1,50) = 5.20$, $p < .05$, suggested that the overall performance of class A was better than class B. The descriptive statistics shows that the mean improvement score (defined by the post-test score minus the pre-test sore) for class A was higher than that of class B (see Table 2). This means that the students taught with inquiry-based instruction showed more improvement than those taught with traditional instruction. Even though class A had a higher mean improvement score on the post-test than class B one cannot assume that this was related to inquiry-based mathematics instruction. A non-significant interaction between test and class was found in $F(1,50) = 2.60$, $p = .113$. This indicated that the improvement from the pre- to post-test had no significant difference between classes A and B.

An independent samples t-test was conducted to compare the improvement scores of class A and class B to check if there was a significant difference. The group statistics shows that the mean for class A was higher than that of class B (see Table 2). This means that the students taught with inquiry-based instruction showed more improvement than those taught with traditional instruction. The Levene's test for equality was significant at .107 so it can be assumed that the variances were approximately equal. The Sig. (2-Tailed) value for unit 1 is 0.113. This value is greater than .05. Because of this, it can be concluded that there is not a statistically significant difference between the mean improvement scores for inquiry (M=9.0, SD=3.78) and traditional (M=7.0, SD=4.84) conditions; t (50) =1.61, $p = 0.113$. Even though it can be observed from Table 2 that there was substantial improvement in test scores, the results from the independent samples t-test in unit 1 did not reach the level of statistical significance needed to claim that inquiry-based mathematics instruction was more effective than traditional mathematics instruction.

Table 2

Unit 1 Improvement Scores

	Group	n	Mean	Std. Deviation	*t*-value
Unit 1	A	22	9.00	3.78	1.61
	B	30	7.00	4.84	

Results of Unit 2

Unit 2 was carried out in the same manner as unit 1 with a pre-test before the unit was taught and a post-test after the unit was taught. The sample sizes for both groups remained the same. The pre and post test used for unit two consisted of six questions and students were scored based on how many questions they answered correctly. As seen in Table 3, Class A had a baseline mean for the pre-test of .91 with a standard deviation of .97. The post-test mean for class A was 4.68 with a standard deviation of 1.49. The results for the pre-test to post-test means show that overall improvement was made in unit 2 just as in unit 1. The baseline mean for class B was 2.07 with a standard deviation of 1.39. The post-test mean for class B was 4.10 with a standard deviation of 1.30. The results for class B also show that improvement between pre and post test mean scores was made.

Table 3

Mean Scores and standard deviations for Unit 2 Pre-test and Post-test

Pre-test			
Class	Mean	Std. Deviation	Sample Size
A	.91	.97	22
B	2.07	1.39	30
Post-test			
Class	Mean	Standard Deviation	Sample Size
A	4.68	1.49	22
B	4.10	1.30	30

Results of repeated measures ANOVA for unit 2 data showed a significant main effect of the test with $F(1,50) = 186.30$, and Wilk's Lambda = .21, $p < .001$. This means that the performance on the post-test was better than the performance on the pre-test for both class A and class B. The results of the tests of between-subjects effects, with $F(1,50) = .93$, $p = .341$, was not significant, and this means that the overall performance of class A and class B had no difference. However, a significant interaction between test and class, $F(1,50) = 16.72$, $p < .001$, suggested that the differences between the pre- and post-test were not the same for class A and class B. An independent samples t-test was performed on the improvement scores to provide further examination of the difference. The results showed that there is a statistically significant difference, $t\ (50) = 4.09$, $p < 0.001$, between the mean improvement scores for inquiry (M=3.78, SD=1.60) and traditional (M=2.03, SD=1.45) conditions.

Even though my hypothesis that inquiry instruction is more effective than traditional instruction can be seen in Table 4 just from the improvement in mean scores, the results from the independent samples t-test for unit 2 confirm my hypothesis. Because the results have reached the level of statistical significance for unit 2, it can be concluded that inquiry-based mathematics instruction was more effective than traditional mathematics instruction.

Table 4

Unit 2 Improvement scores

	Group	n	Mean	Std. Deviation	t-value
Unit 2	A	22	3.78	1.60	4.09 ***
	B	30	2.03	1.45	

*** $p < .001$

Chapter 5

Discussion and Implications

After analyzing the results of this quantitative study, it is clear that inquiry-based mathematics instruction is effective in improving students' understanding and comprehension. Most school districts and mathematics teachers would desire any effective mathematics curriculum but inquiry-based mathematics offers a richer and deeper approach to the mathematical concepts covered in mathematics education. The reported results lead to practical applications and also can be used in further studies.

Interpretation of the Results

Both models of instruction were effective. After analyzing the students' test scores through SPSS and comparing the class means, both methods of instruction improved student scores from pre-test to post-test significantly. Neither instructional method resulted in lower scores. With a mean score increase of 9 points (inquiry model) and a mean score increase of 7 points (traditional model), it is fair to say that since the overall goal of teaching mathematics is increased student understanding and comprehension, any curriculum used that produces an improvement in scores is effective.

Inquiry-based mathematics instruction was more effective than traditional instruction. The goal of this study was to test and see if inquiry-based instruction or traditional instruction was more effective in improving student comprehension and learning. Although both methods proved to be effective, the inquiry-based instruction model proved to be more effective in this study. In units one and two, students' test scores improved more for students receiving instruction through the inquiry model as opposed to students receiving instruction with the traditional model. The improvement for unit one did not come out to be statistically significant but was statistically significant for unit two.

Potential Applications of the Findings

Increase student conceptual understanding through inquiry. One of the many advantages that inquiry-based instruction has over traditional models is that students are encouraged to look for patterns without teachers directly giving them formal algorithms and rules. When teachers do this their students are not required to understand why the algorithms work, but instead only need to remember when and where to plug numbers in the way they were shown how to. The problem with not having a conceptual understanding of the algorithms used in mathematics is that students have difficulty applying the rules and patterns underlying the algorithm to new and more complex problems. Mathematics naturally progresses from basic skills to more challenging computation and algebraic thinking. A proper conceptual understanding allows for this progression to be less frustrating for students because they are able to pull from their own understanding rather than depending on the teacher to spoon-feed them each step of the way. On the flip side, it is not enough to leave it to the students to fully develop the formal algorithms used in mathematics such as area and volume without any formal instruction. When using inquiry-based models of instruction it is important to use discretion when the use of formal algorithms is needed to complete the tasks. Student discovery can be time consuming and teachers must plan their instruction accordingly or valuable instruction time will be lost.

Improve Teacher Instruction: Apart from the benefit of improved student understanding, the inquiry model also improved teacher instruction by using effective guided questions. These questions were suggested by the curriculum and followed a natural progression based on student responses that lead students to a better understanding of the concept they were learning. These questions allowed me to know individual students' misconceptions and helped me guide students into correcting these misconceptions. To assist the questioning facet of the inquiry model, written explanations to questions were also incorporated frequently to give students the opportunity to put their thinking into words. Reading student responses pointed out individual misconceptions and allowed me to focus my discussion with them about these misconceptions. Guided questioning and written explanations were not a part of the traditional model. The inquiry model allowed me to pinpoint specific gaps in student understanding and help me close them whereas the traditional model simply let me know if a student could get an answer correct or not. Knowing whether or not a student can get an answer correct is not enough because it does not tell me as a teacher if the student understands why they solved it the way they did or if they just memorized the series of steps taken that they observed me doing. A written description of the steps and an explanation of each step does a better job of showing teachers what students understand about the math rather than just getting an answer correct. As a teacher, understanding the misconceptions students have about mathematics is what allows me to help them learn and the inquiry-model guided me in pulling out those misconceptions.

Carefully consider the available space needed for instruction with an inquiry-model. Teachers need to consider the available classroom space when deciding how to arrange the desks. Often classrooms are crowded and, if an inquiry model is being used, students' desks need to be carefully placed. Issues to consider include ability grouping, grouped desks or in rows and space for easy movement throughout the classroom. This will help determine the physical arrangement of the classroom being used.

Invest adequate time and resources. In addition to deciding the physical arrangement of the classroom, extensive training should be implemented for teachers. The company from which the inquiry model curriculum is purchased will most likely provide valuable online resources and strategies for its intended use. This will allow the greatest educational benefit to be gained. Once trained, teachers need to teach using the model and not default back to the traditional approach they are used to or feel more comfortable using. Any new instructional approach takes time before teachers feel comfortable using it, but it is a must with inquiry because of its unique approach to mathematics instruction.

If resources exist, a mounted projector or TV is ideal that is connected to a laptop, desktop PC, or ELMO. Many resources are included on disks that are included with the curriculum that can be used with a computer. Teachers need to have a student-free area to extend cords or a method to secure them. Having the ELMO encourages increased student involvement. Therefore, the placement of the ELMO so that all students can access it and easily view it is important. The relatively substantial price of ELMOs also must be considered. If adequate resources are not available, schools should research grants or consider buying a limited number of ELMOs to be placed in general education classrooms.

Increase involvement and motivation of students in the classroom. Finally, an inquiry-based model of instruction can serve to increase student involvement and motivation in the classroom. In the present study, students that normally stay quiet were getting involved in class discussions that revolved around mathematics. Students gain confidence when they are given the chance to explain how they solved a math problem and find out they are the only one that solved it their way. An inquiry model would continue to increase their interest and engagement. One way this can be accomplished is by having students answer questions at the ELMO (if available) in front of the class. Another way to increase involvement could occur by assigning a problem, and then having them show and explain how they arrived at their answer.

Biblical Integration

As a Christian educator, incorporating a new curriculum, such as an inquiry-based model, into the classroom also must be analyzed from a Christian perspective. Since Creation, God has called us to be stewards with what He has provided. God gives three clear commands in Genesis 1:28 (New International Version): be fruitful, fill the earth, and subdue it. Being fruitful involves procreation and proliferation, filling the earth involves adding value, and subduing involves taming the creation. Later in Genesis 2:15 these commands are reiterated as God stated that Adam and Eve were to cultivate and keep [the garden]. Cultivate could be translated culture, and keep could be translated to take care of. Therefore, this command can be interpreted that Adam and Eve were to create culture and take care of it. Adam and Eve were to be stewards of all that was entrusted to them, and being a steward involves adding value. This is exemplified in the parable of the talents in Matthew.

In education, adding value includes using the available tools to further enhance the educational process. A proper, Biblical response to instructional curriculum must be formulated if any enhancements are to occur. An instructional curriculum is not independent of the teacher and must remain an aid to the teacher delivering the instruction. In 1 Corinthians 9, the Apostle Paul described the importance of keeping a goal in front and what it then takes to achieve a goal; in this case, he wrote about spreading the gospel to as many as possible, and then states in verses 25-27, “Everyone who competes in the games goes into strict training. They do it to get a crown that will not last; but we do it to get a crown that will last forever. Therefore I do not run like a man running aimlessly; I do not fight like a man beating the air. No, I beat my body and make it my slave so that after I have preached to others, I myself will not be disqualified for the prize." When there is a main goal, everything else is to be subject to that goal. Furthermore, the goal itself is to be worthy of this attention. In the life of the Christian educator, all is to be subservient to following after Christ. If this is to be true, then all matters of instructional curriculum must also be subject to a life of discipleship under the headship of Christ.

The literature review in this study points out that student misconceptions of mathematics comes from misunderstanding in the foundational years of mathematics. Mathematics was not an invention of man but rather a discovery of the laws and order embedded in creation by God. When God said his creation was "good" in Genesis 1, I believe it was at such a state that He wanted it to be for the purpose of mankind to learn about it and add value to it. It should not be interpreted to mean that the Earth was perfect. The laws and rules of mathematics have allowed mankind to learn and understand how the universe works and has lead to a better understanding of the design and order existent in creation and that God is A God of order. As a Christian educator, my goal is to show that God is faithful and reliable in upholding the world through orderly mathematical patterns, laws, and structures that He embedded in His Creation. The curriculum I use to convey the rules and relationships in mathematics is the medium through which I teach these concepts and should be considered with great care. When I see a mathematical relationship or pattern in action, it brings excitement because it confirms the existence of God. It also brings a sense of awe for it is because of these mathematical laws that life on Earth is possible and it is only by God's grace that they are upheld.

Discovery Learning: Jesus' Teaching Style

Jesus primarily taught by guiding inquiry with intriguing questions. Jesus' teaching was mainly oral. However, his questions are neither in single word answer format nor a simple true/false statement. Jesus asked questions to review general principles and to inspire audiences to think deeply about the content. There is a big difference between Jesus' teaching and the teaching of the Jewish leaders. The Jewish leaders' teaching primarily focused on repetition so their learners would remember their teachings verbatim. Jesus' questions are mainly focused on a learner's ability to search out a principle or find relationships that were hidden under the surface level of the question.

In discovery learning, teachers stimulate learners' interest through a variety of instruction methods such as inquiry, experimentation and observation. In the same way, Jesus motivated learners by adopting such teaching methods to inspire learners to think deeply. Listeners of Jesus' teaching would remember the teaching and later think more deeply about his message with new insights. He used parables with the masses for the same reason. Parables are not meant to be understood by everybody (Matthew 13:35), but he waited until he was alone with his disciples to explain them the true meaning of the parables (Matthew 13:10-15). Mark 4:33 says, "With many similar parables Jesus spoke the word to them, as much as they could understand." Jesus rarely spoon-fed the truth to his disciples. He usually mentioned, 'he who has ears let him hear (Matthew 11:15, 13:9, 43, Mark 4:23; Luke 14:35). Instead, his use of parables invited them to grapple with questions they might not have otherwise considered.

With both the culture and educational process having embraced the importance of mathematics, I must wisely use the instruction curriculum I am given to instruct my students.

Clearly, all Christian educators can take the Biblical principles of stewardship and diligence and apply them to education. Instructional curriculum is constantly being evaluated for effectiveness, and this must be something I do on a continual basis as I use the inquiry model. I believe that with proper training and consideration, Christian educators can successfully use the instructional curriculum to engage students in the learning process.

Relation of the Results to Literature

Analyzing the results in light of the current research gave insight to the effectiveness of inquiry-based mathematics instruction verses the traditional approach. Previous research supports the present finding that teaching through inquiry improves student learning and understanding more effectively than traditional approaches. In the current study, students receiving instruction through inquiry showed more improvement in their pre and post test scores for each unit of study. Similarly, the results of Riordan and Noyce's study (2001) showed that students in schools using inquiry-based programs as their primary mathematics curriculum performed significantly better on the 1999 statewide mathematics test than did students taught from a traditional approach. Crawford and Snider's study (2000) of an inquiry-based curriculum and a traditional curriculum found comparable results. They reported that the students being taught through inquiry scored significantly higher than did the group using the traditional textbook on the computation subtest of the National Achievement Test as well as curriculum-based tests constructed from the inquiry and traditional programs.

The finding that inquiry increases student conceptual understanding also is supported by previous reports. In the present study, students' discovery of rules and mathematical relationships allowed for a deeper understanding about the mathematics taking place. Bonner's study (2006) was similar to the current research which found that students were able to apply the mathematical knowledge they already had to the general guidelines of questions and constructed their own process for solving problems. Students were then able to share how they got their solution with the class which gave them the opportunity to orally communicate their mathematical understanding.

Previous research also supports the finding in the current study that inquiry-based instruction increases involvement and motivation of students in the classroom. In the current study, students normally unmotivated in math class were getting more involved and participating in discussions. Turner, Daggs & Styers' study (1997) reports that students get more involved when they are challenged more in the classroom. Inquiry-based instruction offers the challenging aspect that the traditional approach often lacks and as a result encourages all students to explore and solve mathematical problems.

Strengths of the Study

This project involved quantitative experimental research which resulted in seemingly robust findings that can be applied to other educational settings. The design of the study allowed each class to serve as its own control. Each class received instruction for a total of four weeks with either an inquiry or traditional approach. The concepts being taught had never been taught to the students involved in the study. Therefore, their previous learning experiences were minimal factors in analyzing the results.

This research focused on the effectiveness of inquiry and traditional approaches to mathematics instruction. The delivery of instruction (inquiry or traditional) was the only mediating variable in the two classes. Students were randomly assigned to their respective classes by the guidance office. As much as possible, other variables such as instructor, duration of class period, activities, and assessments were kept constant between the groups. Therefore, this allowed students' pre and post test scores to directly reflect how the method of instruction affected students' understanding and comprehension of the topic covered. Also, addressing one subject area allowed for greater attention put on the impact inquiry had in mathematics since delivery methods would differ in other content areas. The reported results are most applicable to the mathematics classroom setting.

The study was strengthened by the use of pre and post tests for both units of study. The pre-tests allowed for a baseline data set for each unit. The methods of data collection involved students' tests scores which strengthened the study's internal validity. Analyzing test scores separately for both units allowed for better comparison of the means and their respective units. All students were tested which provided a rich data set.

Limitations of the Study

Remaining threats to internal validity. The inquiry method of instruction was a newer approach to learning to most of the students in the study. It was also new to me as the teacher to implement it. As a result, the study captured the students' fascination with this new approach to learning mathematics. However, the novelty of the inquiry method may subside later in the school year or as students progress through their academic careers. The possibility of this effect could not be studied given the time constraints of the present research.

Remaining threats to external validity. Random selection could not occur in class formation as a result of Junior High scheduling. Most of the students involved in the study were average students but varied greatly within that average category. The diversity of the students was also limited. All but two students were Caucasian in class A and all but five students were Caucasian in class B. All students involved in the present study lived in suburban settings. As a result, this study was highly focused on a select group of students, and, therefore, the results are not entirely generalizable to all grades in the United States. Namely, one cannot take the present findings and generalize them across multiple Junior High populations. Nonetheless, beneficial educational information still can be gleaned from the study and applied in many classrooms sharing similar demographic characteristics.

Suggestions for Future Studies

For future research, this study should be expanded to include a greater number of schools with diverse groups of students. Since this study focused on quantitative issues and drew the conclusion that inquiry-based mathematics instruction had an overall more positive effect than traditional instruction on students' comprehension and understanding, the next logical step would be to analyze these effects qualitatively. For example, students in this study showed improved learning and comprehension through their pre and post test scores. Next, actual student perceptions of inquiry instruction compared to traditional learning should be assessed. This would further the quantitative findings reported in the present research, providing feedback on whether or not students' interest played a part in enhancing learning.

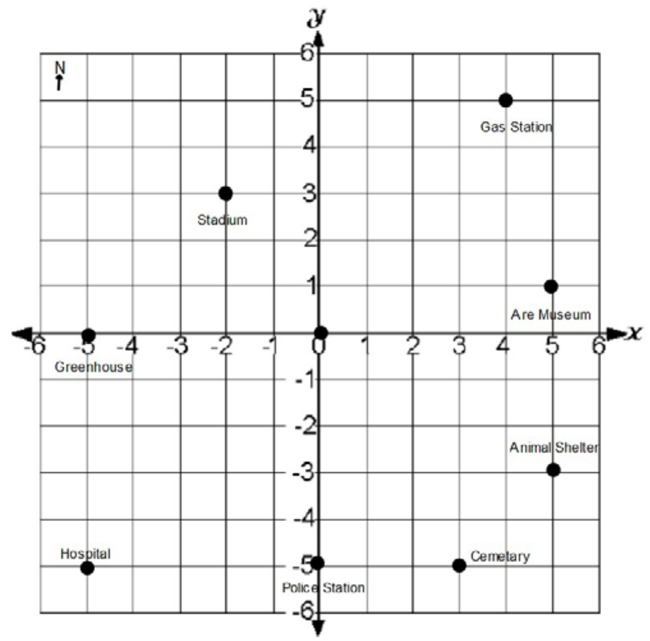
The present study focused on two units of study taking place over the course of four weeks. A replication study could be performed over the course of an entire school year to allow for more data to be analyzed and checked for statistically significant differences in all units of study. The results would either confirm or not confirm that inquiry-based instruction is more effective than traditional instruction as did the results of the present study.

Another area for future research involves analyzing the perspectives of teachers who regularly use inquiry-based instruction in their classroom. This would give further insight into areas that are most effective and give practical suggestions for limiting problems that may arise. Such research likely will become feasible as more classroom teachers adopt this style of instruction in their respective classroom

APPENDIX A

Unit 1 Pre and Post Test

For questions 1-2, use the diagram at the right.



1. Identify the coordinates each of the following:

- Stadium

-Cemetery

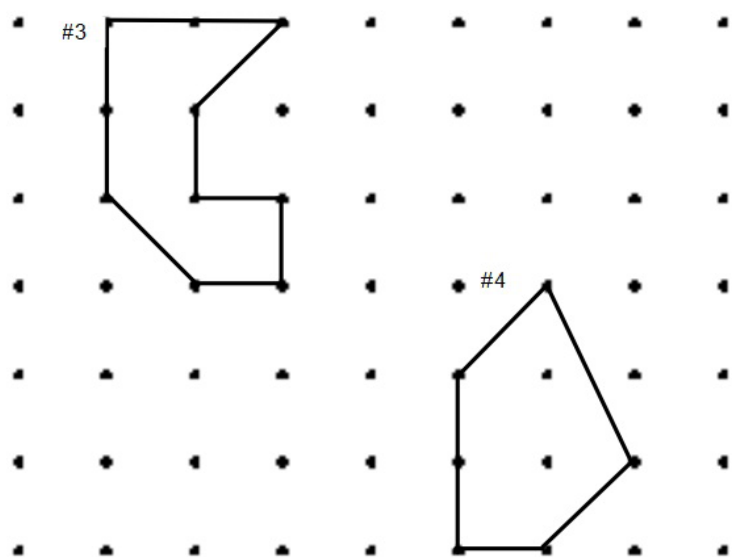
-Police Station

2. Suppose you are located at the gas station, give directions

to the hospital that would result in the shortest distance. The grids represent roads and each section is 1 mile. Use only coordinates and directions North, South, East, West in your answer.

Find the area of each figure to the right. Units are in

cm.



3.

4.

5. Find the side lengths of squares with areas of

1,9,16, and 25 square units.

6. Estimate the following to the nearest hundredth

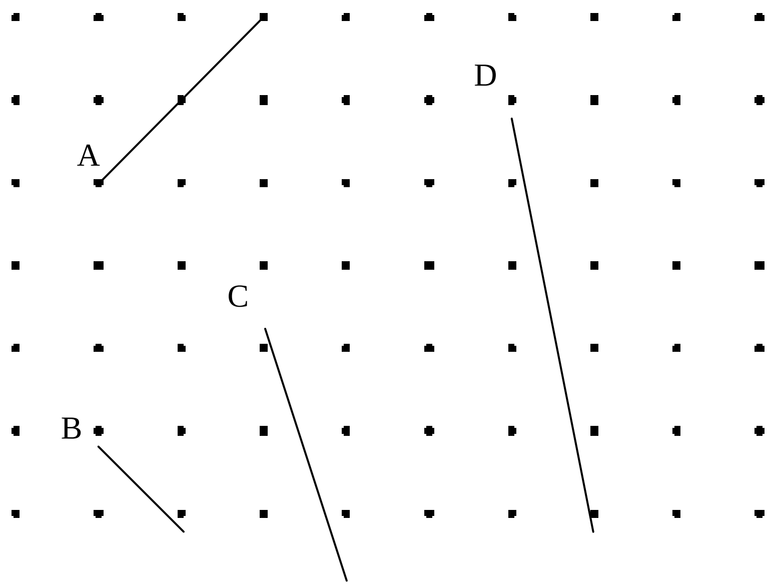
$\sqrt{2}$ $\sqrt{13.5}$ $2\sqrt{5}$

7. Which two whole numbers are $-\sqrt{6}$ and $-\sqrt{2}$ between

8. Compare $\sqrt{34}$ and $5\frac{3}{8}$ by using <, > or = to make a true statement. Estimate their location by place them on a numberline below.

9. Find the lengths of the 4 lines to the right.

Use the $\sqrt{}$ if necessary



10. Find the missing number

$\sqrt{81}$ = ?

$\sqrt{?} = \frac{1}{4}$

$\sqrt{?}$ = 3.2

$\sqrt{28.09}$ = ?

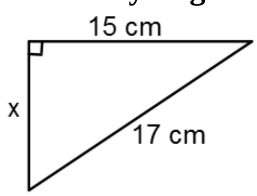
APPENDIX B

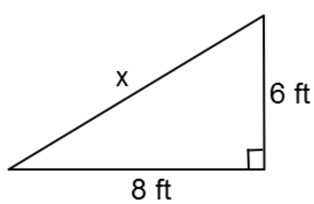
Unit 2 Pre and Post Test

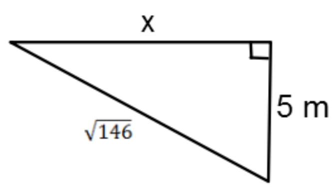
1. Can you form a right triangle with the following side lengths? Prove it by showing work.

   20, 21, 29

Use the Pythagorean Theorem to find the missing side of each right triangle

2. 

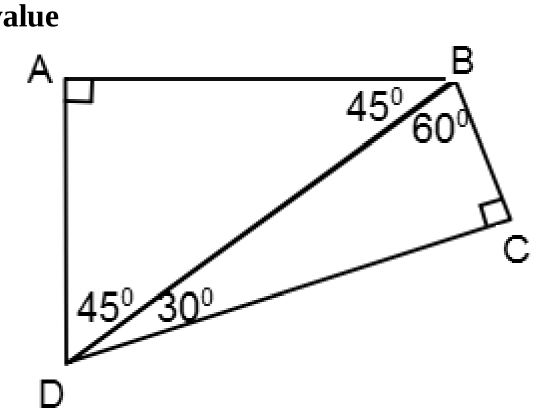
3. 

4. 

In the figure, $\overline{BD} = 6\sqrt{2}$. Find each value

5. $\overline{BC}$

6. $\overline{AD}$



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