

THE EFFECT OF AN INSTRUCTIONAL MODEL UTILIZING HANDS-ON LEARNING
AND MANIPULATIVES ON MATH ACHIEVEMENT OF MIDDLE SCHOOL STUDENTS
IN GEORGIA

by

Kara Morgan White

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

Liberty University

October, 2012

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THE EFFECT OF AN INSTRUCTIONAL MODEL UTILIZING HANDS-ON LEARNING AND USE OF MANIPULATIVES ON STANDARDIZED TEST SCORES OF MIDDLE SCHOOL STUDENTS IN GEORGIA.

ABSTRACT

The concepts and ideas of mathematics is a major element of educational curriculum. Many different instructional strategies are implemented in mathematics classrooms. The purpose of this study was to evaluate the effect of an instructional model utilizing hands-on learning and use of manipulatives on mathematics achievement of middle school students. A quasi-experimental non-equivalent control-group design was used to examine 145, seventh-grade students from a North Georgia middle school. Data was collected to analyze if changes were experienced in pretest/posttest scores. A Mann-Whitney test was run and revealed initial group differences between the whole control and whole experimental groups, and also between average-achieving control participants and average-achieving experimental participants. An ANCOVA was then run to analyze the null hypotheses for the first and third research questions, revealing that there was no significant difference between posttest scores of the control and experimental groups when compared as whole groups. In addition, no significant differences were found between posttest scores of average-achieving participants in the control and experimental groups. Individual Mann-Whitney tests were used to examine the second and fourth research questions. The results showed that there were no significant differences between two of the subgroups (low-achieving control versus low-achieving experimental, high-achieving control versus high-achieving experimental) of the control and experimental groups.

Descriptors: mathematics instruction, math manipulatives, hands-on learning, middle school mathematics, math education

Dedication

I would like to thank God for giving me the opportunity and ability to take this journey, and for granting me the clarity and motivation I needed to complete the process.

To my husband, Justin, thank you for being so patient and supportive of me during this process. You are a wonderful husband and father, and I would not have been able to complete this goal without your help. I love you.

To my sweet girls, Morgan and Emory, thank you for being such precious gifts to my life. To Morgan, I have watched you grow from an infant to a young girl as I have worked to complete this task, and to Emory, you were a wonderful addition to our lives during the process. I love you both more than words can express. You will always be my greatest achievement.

To my mom and dad, Gary and Karen Morgan, words cannot express how grateful I am to have you as parents. Your constant providence and encouragement through my life has made me who I am. Thank you for instilling in me the drive and work ethic I needed to complete this goal.

I would also like to thank my colleagues and friends who have helped and encouraged me. To my committee chair, Dr. Constance Pearson, thank you for always being positive and encouraging. To my committee members, Dr. Gary Kimball and Dr. Deborah McAllister, thank you for your expertise and guidance. It has been a true blessing being able to learn from and work with you all.

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List of Abbreviations

Analysis of Covariance (ANCOVA)

Adequate Yearly Progress (AYP)

Concrete Representational Abstract (CRA)

Criterion Referenced Competency Test (CRCT)

National Assessment of Educational Progress (NAEP)

No Child Left Behind (NCLB)

CHAPTER ONE: INTRODUCTION

Background

Mathematics education has changed over time as educators and policymakers strive to produce more knowledgeable students in the area of mathematics. Emphasis has been put on math and science in an effort to raise national test scores and American student achievement in these content areas. Under direction of the United States Department of Education, the National Assessment of Educational Progress (NAEP) is given to select students in fourth and eighth grades to study the effectiveness of current mathematics instruction and evaluate student achievement (Lee, Grigg, & Dion, 2007). According to the NAEP report in 2009, though percentages of student achievement in mathematics had increased since past NAEP administrations, the study showed that only 26% of eighth-grade students tested were at a level considered proficient in the understanding of mathematical concepts (U.S. Department of Education, 2010). While proficiency indicates an average understanding and may be acceptable for some postsecondary jobs or educational paths, some careers will require more of an advanced knowledge base. Only 8% of eighth grade students obtained an above average level of achievement on the 2009 NAEP study, leaving more than half of students tested in the basic or below basic understanding level (U.S. Department of Education, 2010). This should be of concern to American people since today's students are the future leaders of the country, but may lack the skills and knowledge base they need to perform important jobs.

The aforementioned statistics prove a need for improvement in mathematics education in America. Part of this improvement may lie in the hands of educators and the

way in which they present and relay information to students. Continuous educational research needs to be done to investigate strategies and trends in teaching and learning that can benefit mathematics students. Traditional instruction, which involves direct instruction led mostly by the teacher, has been used by educators in the past and has been effective for some students in terms of computing mathematical problems (Battista, 1999). However, traditional-based teaching strategies do not always accommodate every learning style and do not teach students application of mathematics, that is, when to apply learned formulas and algorithms to real world situations (Battista, 1999). Therefore, the desire to reach more students and increase achievement levels of students has led to an interest of math educators to consider reform-oriented strategies. Reform-oriented strategies may include but are not limited to such methods as cooperative learning, peer tutoring, use of visual aids, and hands-on learning. These strategies, though currently in use, are supported by historical foundations in education, specifically by theorist John Dewey who believed learning derived from activity and real-life experiences (Gutek, 2005). Dewey supported interaction with objects around oneself to promote learning (Gutek, 2005). This philosophy fully supports the integration of hands-on learning and use of manipulatives in the mathematics classroom, as students are required to explore and literally handle learning tools that are intended to encourage learning and assist students in going from concrete to abstract understanding of mathematical ideas. This study is designed to evaluate the effectiveness of a model that aligns with Dewey's philosophy in comparison to another instructional model that leans more towards traditional mathematics instruction.

Problem Statement

Mathematics education is at the forefront of concern in America's public education system. Various strategies and methods are being implemented in classrooms to enhance instruction. The problem is that even with efforts to enhance student learning, most American students continue to be only at or below average in terms of mathematical achievement (Lee et al., 2007). Educators must gain a deeper understanding of factors that contribute to mathematical achievement and explore what types of instructional strategies influence student performance in mathematics. What may be effective for an individual student may not prove successful for another student. Furthermore, a strategy that produces positive results with a particular subgroup of students may not have the same effect on other subgroups.

Educational research in the area of mathematics that analyzes subgroups of students defined by performance level could provide more detailed data as to what strategies work best for particular groups of individuals. To contribute to the existing literature, a quasi-experimental design was used to study two groups of seventh grade students in North Georgia, one group who received more traditional instruction and one group who received instruction using hands-on activities and use of mathematics manipulatives. Results of the study were used to determine if there was a statistically significant difference in performance between the control and experimental groups. Furthermore, performance levels of students were considered when analyzing effectiveness of an instructional model to add to the existing literature in mathematics education. These results give insight into what types of instructional strategies prove successful for learners at various levels of mathematical performance.

Purpose Statement

In order to enhance student learning of mathematics, educators must gain a deeper understanding of and explore what types of instructional strategies positively affect the achievement levels of students in the area of mathematics. Several factors must be considered in the improvement of mathematics education but one facet that can be modified individually by teachers is the implementation of different instructional strategies. The purpose of this quantitative study was to evaluate the effect of a student-centered instructional model involving hands-on learning and manipulatives on student achievement of middle school students in mathematics. A quasi-experimental control group design was used to study two groups, control and experimental, of seventh- grade middle school students in North Georgia. The intent was to not only consider whether a statistically significant difference exists between two groups of students based on instructional model (hands-on learning and manipulatives versus traditional), but also to determine whether there is a statistically significant difference between subgroups of students defined by mathematics achievement level (low-achieving, average-achieving, high-achieving) based on the instructional model used to teach mathematics. Subgroups of low-achieving, average-achieving, and high-achieving seventh grade students will be analyzed to determine if a particular instructional model may be more suitable for each group depending on existing achievement level.

Significance of the Study

The use of manipulatives for math instruction may seem like a sure-fire approach, especially for students who are tactile kinesthetic or visual learners; however, research has actually shown mixed findings relevant to the strategy. Although many studies have

revealed that some manipulatives help some students under some conditions, several studies have shown no benefit of using them, and others have suggested the use of concrete objects may actually hinder learning (McNeil & Jarvin, 2007). The research on the topic of math manipulatives is complicated and must also be considered from another viewpoint. Though past studies may have alluded to the fact that a certain manipulative caused a particular child to understand a given concept, the idea cannot be generalized that all manipulatives help all children in all situations (McNeil & Jarvin, 2007). In essence, students are not always able to apply the knowledge gained from use of concrete objects to solve problems in writing unless they are reminded to think about the manipulatives, and even then it is not always successful. Some theories opposing the use of concrete, tangible objects to guide math instruction tend to devalue theories advocating their use. McNeil and Jarvin (2007) write that one reason why they may not be effective is that teachers can unintentionally misuse manipulatives, using them as a way to make an activity more appealing, rather than stressing it as a learning tool. When this is the case, students' actions feed off of the teacher's attitude and may see the objects more as toys rather than mathematical representations. Another theory suggests that though there is a positive aspect of manipulatives in math education through their ability to represent concepts in multiple ways, dual representation is not automatic and must emerge over time. Furthermore, another theory adds to the problem with dual representation by suggesting that since children have limited cognitive resources and dual representation is resource intensive, they may miss relevant concepts and appropriate procedures due to their focus on manipulating the object (McNeil & Jarvin, 2007).

This study was designed to identify if there was a difference in achievement

between a group of students who were taught a specific mathematics unit through use of hands-on activities, including the use of mathematics manipulatives and another group of students who received more traditional instruction with little to no use of manipulatives to enhance instruction. The daily routines, surroundings, and amount of required coursework of the two groups remained the same, which reduced the number of external variables that could have affected the results. This study was important to me as a math educator, as well as the other local educators that participated in the study. In this particular area in North Georgia, the instructional model used by the experimental group has been encouraged in mathematics classrooms; however, not all schools in each district have adopted the strategy. In order to effectively implement the strategy school-wide, financial and time resources would be needed. This study could help decision-makers in the schools to make a more informed decision about whether school-wide implementation of the experimental model would be wise. Furthermore, outside of school-wide implementation, it provides individual math educators with data that may improve their own teaching strategies.

In addition to providing helpful research for educators at a local level, the study helps fill the gap in literature about mathematics manipulatives as an instructional tool. The study focused on middle school students, particularly seventh graders who are in general education or inclusive classrooms, and took into consideration the existing mathematics performance level of students when making analyses. The data revealed in the study allowed more insight into the middle school student in reference to mathematical learning and helped determine whether existing performance level may have an effect on the effectiveness of a particular instructional model.

Research Questions

While conducting the study, the researcher found answers to the following research questions by evaluating data collected from the control group (participants who received traditional mathematics instruction) and the experimental group (participants who received mathematics instruction through hands-on learning with manipulatives):

Research Question 1: Will there be a significant difference in mathematics achievement of seventh-grade students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

Research Question 2: Will there be a significant difference in mathematics achievement of low-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

Research Question 3: Will there be a significant difference in mathematics achievement of average-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

Research Question 4: Will there be a significant difference in mathematics achievement of high-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

Research Hypotheses

Results obtained from the study addressed the research questions and either rejected or accepted the following null hypotheses:

H1₀: There will be no significant difference in mathematics achievement of seventh-grade students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction).

H2₀: There will be no significant difference in mathematics achievement of low-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction).

H3₀: There will be no significant difference in mathematics achievement of average-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction).

H4₀: There will be no significant difference in mathematics achievement of high-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction).

Identification of Variables

The independent variable in this study was the instructional model used to teach mathematics. The model for the control group was more traditional-based instruction without the use of mathematics manipulatives, while the model for the experimental group involved hands-on learning and manipulatives in mathematics education at least one time each week. The traditional model consisted of the same standards and objectives, but lacked manipulatives as a learning tool. The model utilizing hands-on learning and manipulatives involved more student-led instruction and student practice through manipulation of objects that represented mathematical scenarios or activities that involved a hands-on approach to learning, where students were guiding their own

learning based on tasks that required them to develop theories based on information given. For example, since students were completing a data analysis and probability unit, students in the control group (traditional instruction) completed activities and worksheets without accessibility to relevant manipulatives such as number cubes, colored discs, etc. In the experimental group (hands-on learning and manipulatives), students used appropriate manipulatives to represent situations described in the activities and tasks. The hands-on learning with manipulatives directly related to the lessons taught in the experimental group classrooms. Several manipulatives were used during the study depending on the objects described and referenced in the given activities. These manipulatives are defined in the lesson plans of the experimental classrooms, provided by the participating teachers (Appendix A). Students in the experimental group were educated about the purpose of the learning tools. The teachers who participated in the study had had experience teaching mathematics with and without the use of hands-on learning and mathematics manipulatives, so they were familiar with both models.

The dependent variable in the study was mathematics achievement of participating students, as measured by the teacher-made unit tests that served as the pretests and posttests. Both were aligned directly with state benchmarks and standards and were administered to both the control and experimental groups. When analyzing data to answer the research questions, achievement levels of students were classified as low-achieving, average-achieving, and high-achieving based on levels preset by the state of Georgia as level one, level two, and level three, respectively. These levels are determined from tests given in the mathematical concept areas of number and operations, data analysis and probability, algebra, and geometry for seventh-grade students (Georgia

Department of Education, 2010a). Using the descriptors provided in the Georgia 2010 CRCT Score Interpretation Guide, low-achieving students were those students who scored level one (did not meet the standards) on the math portion of the Georgia CRCT for the 2011-2012 academic year, signifying they showed limited conceptual knowledge of the four aforementioned domains. Average-achieving students were students who scored level two (met the standards) on the math portion of the Georgia CRCT, demonstrating adequate knowledge in the four domains. High achieving students included students who reached level three (exceeded the standards) on the math portion of the Georgia CRCT, proving to have an in-depth understanding of the previously defined concept domains for seventh-grade mathematics in Georgia (Georgia Department of Education, 2010a).

Definitions

Coin: A metal coin with 2 sides, a head and a tail.

CRCT: “An assessment designed to measure how well students acquire the skills and knowledge described in the Georgia Performance Standards. The assessments yield information on academic achievement at the student, class, school, system, and state levels. This information is used to diagnose individual student strengths and weaknesses as related to the instruction of the GPS, and to gauge the quality of education throughout Georgia.” (Georgia Department of Education, 2010c).

Number Cube: A six-sided cube, numbered 1-6, with one number on each side.

Playing Cards: A 4-suit deck made of 52 cards.

Spinner: A circular divided into equal parts with one clock hand used for spinning.

CHAPTER TWO: REVIEW OF LITERATURE

Mathematics is a critical component in today's educational curriculum. The National Council for Teachers of Mathematics (2010) holds that understanding mathematical concepts is essential for the development of mathematical competence. Students must grasp the fundamentals of mathematics before they can build on and transfer mathematical ideas. However, oftentimes, students lack understanding in this subject area and have negative attitudes about learning mathematical concepts. According to a standard of the National Council for Teachers of Mathematics, all students should have the ability to solve problems and make connections between mathematics and the real world (National Council of Teachers of Mathematics, 2010). Today's mathematics content and process standards provide the framework and strategies to give every student an opportunity to succeed in mathematics. Since all students learn differently and come from various backgrounds, it is unrealistic to assume that one method of teaching will be effective for every student.

Research by the U.S. Department of Education (2010) has shown that students in today's mathematics classrooms are struggling with understanding mathematical concepts. National testing of eighth-grade students in the area of mathematics resulted in less than half of students scoring average or above average in content knowledge (U.S. Department of Education, 2010). According to Lerner (2003), between six and seven percent of students in general education classrooms have characteristics of an arithmetic disability. Furthermore, according to Cass, Cates, Smith and Jackson (2003) citing the National Center for Education Statistics, a study from the Third International

Mathematics and Science Study in 1996 showed that 8th and 12th grade American students scored below the international math average. In order to enhance student learning of mathematics, educators must gain a deeper understanding of and explore what types of instructional strategies positively affect the achievement levels of students in the area of mathematics. Several factors must be considered in the improvement of mathematics education but one facet that can be modified individually by teachers is the implementation of different instructional strategies. According to Puchner, Taylor, O'Donnell, and Fick (2008), internal representations of mathematical ideas are what constitute mathematical understanding. Internal representations refer to the meanings that individuals assign to an idea or concept. External representations, such as math manipulatives, may be used to assist in internalization of concepts, but external representations do not assure internal representations.

This chapter provides a theoretical framework related to the use of mathematics manipulatives as an instructional tool. Existing literature is presented to provide the background of what has been done in relation to this topic, and a summary is provided to support the need for further research. For this study, a quasi-experimental study using a non-equivalent control group design evaluated the effectiveness of a particular hands-on instructional model, hands-on learning and manipulatives, to enhance mathematics instruction. A pretest and posttest was given to both the control and experimental groups to determine if there was a significant difference in student achievement based on the instructional method.

Conceptual or Theoretical Framework

The implementation of hands-on teaching strategies and particularly the use of

manipulatives to enhance the learning of mathematical concepts are characteristic of the constructivist theory of education. Instructional methods that revolve around constructivism call for students to take a lead role in learning, taking ownership for the ideas they derive and conclusions that they make. In contrast, in traditional mathematics teaching, students take more of an inactive role in the teaching and learning process, as the teacher typically imparts information to the students, while students then use memorization and repetition to master skills and concepts. Much of the exercise is rote and calls for little abstract thinking on the part of the student. Reform-based techniques such as the use of objects to support learning and activities that involve students experimenting and discovering findings require students to be more involved and engaged in their learning.

Based on the Southwest Consortium for the Improvement of Mathematics and Science (1995), many theorists have studied and developed ideas of the learning process based on the constructivist theory. As far back as the 18th century, Giambattista Vico supported the idea that humans can only clearly understand what they have themselves constructed. Vico believed that humans were not born rational and did not learn by being exposed to ideas; yet they had to take part in constructing the ideas themselves (Flint, 1884).

The 20th century brought the psychological theories of Jean Piaget. Piaget based his thoughts on the psychological development of children and believed the fundamental basis of learning was discovery and suggested that understanding is built step-by-step through active involvement. According to Piaget, children experience mental growth by using simpler concepts that they have previously learned to master higher-level concepts

(Miller, 2002). Since this idea required students to learn in stages, it supported Piaget's developmental theories of children and adolescents. Piaget described the developmental growth process of humans in four stages: sensorimotor, preoperational, concrete operational, and formal operational, as described by Miller (2002). The first stage, sensorimotor, occurs during the first two years of a child's life when he/she is occupied with his/her own physical actions and awareness of himself and other objects around him/her as a separate entity. The preoperational stage, ages two to six or seven, brings learning of how to represent objects with words and manipulate those words. This leads into the concrete operational stage and the beginning of logical thought processes. At this stage, when children are between the ages of seven and 12, they learn to recognize similarities and differences of objects and are able to classify them according to their characteristics. The final and most mature stage of development takes place at approximately 13 years of age and is termed as the formal operational stage. Adolescents and adults at this stage are able to order their thinking, master logical thought, and in terms of learning are able to work with abstract ideas and develop hypotheses.

Philosophies of John Dewey also tie into the constructivist movement and support the instructional method of hands-on learning and using math manipulatives to improve learning. Seen as a proponent of progressive education, Dewey felt that traditional education was too formal and narrow (Miller, 2002). He supported one of the main concepts of the progressive movement which focused on educating the whole child (Miller, 2002). In doing so, the child had to be an integral part of his/her own learning by being active in the learning process through discovery and active participation. Dewey elaborated on this belief to form a more clear idea of how the theory applied to the

classroom. Based on his studies, Dewey determined that education was dependent on activity and that experiences that students felt were relevant allowed knowledge to emerge (Southwest Consortium for the Improvement of Mathematics and Science, 1995).

The contributions of all three of the aforementioned theorists create a framework for the instructional use of hands-on learning and use of manipulatives in mathematical teaching which is characteristic of constructivism. Though Vico recognized it early on, Dewey's thoughts expanded on how progressive philosophical beliefs of education could be incorporated into the physical classroom. The classroom environment provides the social atmosphere necessary for cooperative learning and allows for manipulation of materials so students can explore and make connections between concepts and visual, concrete representations.

McNeil and Jarvin (2007) claim that interaction with manipulatives in early education can lead to an even greater understanding of abstract math as students progress into higher-level mathematics. This argument is validated by Piaget's theories of development and timeline of learning. At an earlier point in students' lives, certain manipulatives are appropriate and could possibly help form basic understanding of mathematical concepts if presented at the right stage of development. As a result, when students begin to grow and mental capacity expands, these fundamental mathematical concepts will be used to form more complex thought processes. According to McNeil and Jarvin (2007), the ideas of these early theorists still inspire teachers today to use manipulatives. Since students are able to actively participate in their learning, it is likely that a positive change in attitude towards the subject may occur and achievement will be enhanced. Contemporary research has also revealed evidence that justify the use of

concrete objects as learning tools for many teachers.

Review of the Literature

Mathematics skills are applicable inside and outside the school classroom. Struggles in math can present problems not only during school years, but also can interfere with functioning in adulthood (Cass et al., 2003). According to Tate (2006), mathematics skills in algebra, geometry, data representation, and statistics are now essential for all students, not just those attending postsecondary institutions. Workforce training programs now require these learning experiences also, so it is critical that students receive the rigorous mathematics education during their elementary and secondary years. Traditional classroom teaching of mathematics may no longer be the answer, as many students are falling behind in mathematics and those who are succeeding are not being challenged to prepare for upper-level courses after graduation or for leadership positions in the workforce (Tate, 2006). Since traditional teaching methods are now leaving many students uneducated in mathematical skills and leaving others short of what they could achieve if challenged, higher cognitive demand of mathematics must take place in classrooms, setting high expectations to enhance learning for all students. It is imperative that instructional strategies are identified that help students acquire, maintain, and generalize mathematical skills (Cass et al., 2003).

There are many factors that determine the success or failure of a student's learning. Some of these include the developmental and academic level of the student, the knowledge and teaching method of the teacher, adequate resources both at home and at school, and the attitude and outlook of the student. Some of these contributing factors are out of a teacher's control, but there are efforts that can be made by mathematics educators

to enhance student learning and create a more positive classroom experience for students. According to Stuart (2000), among the strategies advised by the National Council of Teachers of Mathematics, making math relevant is a significant practice that allows students to develop a connection with content. Using instructional strategies in the classroom that concentrate on real-world application rather than the memorization of facts and formulas can help students make connections and realize that learning mathematics is necessary. In turn, students may develop a better attitude towards mathematics and become more receptive to learning mathematics since they understand the concepts are beneficial to them. By helping students apply mathematical concepts to situations to which they can relate, the effort will also attempt to promote a more thorough understanding of mathematical concepts, rather than simply memorizing facts, and working problems on paper.

Anstrom (2007) reveals that instructional strategies should always include four major elements. They include student understanding, active and purposeful learning, linking new concepts and formal instruction to existing informal knowledge, and promoting discussion and reflection. Anstrom goes on to advise that math instruction specifically requires even deeper instructional techniques for all children, especially those with learning disabilities. Math instructors should provide a broad range of mathematical concepts that stretch beyond computation. Lessons should be rich and purposeful, and should involve students actively participating in their learning. Also, it is important to build on students' strengths and outside knowledge. Lastly, students should be encouraged to discuss and compare their ideas and examine their thought processes used to solve problems and make conclusions (Anstrom, 2007).

Based on the current standards set forth by the National Council of Teachers of Mathematics, students are now required to not only know concepts and apply formulas, but are challenged to internalize theories and concepts and apply them to real-world situations. With these types of standards, the use of traditional teaching methods in the mathematics classroom, characterized mostly by teacher-led instruction and minimal student exploration, lacks the element of student discovery and autonomy. Though there are elements of mathematics that must be memorized, a problem-centered approach can create a connection to the real world for more students more of the time (Kelly, 2006). The use of a more hands-on approach to learning may be necessary and provide the greatest opportunity for academic growth. This idea is supported by the constructivist learning theory which says that students learn through action and experiences (Southwest Consortium for the Improvement of Mathematics and Science Teaching, 1995).

Traditional mathematics teaching has been the primary instructional strategy in mathematics education for many years (Battista, 1999). These strategies focus on mastering mathematics computation through teacher demonstration and repetitive practice and homework by students, where students apply formulas and algorithms to solve problems. While this type of teaching may be effective for some students, Battista (1999) points out that approximately 60% of college mathematics enrollments are in courses that are typically taught in high schools and also states that businesses spend as much on remedial math programs for employees as is spent on math education in secondary schools, colleges, and universities combined. These statistics indicate that the instructional strategies that have been used in classrooms in the past may not be the most beneficial to students in the long-term. Though students may successfully calculate

answers and derive solutions at the current moment, they are not retaining the information and skills needed to apply mathematical concepts later in life.

Several factors have caused the rise in use of manipulatives for mathematics instruction in the past century (Moyer, 2001). Educational research that has been done on the topic of the connection between the use of physical objects and mathematical learning has helped persuade many classroom teachers, especially those teaching kindergarten through eighth grades, to attempt to implement this learning technique in their mathematics classes (Moyer, 2001). According to Moyer (2001), teachers play a critical role in creating a mathematics learning environment that exposes students to representations that increase their understanding and ultimately enhances their learning of mathematical concepts.

Cass et al. (2003) describe mathematics manipulative materials as concrete materials that are used to represent mathematical relationships, and includes materials such as geoboards, pattern blocks, chip-trading boards, counters, algebra tiles, attribute pieces, fraction bars, and Cuisenaire rods. Kelly (2006) goes on to define manipulatives as any tangible object, tool, or model that can be used to demonstrate a depth of understanding about a specified mathematical topic. According to The Access Center (2004), students who use concrete manipulatives gain a more precise and thorough representation and can make the ideas more applicable to the real world. Furthermore, use of concrete manipulatives promotes the long-term maintenance of mathematical skills (Cass et al., 2003). Exposure to an instructional model that utilizes hands-on learning and use of manipulatives may increase involvement with curriculum for students at any level and lead to a greater understanding of concepts. Integration of these learning

strategies requires transformation to a more constructivist-based classroom. Rather than a structured environment of teacher-led instruction and individual work, students are required to take more initiative and ownership of their learning, have time to reflect and respond through interaction with one another, are encouraged to think on a higher-level and make connections, and are allowed to complete activities that allow predictions to be made and hypotheses to be challenged (Southwest Consortium for the Improvement of Mathematics and Science, 1995). Lastly, resources such as raw data, manipulatives, and physical, interactive materials are used to relate concepts to real-world scenarios (Southwest Consortium for the Improvement of Mathematics and Science, 1995).

In a study done by Cass et al. (2003), students with learning disabilities in the area of mathematics were taught problem-solving skills for area and perimeter through modeling, prompting, and independent practice in conjunction with manipulative training. Results revealed that rapid acquisition of the skills took place and were maintained. The students also appeared to have gained ability to transfer from the use of concrete manipulatives to paper-and-pencil problem solving. Furthermore, Bouck and Flanagan (2010) suggest that the use of virtual manipulatives may also benefit students with high-incidence disabilities. While no research was found dealing directly with students with high-incidence disabilities and use of virtual manipulatives, they found positive research for the use of online virtual manipulatives in general education classes. According to Bouck and Flanagan (2010), virtual manipulatives are similar to concrete manipulatives, often having the same look and names, but they are accessed via the Internet or computer software. This interactive manner allows students to use multiple manipulatives at one time, and programs often provide prompts and feedback to guide

students. In addition, virtual manipulatives offer teachers the ability to differentiate instruction by selecting appropriate developmental level activities that can be completed by a student or group of students, while continuing a lesson on a different developmental level with other students (Bouck & Flanagan, 2010).

According to McNeil and Jarvin (2007), new theories supporting the use of manipulatives in math education include first, the idea that students have an additional resource to use and are then more likely to perform at optimal levels because of the access to multiple resources. Next, concrete objects used in math instruction can help children transfer practical, real-world knowledge. Third, physical action is induced with the use of manipulatives which has been shown to promote understanding and enhance memory according to past studies by Glendberg, Gutierrez, Levin, Japuntich, & Kaschak (2004) as cited by McNeil and Jarvin (2007). Based on these theories, it is not surprising that many teachers are convinced of the benefits of integrating use of manipulatives in math instruction and learning time.

Mathematics Education Reform

Reform-based mathematics education has slowly been considered by math educators and school districts as an answer to promoting mathematical learning of students. The goal to increase mathematical achievement of students within schools is no longer for the sole purpose of producing more knowledgeable individuals. Federal legislation has placed greater responsibility on school administrators and teachers by setting aggressive benchmarks that students must meet through standardized testing. The enactment of the No Child Left Behind Act (NCLB) of 2001 required schools to raise the bar for student performance in reading and mathematics (Georgia Department of

Education, 2010b). Under the Act, all states had to establish academic standards along with a testing procedure that met federal guidelines. The intent was to hold schools and educators, in particular, more accountable for the content they were teaching and for the way they were assessing students, in order to ensure student success. Annual evaluations of all state schools were established through a measure of Adequate Yearly Progress (AYP) (Georgia Department of Education, 2010b). With this implementation, schools now had to show accountability by proving that they had not only maintained, but increased student performance since from the previous school year. Annual increases in performance expectations called for constant research and student assessment on behalf of school administrators and classroom educators to ensure students would meet the standards set forth in the given academic year. With more rigorous standards in place and a higher demand for students to meet state testing benchmarks, school leaders and classroom teachers began to reevaluate existing practices and instructional strategies in order to promote higher student achievement, specifically in the areas of mathematics and reading. The need to be more effective in the classroom led to consideration of new instructional strategies.

Reform-based strategies include those supported by the National Council of Teachers of Mathematics that give students opportunities to solve complex problems, to read, write, and discuss mathematics, and to hypothesize, test, and construct mathematical ideas on their own. During this process, students may use visual demonstrations, drawings, and tangible objects to support and/or derive mathematical and logical arguments (Battista, 1999). They are not following a set procedure of rules, but

instead are drawing conclusions through active participation. This can lead to a broader understanding of mathematics.

With the benefits that can be produced by using reform-based instruction in mathematics education, the question could arise as to why all educators and school systems do not adopt the practice. Hesitation to stray from traditional instruction to more reform-based instruction is due to several factors including but not limited to lack of knowledge, standardized testing, and mixed findings of past literature on the topic of mathematics education.

According to Battista (1999), most adults today were taught mathematics using traditional methods. They were not exposed to reform strategies as students and have a difficult time adopting a different practice when teaching students. This can be due to the lack of knowledge about reform-based instruction and about mathematics in general. As discussed previously, traditional instruction can result in a superficial understanding of mathematics where formulas can be followed and answers can be found, but application cannot be made to real-life situations. Given that adults who are currently teaching mathematics probably received this type of instruction, they may have a minimal understanding of the concepts they are trying to relay to their students. This is problematic because educators cannot help guide students to a broader understanding of a concept if they do not possess the understanding themselves.

The other piece of lacking knowledge has to do with the unawareness of how to implement reform-based mathematics education in the classroom. In continuance with the point made above, if math teachers have only been exposed to one type of teaching, it should not be expected that they know how to effectively introduce another type of

strategy much different from the existing one without guidance and professional development. As stated by Battista (1999), this involves educating math educators, administrators, and parents about reform. A task such as this stretches beyond a select group of teachers and makes it difficult for school systems to implement true reform where all stakeholders are on board.

Another issue with implementing reform in mathematics education is the ever-increasing dependence on standardized testing as a measurement of student achievement (Battista, 1999). Standardized testing is a form of traditional assessment so educators are tempted to use traditional strategies to teach material that will most likely be on the test. It would be optimal if testing could be taken out of the equation when considering mathematics instruction and student achievement, but for most educators, this is nearly impossible because of the stress on teachers to ensure that all students pass standardized tests. Teachers may feel it is too great of a risk to teach using reform-based strategies when students will ultimately be tested using a traditional approach.

One element of reform-based mathematics instruction involves the use of tangible objects to solidify understanding of mathematical concepts, as mentioned previously. In the discipline of math education, these objects are referred to as math manipulatives. In addition to the aforementioned issues hindering reform, the use of manipulatives in the classroom also pose a dilemma due to mixed findings from previous studies. Literature shows both positive and negative ramifications of use of math manipulatives to improve understanding of mathematical concepts.

Two specific reform-based instructional models that support the idea of hands-on learning and use of manipulatives and multiple representations to increase understanding

are the Concrete-Representational-Abstract (CRA) approach (also known as Concrete-Pictorial-Abstract approach) and the Workshop Model according to The Access Center (2004) and The City College of New York (2006). While they differ procedurally, both methods encourage students to be actively involved in their own learning, promoting deeper understanding and ownership through active discovery of concepts and ideas.

Concrete-Representational-Abstract Approach

Based on information from The Access Center (2004), the Concrete-Representational-Abstract (CRA) approach involves three stages of learning including the concrete stage, the representational stage, and the abstract stage. At the first stage, concrete, teachers begin modeling each mathematical concept with tangible materials such as fraction bars or geometric figures. The representational stage follows and transformation takes place from the concrete model into a stage involving visual aids such as drawings. Students then move into the last phase, the abstract stage, where the teacher models the mathematic concept symbolically, using only numbers and mathematical symbols. This model differentiates instruction by presenting the same content in multiple ways. This model is supported by research that shows that students who use concrete manipulatives gain a more precise and thorough representation and can make the ideas more applicable to the real world (The Access Center, 2004).

There are several advantages to using the CRA model in the classroom. Steedly, Dragoo, Arafah, and Luke (2008) report that it is an instructional model that is applicable to all levels of learners, elementary through secondary, and it has also been proven to work well in various settings including individualized learning, small-group activities, and whole-group instruction. Another benefit of the strategy is that it is effective when

teaching students with disabilities (Anstrom, 2007). Increasing demands on mathematics place students with disabilities at an even greater disadvantage since they often have difficulty retaining information and recalling previously learned concepts. However, when students with learning disabilities develop understanding of a mathematical skill at the concrete level first, they are more likely to then be able to apply that skill and understand it conceptually at the abstract level (Anstrom, 2007).

Workshop Model

Standards-based instruction enriches content and causes students to think and perform on a higher level (The City College of New York, 2006). The Workshop Model is a standards-based strategy that can be used interchangeably with the CRA model, or on its own. It relates to the constructivist theory by giving students that chance to engage in relevant mathematical activities and interactions through questioning, exploration, and reflection. The City College of New York (2006) indicates that the structure of the model consists of three main components: the mini-lesson, work period, and closing. The mini-lesson begins the model each day and provides students with a brief instructional period that may involve introduction of new concepts, review of previously learned material, activation of prior knowledge, or discussion of expectations for a new activity. This stage can be modified to meet the needs of students each time it is used. The next stage, the work period, often includes the incorporation of small group learning, where students are required to investigate problems, assess data, and work towards a conclusion. The final step is the closing. Students basically become the teachers at this point when they present their findings and explain the process used to obtain results. The role of the teacher in this model is different from traditional strategies in that the teacher becomes

more of a facilitator, using probing questions to challenge students to think beyond factual information. As in the CRA model, this technique works towards transferring ownership of learning from the teacher to the student.

Previous Findings Regarding the Use of Manipulatives

Much of past educational research on the use of hands-on learning with use of mathematics manipulatives has focused on elementary classrooms and/or students with disabilities as demonstrated in studies by Cass et al. (2003), Bouck and Flanagan (2010), and Anstrom (2007). Fundamentals of mathematics are taught and established early in a child's education, so it is not surprising that early education teachers are more apt to use concrete materials to help students understand mathematical concepts. In a study by Moch (2001), the researcher used manipulatives to help reinforce and introduce mathematical ideas to a group of about 60, fifth-grade boys and girls. These students had been given a pretest which helped identify areas that needed improvement. The researcher found that the students were eager to learn using the manipulatives and experienced an average of 10% gain on the posttest over the same material. Moch (2001) pointed out that many teachers do not use manipulatives because they feel they are too time-consuming, given the amount of material that now has to be covered in an academic year prior to standardized testing. Moch argues that while use of manipulatives may take more instructional time than traditional instruction, the benefits of their use may be evident in years following due to less time spent on remediation of concepts that were not previously understood or mastered. She further expresses that many problems students experience with mathematics could be thwarted altogether if students were exposed to concrete ideas prior to abstract concepts. A greater understanding of fundamental

mathematical concepts is enough of a reason to consider using manipulatives as learning tools, but research by Cain-Caston (1996) shows even greater advantages. In a study, third graders in an experimental group who were taught using math manipulatives, rather than worksheets, outperformed their peers in the control group, scoring two grades above grade level while students in the control group scored on grade level. Based on the results of the study, both forms of mathematics instruction seem to produce positive results as all students showed evidence of being on grade level, however the use of math manipulatives could be the factor that enhanced student performance for students who tested above grade level. Rather than solving mathematical problems based solely on procedure and algorithms, manipulation of objects to solve mathematical ideas promotes critical thinking and may result in a deeper understanding of concepts. At every level of mathematics, rising standards have encouraged the development of higher-level thinking skills. At the elementary level, this includes fluency and flexibility with numbers (Kelly, 2006). According to Kelly (2006), use of manipulatives in elementary classrooms provides a performance-based option for assessment of problem solving.

Reform-based teaching of mathematics involves an active approach to education using hands-on activities and use of tangible objects (manipulatives) to increase understanding. Mixed results can be found in past studies regarding the implementation of reform-based mathematics in classrooms. In a three-year study performed by Alsup and Sprigler (2003), traditional and reform curricula were evaluated using eighth-grade students' SAT scores. During the first year, a traditional curriculum was used; the second year, a reform-based curriculum was used. During the third year, a combination of the two was utilized to teach mathematics. Results indicated that students performed at a

higher level when taught using the traditional curriculum, followed by a combination of the two instructional strategies. Students' scores showed that performance was lowest when reform-based instruction only was used to teach mathematics. The study, as with any study, had limitations and could not be generalized, especially considering the group of students being studied changed from year to year. However, the study did indicate that using only a reform-based instructional model may not be the best answer to promote performance for all students. When a combination of methods was used, results were better (Alsup & Sprigler, 2003). These results support the idea of differentiating instruction to reach more learners by teaching the same idea in multiple ways.

Though literature has shown the effective use of manipulatives for mathematics instruction, several other studies indicate that they may not be the answer to enhancing mathematics instruction for all students, especially those with limited cognitive resources, as described in a study by McNeil and Jarvin (2007). While results may differ, depending on the use of manipulatives and what objects are used in learning environments, a positive correlation has been found in past studies between their use and later development of mental mathematics, achievement, and understanding (Green, Peil, & Flowers, 2007). It seems that if they produce a better conceptual understanding, manipulatives would be used by mathematics educators and pre-service teachers. However, that is not the case. According to Green et al. (2007), one reason may be that teachers feel they are enjoyable to students, but are not necessary for teaching and understanding of mathematics. A demonstration of their effectiveness was proven for pre-service teachers in a study conducted by Green et al. (2007), where undergraduate participants underwent an elementary education mathematics course that focused on

using manipulatives to teach basic operations of mathematics. Action language was used along with the manipulatives to cue participants about which operations would be appropriate for the current scenario. For example, to cue for addition, teachers used the phrase “joined with” and used “sets of” to cue for multiplication. These phrases, along with others, were modeled by the instructors throughout the process to guide the students, along with the use of manipulatives. Results revealed that the undergraduate, pre-service teachers benefited from the treatment, having many past misconceptions about mathematics clarified and resolved (Green et al., 2007). The relevance of this study shows that even later in their educational career, students can benefit from the use of concrete objects as learning tools for mathematics.

Hands-on teaching methods such as the use of manipulatives can be very appealing to educators. While they may involve a novel and interactive way of instructing, teachers need to ensure that any technique used to teach creates a deeper understanding of the subject matter. Otherwise, the method has just become an entertaining activity, rather than a learning activity. When using strategies that involve hands-on methods, particularly learning tools such as math manipulatives, it is critical that these methods are used to teach new concepts or reinforce skills with which students may be struggling. To measure effectiveness, teacher reflection is important to determine if student learning actually progressed. If learning tools do not help in the learning process, they should be eliminated from use. In a qualitative case study performed by Puchner et al. (2008), participating teachers found mixed results when implementing manipulatives in their lessons and realized that other factors play a role in the successfulness of using manipulatives as learning tools.

Puchner et al. (2008) studied 23 teachers in kindergarten through eighth grade who had all received professional development in the use of manipulatives to enhance classroom instruction. Of these teachers, in grade levels three, six, and eight, some experienced positive results, but most also experienced issues of concern. In a third-grade lesson, when given the opportunity to demonstrate place value in multiple ways, teachers found that students depended heavily on a teacher-made poster and made their representation the same as the one on the poster. In response, the third-grade teachers decided to remove the poster and try the activity again, hoping to encourage the use of base 10 blocks, which serve as appropriate mathematics manipulatives for the concept that was being taught. However, teachers were disappointed even in their reteaching efforts because students did not choose to use the blocks in their demonstrations. The teachers felt the reason was because students failed to make the connection between the blocks and the concept that was being presented.

In the same study by Puchner et al. (2008), in a lesson at the sixth-grade level, students were asked to demonstrate the multiplication algorithm using base 10 blocks, decomposition, and arrays. In this case, all students chose to use the base 10 manipulatives, which made group presentations redundant, according to teachers. In reteaching, teachers chose to require students to solve the problem differently than their partner and did a gallery presentation rather than oral group presentations. The eighth-grade students were asked to use interlocking cubes to help answer a word problem posed to them. While manipulatives did seem to help some students solve the problem, the teachers felt that the manipulatives were given out too soon in the process which limited independent thinking time, and in turn, may have hindered the learning process.

In conclusion, there were successes to some extent, but this study alone shows the importance of using appropriate manipulatives at the correct time, and indicates that the implementation of hands-on activities and use of math manipulatives is a process that cannot be done instantaneously. Students must be taught how to use learning tools to benefit their understanding, while teachers must continuously monitor student work and progress to ensure the tools are serving the purpose they were intended to serve.

Effective Use of Manipulatives

The instructional methods of many teachers have been influenced by how they learned a concept, usually through an abstract word problem or algorithm written on a chalkboard (Kelly, 2006). Though the research on use of manipulatives in math instruction has revealed pros and cons, Kelly (2006) recommends that teachers make informed decisions and use manipulatives minimally that are highly concrete and highly familiar to children in nonschool contexts such as toys. The following actions should also be taken for effective introduction and implementation of manipulatives to enhance mathematical ideas (Kelly, 2006):

1. Clearly set and maintain behavior standards for manipulatives.
2. Clearly state and set the purpose of the manipulative within the mathematics lesson.
3. Facilitate cooperative and partner work to enhance mathematics language development.
4. Allow students an introductory timeframe for free exploration.
5. Model manipulatives clearly and often.
6. Incorporate a variety of ways to use each manipulative.

7. Support and respect manipulative use by all students.
8. Make manipulatives available and accessible.
9. Support risk-taking and inventiveness in both students and colleagues.
10. Establish a performance-based assessment process.

Effective use of manipulatives by students involves work on behalf of the mathematics educator. According to Kelly (2006), teachers must first know when, why, and how to use math manipulatives to allow learning through exploration with concrete objects. Next, teachers must introduce and refer to manipulative objects as tools, so students will understand the objects are to be used for learning rather than playing. In addition, behavior expectations during the use of manipulatives must be clearly expressed and modeled to develop a respectful knowledgebase about using the tools for mathematical learning. Also, manipulatives need to be modeled often and directly by teachers to help students understand their relevance to the lesson. Finally, continuous use of manipulatives is needed in order to be most effective in the classroom (Kelly, 2006). Review of the literature on use of math manipulatives reveals that they are used more at the elementary level than in middle and secondary schools. While the use at a younger age can be beneficial, students who become accustomed to learning mathematics using concrete objects may suffer in higher level math courses due to the absence of these learning tools. Furthermore, if they are not used consistently, year after year, students are not as likely to view the manipulatives as learning tools, which can cause setbacks with their use in the classroom.

Moyer (2001) conducted a study on 10 middle school mathematics teachers over the period of one year and obtained qualitative data to examine the frequency at which

they used manipulatives in their lessons and the particular manipulatives they used, along with how they used the manipulatives to enhance the lesson. Results showed that though the frequency of use varied, a variety of manipulatives were used in all of the teachers' classrooms, on an average of approximately seven minutes out of a 57-minute lesson. In half of the 40 lesson observations, manipulatives were used during instruction. Most of the instructional time was teacher-directed with students using the learning tools as directed by the teacher. Other uses of math manipulatives included enrichment activities or games when there was additional time at the end of the lesson. The purpose of the manipulatives for the participating teachers consisted of assistance with problem solving, enrichment, to provide a visual model, to reinforce concepts, and as a fundamental, concrete way to demonstrate a concept and then move on without the use of it (Moyer, 2001). All of these uses are sufficient, but several of the participating teachers often described the use of the manipulatives as a fun way to teach, and also used the tools to reward good behavior. A possible problem with both of these actions is that students may then begin to view manipulatives not as a tool to aid their learning, but instead as a toy or optional activity. For teachers, thinking of manipulatives in this way does not necessarily change their method of instruction because students are not making connections between what the manipulatives represents and the abstract mathematical idea.

Contribution to the Body of Literature

Studies have been conducted that evaluate traditional and reform-based instruction with helpful results that have contributed to the literature of mathematics education. In reviewing the existing literature, an abundance of information was found

about the use of manipulatives in teaching mathematics to elementary-aged students and/or students who have learning disabilities. This study contributes to the literature by focusing on middle grades classrooms, specifically seventh-grade inclusion and general education classrooms, and by considering existing performance levels and attitudes towards mathematics to determine if they had an impact on either instructional model used in the study.

Middle School Student

This study helps to fill the gap in literature in several ways. The subjects of the study are middle school students, specifically seventh-grade students within the age range of 12 and 14. Adolescents at this age undergo many physical, mental, and emotional changes that make the middle school learner unique from students of other ages. Sousa (2008) reports that in the adolescent brain, processes that control voluntary behavior are not fully operational. This factor explains the spontaneous and erratic behavior of teenagers both inside and outside of the school environment. With regard to learning, one should look particularly at the changes that take place in the preadolescent/adolescent brain to consider the best alternatives for teaching these students. According to Sousa (2008), the brain evolves sporadically and different parts of the brain develop at different rates. The brain activity of adolescents should be analyzed when determining the most effective teaching strategies for middle school students, particularly eighth-grade students.

To understand the learning process that adolescents may undergo, one should first consider the preadolescent brain and the changes experienced in the years prior to the adolescent stage. Preadolescent children between the ages of six and 12 experience

physical changes within their brain that affect how and what they learn. The parts of the brain that control basic functions develop early beginning with sensory and motor functions, so a multimodal approach to teaching may enhance student learning while other areas of the brain continue to develop (Sousa, 2008). Areas of the brain that control skills such as problem solving, reflection, and analysis develop later, so multi-step problems, though doable, may be challenging for many students (Sousa, 2008). Considering this information, hands-on learning and use of manipulatives at the elementary level could produce both positive and negative outcomes. This type of instructional strategy involves multiple representations which would support a multimodal approach but it also requires more working memory to try to make the connection between the concrete and the abstract, which could be difficult for preadolescent students, as previously stated. Nonetheless, mastery of fundamental skills at a younger age requires less working memory over time because students do not have to relearn concepts they have already been exposed to while also trying to grasp newer, more complex mathematical ideas. While the use of concrete objects and allowance of students to develop their own algorithms may seem burdensome for them at the time, deeper understanding through use of these instructional methods could allow for easier transfer of algorithms from one mathematical situation to the next.

Scientists have found that the brain grows in size and the volume of gray and white matter in the brain increase continuously from childhood to puberty (Sousa, 2008). Therefore, students should be able to solve problems of increasing complexity as they pass through higher grade levels in school. This evidence of physical change in the brain supports Piaget's stages of development and also supports the notion that educators must

take into account what students' bodies are undergoing in order to be able to help them reach their fullest potential. Sousa (2008) concludes that as adolescents mature, their brains also do and they begin to distribute tasks to more specialized areas of the brain which reduces the amount of stress on the brain as a whole. The same level of performance can be achieved with less effort on behalf of the brain. Working memory, however, still matures slowly so while adolescents have the ability to think inductively and deductively, overworking the frontal lobe, the area of the brain responsible for producing working memory, can lead to impulsive and irrational response during problem solving (Sousa, 2008).

One psychological characteristic preadolescents and adolescents share is the search for novelty, which becomes more intense as children change into older adolescents (Sousa, 2008). The curiosity that comes with a new challenge or the conclusions that are drawn from a new experience draw adolescents into the situation. When learning mathematics, novelty can be present or void depending on the strategies applied by the teacher. This is not to say that teachers should find a new way to teach everyday for every lesson nor is the idea implying that only the newest and most entertaining techniques should be used in all classrooms. Practice is necessary for mastery and understanding of mathematical operations, but requiring students to continue to perform skills that they have previously mastered just for the sake of repetition, as is sometimes done in more formal approaches to teaching, may have a negative effect on the engagement of students. At the same time, though hands-on learning and use of manipulatives can provide students with a novel experience, these strategies can also

become mundane if students are not given guidance throughout the exercise or if learning tools are being used by students more for entertainment than for learning.

With the brain research presented, it is evident that students of different ages have different abilities to process information. Conclusions found in studies conducted on younger students cannot be generalized to older students who are at a more complex stage of development and who are learning concepts that are at a higher-level than those learned in elementary years. This study will help contribute to research about the use of manipulatives to teach seventh-grade concepts.

Inclusive Environment

The participants in this study were in an inclusive environment. Therefore, the study evaluated pretest and posttest scores of general education students along with students that have disabilities. There is no doubt that students with learning disabilities can require more support and various instructional strategies in order to experience success in their learning. Studies by Cass et al. (2003), Bouck and Flanagan (2010), and Anstrom (2007) showed that hands-on learning and the use of manipulatives can produce positive results for students with disabilities. However, general education students do not always experience the same difficulties as students with disabilities so applying results that were found when evaluating only students with disabilities to students who do not have disabilities would not be reliable. Given the inclusive environment, this study will add to the existing literature on the topic of hands-on learning and use of math manipulatives.

Student Achievement Levels

It is evident in any chosen classroom that all students do not perform on the same level and do not process ideas in the same manner. Among the sample of general education students that were studied, there were some students who are more advanced than the average student in the area of mathematics. Considering multiple achievement levels will also help fill a gap in the literature since it is unlikely that one instructional strategy could improve all students' mathematical performance. For this reason, achievement levels need to be considered when evaluating the effectiveness of a particular instructional strategy that is intended to increase mathematical achievement of students.

Individuals who perform above average can often be overlooked in mathematics classrooms because it is assumed that they understand curriculum in greater depth and at a faster pace than other students. Rongel and Fello (2004) stated that mathematically-talented students are often able to solve problems with atypical speed and accuracy, no matter what skill is required. These skills may be computational, problem-solving, inferential thinking, or may involve deductive reasoning, but still above average math students are able to attain correct solutions. While this may be true, brighter students have needs of their own that should be met to help them reach their fullest potential. According to Sheffield, cited in Rongel and Fello (2004), gifted math students usually are more interested in why and how mathematical ideas work, rather than how to solve problems through calculation. An instructional strategy that broadens understanding and allows for development of their own conclusions could lessen frustration that talented math students may experience, and at the same time may challenge them to help them

reach a higher potential. Battista (1999) describes an above-average high school student who was two grade levels ahead of her peers in math and excelled at math computation, but could not decipher when to use appropriate formulas and concepts to solve everyday problems. Part of this lack of knowledge could be due to the traditional instruction she had received that had not allowed her to think outside of a set of rules. Allowing gifted students an opportunity to explore how mathematical concepts are derived and test them in a classroom setting using illustrations, tangible objects, and other hands-on resources may enhance their understanding.

Summary

In addition to contributing to the current body of literature about the use of mathematics manipulatives to increase middle school student performance, the study provided beneficial information to schools considering adopting instructional models that involve hands-on learning and use of manipulatives in mathematics education. Implementation of new programs and curriculum can be costly for individual schools and school districts. Educational research can provide helpful information to school leaders and allow them to weigh the risks and possible improvements before committing to a particular plan of action. As with any instructional model, and as shown in the literature relating to mathematics manipulatives, proper use and implementation of the learning tools are critical to effective learning. Future studies of the use of manipulatives in the mathematics classroom should focus directly on the appropriate use of the learning aids. Previous studies have shown pros and cons to using manipulatives in the classroom, but a more accurate representation would be to evaluate the effect manipulatives have on student learning when they are used to specifically represent mathematical ideas

concretely, not just to serve as objects that will catch students' attention or make the activity more appealing to students. Research has shown that many teachers use manipulatives for this reason, and unfortunately, that should not be the purpose of implementing them in the classroom. Past studies that have identified this misuse are valuable because they make mathematics educators more aware of how to use them in a way that will benefit learners. They also benefit educational researchers by revealing a problem area that could use further research and focus.

Mathematics is used everywhere and is a life skill that is used daily inside and outside the classroom. The mastery and understanding of mathematics concepts is essential. Therefore, mathematics educators must try to evaluate the needs of students and be willing to try to implement techniques that will help them reach their highest potential. Using a hands-on approach with the use of manipulatives to allow students to understand concepts at various representational levels may be one of these techniques. The results of this study help fill the gap in educational research that focuses on middle school mathematics and the use of hands-on learning and mathematics manipulatives as instructional methods. Furthermore, it gives more insight as to how students' existing performance levels may affect the effectiveness of a traditional-based instructional model and a hands-on model with use of mathematics manipulatives.

CHAPTER THREE: METHODOLOGY

The purpose of this study was to determine if there is a statistically significant difference in student achievement, as measured by administration of a teacher-made unit pretest and posttest, between students who were exposed to an instructional model utilizing hands-on learning and manipulatives and students who were taught using more traditional-based teaching (without the use of manipulatives). In this chapter, methodology is described including how the study was carried out, an overview of the study, a description of the participants of the study, the data collection process, and data analysis procedures.

Design

A quasi-experimental study was conducted to evaluate pretest and posttest scores of seventh-grade mathematics students from a middle school in Northwest Georgia who were taught a mathematics unit using two different instructional models for mathematics instruction. A non-equivalent control-group design was used since students were not randomly assigned to the groups and since both groups completed a pretest and posttest (Gall, Gall, & Berg, 2007). Participants could not be randomly assigned to the control group and experimental group due to predetermined class scheduling. Both groups had a pretest and posttest conducted in order to evaluate difference in achievement between the groups. As indicated by Gall et al. (2007), a threat to internal validity in this type of study is that differences shown on the posttest could be a result of pre-existing differences of the groups prior to the study, and not necessarily the treatment itself. In order to reduce the effects of initial group differences on the results produced by the

study, a pretest served as a covariate which strengthened the experiment by removing an extraneous variable that could have a direct effect on the dependent variable (student achievement) (Ary, Jacobs, Razavich, & Sorensen, 2006).

Questions and Hypotheses

The study specifically attempted to answer the following research questions:

Research Question 1: Will there be a significant difference in mathematics achievement of seventh-grade students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

H1₀: There will be no significant difference in mathematics achievement of seventh-grade students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction) while controlling for initial group differences in mathematical achievement.

Research Question 2: Will there be a significant difference in mathematics achievement of low-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

H2₀: There will be no significant difference in mathematics achievement of low-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction).

Research Question 3: Will there be a significant difference in mathematics achievement of average-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

H3₀: There will be no significant difference in mathematics achievement of average-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction) while controlling for initial group differences in mathematical achievement.

Research Question 4: Will there be a significant difference in mathematics achievement of high-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

H4₀: There will be no significant difference in mathematics achievement of high-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction).

Participants

The target population of the study was middle school mathematics students in the United States. Since it is neither possible nor feasible to gather data from every middle school student in the country, a sample of participants was chosen. Convenience sampling was used due to location and my familiarity of the school that hosted both the control and experimental groups. The school identified for the study was the researcher's workplace. Because of experience with the participating school, she was familiar with the site and everyday operations of the school setting. As recommended by Gall et al. (2007), the researcher has provided a careful description of the sample, so that an inference can be made about generalization of the results obtained from the study.

The sample consisted of two groups of seventh-grade mathematics students from a middle school in Northwest Georgia. The participating school has approximately 700

students enrolled with the following demographics: 630 Caucasian, 28 Black, 14 Hispanic, 14 Asian, and 14 multiracial. Approximately 61% of students attending the participating school receive free and reduced lunch. The sample was chosen based on enrollment records for the 2011-2012 school year. Classrooms were already intact prior to the study, so selection threat to validity was a possibility (Ary et al., 2006). In order to help control this internal threat, homogenous groups were used. An analysis of covariance was also used to control the variable of initial differences that were found within some of the groups (control versus experimental and average-achieving control versus average-achieving experimental) (Ary, et al., 2006). Participants included 145 male and female mathematics students in the designated grade level. The experimental group, those receiving instruction with the use of manipulatives, consisted of 80 students including 34 females and 46 males eight of whom were inclusion students who were accommodated by an Individualized Education Plan. The control group was made up of 65 students including 32 females and 33 males. Twelve of these students were inclusion students. The study was designed to make the control and experimental groups as homogenous as possible with the given sample in order to evaluate the effectiveness of use of manipulatives between a whole control group and whole experimental group. To create even more homogenous groups, subgroups were created when analyzing data, based on performance levels established by the Georgia Criterion Referenced Competency Test (CRCT). The CRCT is given in the areas of English/language arts, reading, mathematics, science, and social studies each academic year to Georgia students in grades one through eight. Scores from the mathematics portion of the 2011-2012 CRCT were evaluated to form subgroups of participants based on achievement levels in

mathematics for data analysis. Predetermined levels of achievement, determined by the Georgia Department of Education, reveal whether a student does not meet (level one), meets (level two), or exceeds (level three) the standards for each academic subject. For this study, students who at scored level one were referred to as low-achieving, students who scored at level two were considered average-achieving, and students who scored at level three were described as high-achieving in the content area of mathematics. The students in both the control group and experimental group were considered together (hands-on learning with manipulatives versus traditional instruction), then were considered within subgroups based on existing mathematics achievement levels (low-achieving hands-on with manipulatives versus low-achieving traditional instruction, average-achieving hands-on with manipulatives versus average-achieving traditional instruction, high-achieving hands-on with manipulatives versus high-achieving traditional instruction) to further analyze the data. Forming subgroups based on performance level not only provided useful knowledge for educators in regards to effectiveness of use of manipulatives with certain ability levels, but also helped existing ability level as an extraneous variable that could have affected the results of the study.

Setting

The study was conducted in a Northwest Georgia middle school. The school was chosen due to convenience for the researcher and more importantly, the ability it provided for the researcher to conduct the study in the way she saw most fitting to produce useful data. Nine seventh-grade classrooms were the setting for the study with four participating teachers. The classes were made up of general education and inclusion students, and all had less than 30 students per class. Teacher A taught two mathematics

classes each day; teacher B taught three each day; teachers C and D taught in an inclusion setting four periods each day. Each teacher taught half of his or classes using a more traditional-based model, while the other classes received instruction with use of mathematics manipulatives. Therefore, there were 5 classes that made up the experimental group and 4 classes that served as the control group. All students within a given class received the same type of instruction. By having each teacher teach both models, it helped limit extraneous variables affected by the individual teacher, which could affect the study.

The setting was a sixth- through eighth-grade middle school. School leaders included one male principal supported by two male assistant principals, along with a strong academic coach who was involved in the process of helping the researcher obtain information needed for the study. All participating teachers also had at least 3 years of teaching experience in the area of mathematics.

The independent variable in the study was the instructional model being used to teach mathematics, in this case a hands-on approach with use of mathematics manipulatives. The control group received more traditional instruction with no exposure to mathematics manipulatives. The experimental group received the treatment, an instructional model involving hands-on learning and manipulatives at least one time each week. The classroom setup and materials for all classes were similar during the study. For the duration of the study, desks were arranged in rows in all classrooms, except during the activities that may have required partnering or grouping with other students. When cooperative learning was used, all classes participated in this type of arrangement and instruction. Each classroom used in the study contained an interactive whiteboard,

but was used mainly for video presentations during lessons in order to minimize technology as an extraneous variable. When the boards were used, they were used for all classes, control and experimental groups alike.

Instrumentation

The focus of the study was to determine whether the use of hands-on learning and manipulatives has an effect on student performance as measured through results of a teacher-made mathematics unit pretest and posttest administered to both groups of participants. Using a pretest and posttest measurement method allowed the researcher to evaluate gains made among each of the groups after the unit content has been presented to both the control and experimental groups. A teacher-made, curriculum-based, unit test that focused on the content standards taught during the four week period was used. The content of the test was based on the curriculum map provided by the state of Georgia, as specific mathematics standards are taught at a designated time during the school year. The content of the pretest and posttest was based on seventh-grade standards set by the state of Georgia, including specific material that was covered during the duration of the study. There were 20 multiple-choice questions (Appendix B) measuring knowledge of the seventh grade standards that fall under the domain of data analysis and probability for the state of Georgia. The concepts included simple probability, independent and dependent events, tree diagrams, and fundamental counting principle. Expert validation was conducted on the pretest and posttest to increase the content-related validity of the instrument which analyzes whether the test is a representative sample of the domain that is being measured (Ary et al., 2006). Four certified educators reviewed the questions on the test. All of these reviewers have a background teaching mathematics and are

presently mathematics teachers or math coaches in the state of Georgia. A Cronbach alpha coefficient was also calculated using MiniTab statistical software once data was gathered to determine the reliability of the testing instrument. A coefficient of .70 was desired in order to accept reliability, and the coefficient calculated from the data was .7054 when considering all 20 questions, proving the instrument to be a reliable form of measure. Results from this test are included in Appendix C of this manuscript.

Scoring of the tests was done by the researcher. The pretest and posttest consisted only of multiple choice questions, so correct answers were predetermined and objective, leaving no room for subjectivity during the grading process. Scores were calculated as the number of correct answers divided by the number of total questions, multiplied by 100. This will give a percentage of accurate responses for each student. A scale from 0 to 100 will be used with 100 points representing a perfect score and signifying that all questions were answered correctly.

The pretest and posttest that were administered to both the control group and the experimental group were multiple-choice unit tests that are aligned with Georgia state learning standards. Since both groups were students of the same Georgia school, they were exposed to the same content and had to meet the same learning objectives during the academic year.

Procedures

Prior to conducting the study, the researcher obtained permission from the Institutional Review Board of Liberty University. Once the approval was granted, the researcher secured permission by the school administrator to use the facility and teachers and students for the study. The contact was through a face-to-face meeting.

Furthermore, the researcher met with the participating teachers to ensure that the researcher understood exactly what type of instruction would be conducted on a daily basis for the control and experimental groups of students and to establish a system for constant communication during the study that would be convenient and consistent. On-going communication with the participating teachers increased the validity of the study by ensuring that the results obtained through the study were a true measure of what the study was designed to evaluate. Furthermore, since the researcher is employed at the participating school, she was able to ensure consistency of treatment that minimized the implementation threat to validity by ensuring that a qualified, single individual was overseeing the implementation at the school and that treatment was being followed exactly as intended by the researcher (Gall et al., 2007).

Once approvals were granted, the researcher identified the sample of students that served as the participants. As mentioned previously, the students were all seventh-grade mathematics students. Since the researcher was an employee of the participating school, to increase validity, the researcher was not a participant in the study. Students in the experimental group were chosen based on their class schedule and included students in general and inclusion mathematics classrooms. Students served in a resource setting would have brought additional extraneous variables that could have affected the results of the study so they were excluded. Based on legal class size requirements defined by the state of Georgia, resource classes are typically much smaller creating a smaller student-teacher ratio (Georgia Department of Education, 2010d). This variable alone could have significantly impacted results since more one-on-one time would have been available to these students.

Prior to data collection, the IRB guidelines and procedures of Liberty University were followed and completed. Data collection started as soon as details of sampling were worked out. The researcher began gathering data from the school on participating students' 2011-2012 CRCT scores, as soon as they were available. The academic coach from the participating school provided the researcher with a spreadsheet that included 2011-2012 math CRCT scores for the participating seventh graders. Names of students were removed and replaced with numbers prior to sending the information to the researcher to uphold confidentiality. Mathematics CRCT scores from the 2011-2012 academic year were collected and used to form subgroups of students: low-achieving, average-achieving, and high-achieving. The state of Georgia's predetermined levels of achievement on standardized testing were used to classify students into subgroups of level one, level two, and level three, as described in Georgia's 2010 CRCT Score Interpretation Guide (Georgia Department of Education, 2010a). Performance levels are based on knowledge of four content domains including number and operations, data analysis and probability, algebra, and geometry. Level one indicates that students did not meet the set standards for a particular grade level and content area. According to the Georgia Department of Education (2010a), in seventh-grade mathematics, students performing at this level have limited conceptual knowledge of the four content domains. Level two indicates that students did meet the standards, exhibiting adequate knowledge of the four content domains presented in seventh-grade mathematics. Level three indicates that students not only met, but also exceeded the set standards for a given grade level and content area. Students at this level showed in-depth understanding of the four concept domains set forth in Georgia's seventh-grade mathematics standards (Georgia

Department of Education, 2010a). For this study, level one students were considered low-achieving, level two were average-achieving, and level three represented high-achieving students in mathematics.

Participating teachers were chosen based on convenience, experience, and their current positions within their schools. All teachers were certified seventh-grade mathematics teachers with 3 or more years of experience in teaching mathematics, who were accustomed to administering pretests and posttests as a measure of student achievement and progress. Prior to implementation of the treatment, the participating teachers administered a teacher-made unit test that served as a pretest for all of the participants in the study. The pretest was multiple-choice and was graded by the researcher. Participating teachers administer the tests and collected them from students. The researcher will collect the tests in the following days, once as many students as possible have taken it. Since it would not have been an accurate measure of prior knowledge if pretest were given once the unit had been introduced, students that were absent or unable to take the pretest on the date it was administered were excluded from the study. Once the researcher received all of the pretests from the control and experimental groups, they were scored and pretest scores were recorded for all participants by the researcher in an Excel spreadsheet, as seen in Appendices D and E.

The curriculum chosen for the study was a unit on data analysis and probability. Instruction was based on the particular content and state standards required by the state of Georgia, and took approximately 4 weeks to complete. The control group received more traditional-based instruction and the experimental group received instruction involving hands-on learning and use of manipulatives at least once each week. Though the

instructional method differed, students were taught the same content standards, set forth by the state of Georgia. Content standards relevant to the domain of data analysis and probability taught during the study included simple probability, independent events, tree diagrams, and fundamental counting principle. Specific lesson plans including activities used were provided to the researcher by the participating teachers and are included in Appendix A of this manuscript. During instructional time and work time for students in the experimental group, manipulatives relevant to the lesson were provided to the students. These included fruit loops cereal, number cubes, colored chips, playing cards, and spinners. At the end of the unit, a posttest was given to all participating students by the participating teachers. The posttests were collected and graded by the researcher. Posttest scores were then recorded by the researcher in an Excel spreadsheet (Appendices D and E) and data analysis began based on the pretest/posttest scores. A Mann-Whitney U test was used to determine if there is a significant difference in pretest scores of the control and experimental groups, which indicated pre-existing group differences between the entire control group and the entire experimental group. Due to this result, an analysis of covariance followed to control the confounding variable(s) (Ary et al., 2006). and to test the null hypotheses of the first research question based on posttest scores. A Mann-Whitney U test was used on each of the subgroups pretest scores to determine if there were initial differences based on performance level. No significant differences resulted between the low-achieving control and low-achieving experimental participants or the high-achieving control and high-achieving experimental participants, so two, separate, Mann-Whitney U tests were run to analyze the second and fourth research questions. However, initial differences were found between average-achieving control and average-

achieving experimental participants. An analysis of covariance was then used to analyze the third research question. Each research question was considered individually to reveal results of the study.

Data Analysis

During the data analysis phase, the researcher used the research questions as a guide when evaluating results and drawing conclusions. Each research question was considered individually and the null hypotheses were tested. Since some of the subgroups had small sample sizes ($n < 30$), normality tests were performed on the data to determine whether data was normally distributed. It was found that some of the data were not normally distributed. Because of this and in order to keep testing consistent even when data was normally distributed, a Mann-Whitney U test was used to evaluate if there was a significant difference in pretest scores between the control group and experimental group (Ary et al., 2006). An analysis of covariance (ANCOVA) was necessary to test the first null hypothesis since it was determined that pre-existing differences existed between the control and experimental groups. This reduced the effect of a Type II error by using the pretest as a covariate so that part of the variance in the posttest scores that was not caused by the treatment was removed, thus improving the study (Ary et al., 2006). Three Mann-Whitney U tests were then run on pretest scores to establish if there were initial differences between low-achieving control group participants versus low-achieving experimental group participants, average-achieving control group participants versus average-achieving experimental group participants, and high-achieving control group participants versus high-achieving experimental group participants. According to Ary et al. (2006), the Mann-Whitney U test is suitable to

initially compare the scores of the control group and experimental group since both samples will be independent of one another, with a sample of students chosen from the population of the experimental school and a separate sample chosen from the population of the control school. No initial differences were found between the low-achieving or high-achieving subgroups, so two other Mann-Whitney U tests were used to test the null hypotheses of the second and fourth research questions. Initial differences were determined between the average-achieving subgroup, so an ANCOVA was used to test the null hypothesis of the third research question. A .05 level of significance was used. A Type I error for this study would have implied that the instructional method used to teach mathematics resulted in a significant difference between groups when it actually did not. Since the statistical tests performed revealed that there was not a significant difference between posttest scores of the experimental and control groups, a Type I error was avoided. Power calculations were performed for research questions one, two, three, and four, and resulted in powers of 84.85%, 12.30%, 62.41%, and 41.08% respectively. The low power, less than 80%, for some of these indicates that a Type II error could have occurred, implying that though statistical tests showed no significant differences, a significant difference may have existed among some of the groups. Results were then evaluated to analyze if existing performance level (low-achieving, average-achieving, and high-achieving) had an effect on student achievement. These subgroups were determined according to the students' performance level on the math portion of the Georgia CRCT.

CHAPTER FOUR: FINDINGS

The purpose of this study was to evaluate the effect of a student-centered instructional model involving hands-on learning and manipulatives on student achievement of middle school students in mathematics. This chapter explains the results of the study.

Data Analysis

A quasi-experimental non-equivalent pretest posttest control group study was conducted to consider the effectiveness of hands-on learning and use of math manipulatives on mathematical achievement. Pretest and posttest scores of seventh-grade mathematics students from a middle school in Northwest Georgia who were taught a mathematics unit using two different instructional models for mathematics instruction were analyzed. The four research questions, defined in chapters one and three, were addressed. Pretest data were tested for normality prior to statistical testing. Most of the datasets were normally distributed, but results, as demonstrated in the Figure 1, revealed that pretest data for the control group when considered as a whole was not normally distributed.

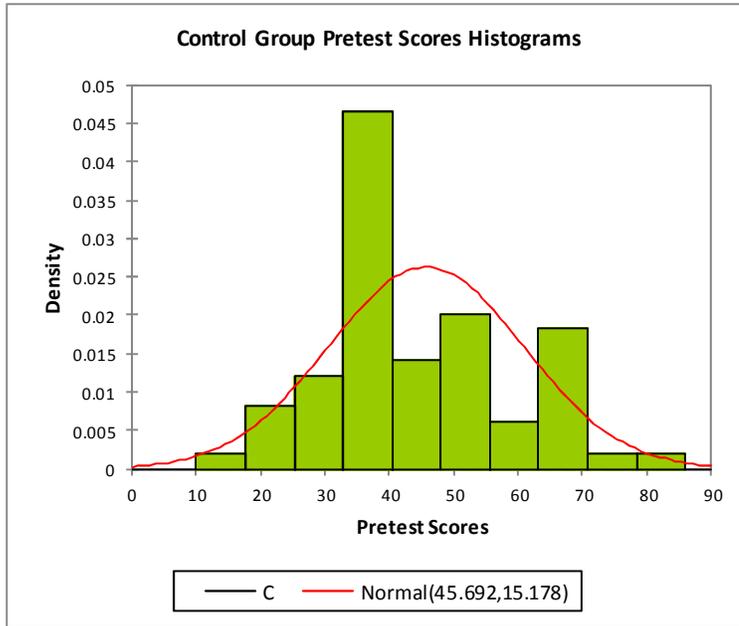


Figure 1. Normality test for control group pretest data.

For this reason, the first statistical test performed on each research question was a Mann-Whitney U test at a 0.05 level of significance. Participants' pretest scores were used in order to reveal any initial group differences that may have existed prior to the treatment. Once the Mann-Whitney U tests were run, an Analysis of Covariance (ANCOVA) was applied to the first and third research questions and a Mann-Whitney U test was applied to each of the second and fourth research questions. All were tested at the alpha 0.05 level. The Mann-Whitney U tests were computed using the XLStat add-on feature in Microsoft Excel, while the ANCOVA tests were calculated in VassarStats: Statistical Computation Website. The statistical data gathered from the study are shown below each research question.

Research Questions

The first research question asked if there was a significant difference in mathematics achievement of seventh-grade students based on the instructional model used to teach mathematics. This question evaluated the two models used in the study, hands-on learning with manipulatives versus traditional instruction. The descriptive statistics are presented in Table 4.1. Results of the Mann-Whitney U test, shown in table 4.2, determined that there were initial significant differences between the control and experimental groups, based on participants' pretest scores ($p = .02$).

Table 4.1

Descriptive Statistics for Pretest Scores by Group

Group	<i>N</i>	<i>M</i>	<i>SD</i>
Control	65	45.69	15.18
Experimental	80	51.50	16.45

Table 4.2.

Pretest Mann-Whitney U test Results Control versus Experimental

<i>U</i>	Expected value	Variance	<i>SD</i>	<i>p</i>	Alpha
2009.00	2600.00	62684.03	250.37	0.02	0.05

Once it was determined that there were preexisting differences between the groups, an ANCOVA was run to calculate whether there was a significant difference between posttest scores of the control and experimental groups. Prior to ANCOVA

testing, other tests were performed to confirm that assumptions were not being violated. Posttest data was plotted and proven to be normally distributed, as shown in Figures 2 and 3. An F-test was calculated in Microsoft Excel at the .05 alpha level, proving variances to be homogenous ($p = .20$), and VassarStats was used to prove homogeneity of regressions ($p = .53$), also at the .05 alpha level. Multicollinearity was tested by calculating the variance inflation factor, showing that there was no correlation between the predictor variables ($VIF = 1.23$). The actual means were calculated as 62.19 and 58.54 for the experimental and control groups respectively. After adjustments, means were 60.89 for the experimental group and 60.14 for the control group.

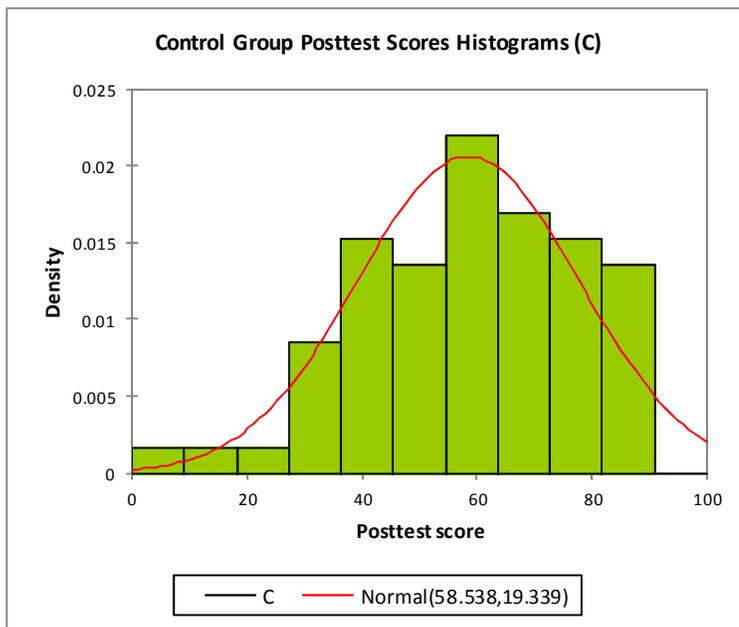


Figure 2. Normality test for control group posttest data.

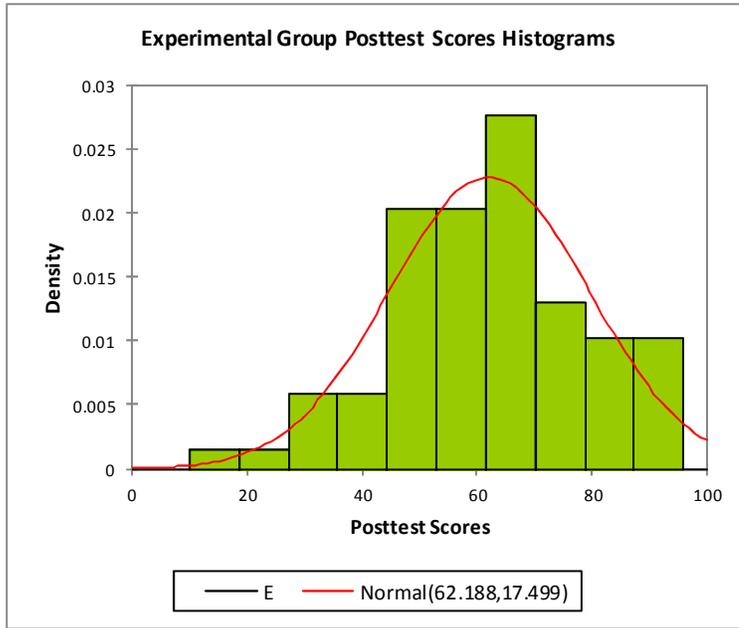


Figure 3. Normality test for experimental group posttest data.

The results of the ANCOVA revealed that there were no significant differences ($p = .79$) between the posttest scores of all of the participants in the control group and all of the participants in the experimental group.

Table 4.3

ANCOVA Results of Posttest Scores (Experimental versus Control Group)

Source	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Adjusted Means	19.51	1	19.51	0.07	.79
Adjusted Error	39129	142	275.60		
Adjusted Total	39148	143			

In regards to research question one, results of the study lead to the failure to reject the null hypothesis: There will be no significant difference in mathematics achievement of seventh-grade students based on the instructional model used to teach mathematics

(hands-on learning with manipulatives versus traditional instruction). There were no significant differences between posttest scores of the experimental group and posttest scores of the control group ($p = .79$).

The second research question asked if there were significant differences in posttest scores between low-achieving mathematics students in the control group and low-achieving mathematics students in the experimental group. This question evaluated the effectiveness of the instructional model in reference to low-achieving mathematics students. The descriptive statistics for pretest scores of low-achieving control and low-achieving experimental participants are listed in Table 4.4. The results of the Mann-Whitney U test, shown in table 4.5 determined that there were no initial group differences when comparing low-achieving control group participants to low-achieving experimental group participants ($p = .58$).

Table 4.4

Descriptive Statistics for Pretest Scores of Low-Achieving Participants by Group

Group	n	M	SD
Control	6	32.50	12.94
Experimental	5	40.00	21.51

Table 4.5.

Pretest Mann-Whitney U test Results Low-Achieving Control versus Low-Achieving Experimental

<i>U</i>	Expected value	Variance	<i>SD</i>	<i>p</i>	Alpha
11.50	15.00	29.32	5.41	0.58	0.05

After it was determined that there were no initial group differences between low-achieving students in each of the groups, a Mann-Whitney U test was run to calculate whether there was a significant difference in posttest scores between low-achieving seventh grade mathematics students in the control group and low-achieving seventh grade mathematics students in the experimental group. The results of the Mann-Whitney U test revealed that there were no significant differences ($p = .55$) between the posttest scores of the low-achieving mathematics students in the control group and the low-achieving mathematics students in the experimental group.

Table 4.6.

Descriptive Statistics for Posttest Scores of Low-Achieving Participants by Group

Group	<i>n</i>	<i>M</i>	<i>SD</i>
Control	6	51.67	18.62
Experimental	5	48.00	15.25

Table 4.7.

Posttest Mann-Whitney U test Results Low-Achieving Control versus Low-Achieving Experimental

<i>U</i>	Expected value	Variance	<i>SD</i>	<i>p</i>	Alpha
18.50	15.00	28.50	5.34	0.55	0.05

Results of the study supported failure to reject the null hypothesis for the second research question: There will be no significant difference in mathematics achievement of low-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction). There were no significant differences between posttest scores of low-achieving mathematics students in the control group and low-achieving mathematics students in the experimental group ($p = .55$).

The third research question asked if there were significant differences in posttest scores between average-achieving mathematics students in the control group and average-achieving mathematics students in the experimental group. This question evaluated the effectiveness of the instructional model in reference to average-achieving mathematics students. Results of the Mann-Whitney U test in table 4.9 show that there were initial group differences when comparing pretest scores of average-achieving control group participants to average-achieving experimental group participants ($p = .05$).

Table 4.8.

Descriptive Statistics for Pretest Scores of Average-Achieving Participants by Group

Group	<i>n</i>	<i>M</i>	<i>SD</i>
Control	41	43.05	12.94
Experimental	44	48.75	14.35

Table 4.9.

Pretest Mann-Whitney U test Results Average-Achieving Control versus Average-Achieving Experimental

<i>U</i>	Expected value	Variance	<i>SD</i>	<i>p</i>	Alpha
676.00	902.00	12789.07	113.09	0.05	0.05

Once it was established that there were initial group differences between average-achieving students in the control and experimental groups, an analysis of covariance was applied to determine whether a significant difference existed in posttest scores between average-achieving seventh grade mathematics students in the control group and average-achieving seventh grade mathematics students in the experimental group. Tests were run prior to administration of the ANCOVA to check for assumption violations. Posttest data of average-achieving participants was plotted and showed a normal distribution, as indicated in Figures 4 and 5. Variances were proven to be homogenous ($p = .26$) using an *F*-test at the .05 alpha level in Microsoft Excel. In addition, a homogeneity of regressions test was run in VassarStats for at the alpha level .05, revealing that a violation had occurred ($p = .01$). Due to this violation, calculations were then performed to

identify if outliers existed within the dataset. The differences between posttest and pretest scores of average-achieving participants were averaged to find the mean difference in achievement, and outliers were considered to be 3 or more standards deviations from the mean (Stevens, 1996). No outliers were found within the data. Due to the large sample size of the groups ($n > 30$), absence of extreme outliers, and since heterogeneity of regressions was the only proven violation, the violation was not considered severe (Stevens, 1996). The variance inflation factor was calculated to assess multicollinearity, and proved that a correlation did not exist between predictor variables ($VIF = 1.04$). The actual means were calculated as 57.39 and 54.63 for the experimental and control groups respectively. After adjustments, means were 56.06 for the experimental group and 56.76 for the control group.

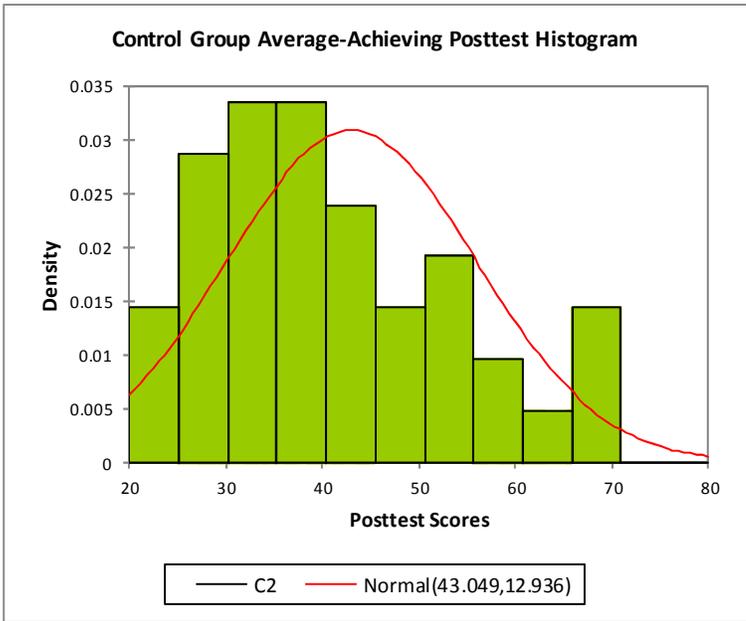


Figure 4. Normality test for average-achieving control group posttest data.

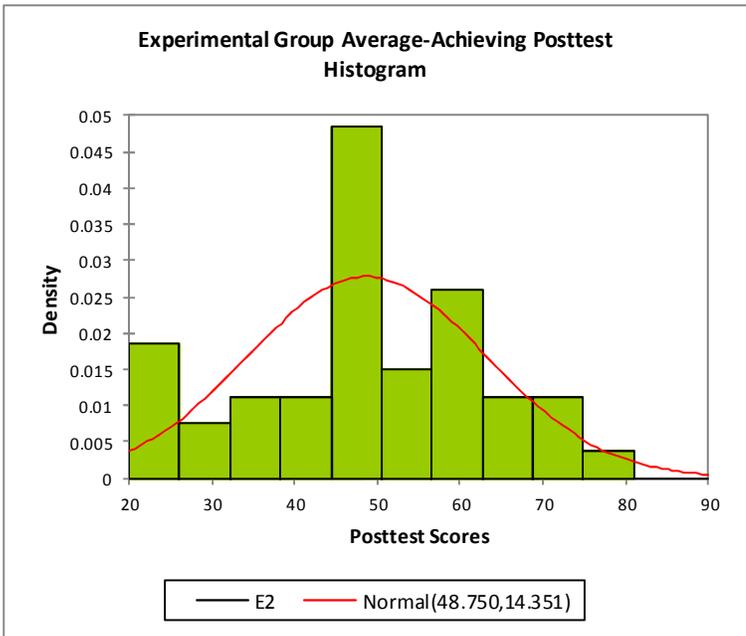


Figure 5. Normality test for average-achieving experimental group posttest data.

The results of the ANCOVA shown in table 4.10 revealed that there were no significant differences ($p = .68$) between the posttest scores of the average-achieving mathematics students in the control group and the average-achieving mathematics students in the experimental group.

Table 4.10

ANCOVA Results of Average-Achieving Control versus Average-Achieving Experimental Posttest Scores

Source	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Adjusted Means	42.72	1	42.72	0.2	.68
Adjusted Error	20032.6	82	244.3		
Adjusted Total	20075.30	83			

The results of the study led to the failure to reject the null hypothesis for the third research question: There will be no significant difference in mathematics achievement of average-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction). There were no significant differences between posttest scores of average-achieving mathematics students in the control group and average-achieving mathematics students in the experimental group ($p = .68$).

The fourth research question asked if there were significant differences in posttest scores between high-achieving mathematics students in the control group and high-achieving mathematics students in the experimental group. This question evaluated the effectiveness of the instructional model in reference to high-achieving mathematics students. The Mann-Whitney U test results shown in table 4.12 reveal that there were no

initial group differences when comparing pretest scores of high-achieving control group participants to high-achieving experimental group participants ($p = .72$).

Table 4.11.

Descriptive Statistics for Pretest Scores of High-Achieving Participants by Group

Group	<i>n</i>	<i>M</i>	<i>SD</i>
Control	18	56.11	15.20
Experimental	31	57.26	16.97

Table 4.12.

Pretest Mann-Whitney U test Results High-Achieving Control versus High-Achieving Experimental

<i>U</i>	Expected value	Variance	<i>SD</i>	<i>P</i>	Alpha
261.00	279.00	2296.29	47.92	0.72	0.05

The Mann-Whitney U test proved that there were no initial group differences between high-achieving students in the control group and high-achieving students in the experimental group. A Mann-Whitney U test was then applied to determine whether a significant difference existed in posttest scores between high-achieving seventh grade mathematics students in the control group and high-achieving seventh grade mathematics students in the experimental group. Results of the Mann-Whitney U test, represented in table 4.13, showed that there were no significant differences ($p = .98$) between the

posttest scores of the high-achieving mathematics students in the control group and the high-achieving mathematics students in the experimental group.

Table 4.13.

Descriptive Statistics for Posttest Scores of High-Achieving Participants by Group

Group	<i>n</i>	<i>M</i>	<i>SD</i>
Control	18	69.72	21.66
Experimental	31	71.29	17.22

Table 4.14.

Posttest Mann-Whitney U test Results High-Achieving Control versus High-Achieving Experimental

<i>U</i>	Expected value	Variance	<i>SD</i>	<i>P</i>	Alpha
279.50	279.00	2287.29	47.83	0.98	0.05

Based on the results found from the study, the null hypothesis for the fourth research question was not rejected: There will be no significant difference in mathematics achievement of high-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction). There were no significant differences between posttest scores of high-achieving mathematics students in the control group and high-achieving mathematics students in the experimental group ($p = .98$).

Chapter Five, the next and last chapter, will provide a summary, along with a discussion of the findings and results of the study. Implications and limitations that may have affected the study will also be mentioned. Recommendations for future research on the topic of this study will complete the manuscript.

CHAPTER FIVE: DISCUSSION

This chapter summarizes the results of the study. It will be divided into sections including an overview, the purpose of the study, and a review of the methodology of the study. The chapter will also provide discussion of the results found during the study and will give implications, mention limitations, present applications of the study, and finally, provide recommendations for future research on the topic of the study.

Overview

Over time, mathematics education has changed as policymakers and educators strive to produce more knowledgeable students in the area of mathematics. Math and science have been put at the forefront of education in America in an effort to raise national test scores and student achievement in these content areas. Under direction of the United States Department of Education, the National Assessment of Educational Progress (NAEP) is given to select students in fourth and eighth grades to study the effectiveness of current mathematics instruction and evaluate student achievement (Lee, Grigg, & Dion, 2007). According to the NAEP report in 2009, though percentages of student achievement in mathematics had increased since past NAEP administrations, the study showed that only 26% of eighth- grade students tested were at a level considered proficient in the understanding of mathematical concepts (U.S. Department of Education, 2010).

A need for improvement in mathematics education exists in America. Educators play a critical role in this improvement by the way in which they present and relay information to students. All stakeholders in the educational system must gain a deeper understanding of factors that contribute to mathematical achievement and explore what

types of instructional strategies influence student performance in mathematics. What may be effective for an individual student may not prove successful for another student. Furthermore, a strategy that produces positive results with a particular subgroup of students may not have the same effect on other subgroups.

Purpose

The purpose of this quantitative study was to evaluate the effect of a student-centered instructional model involving hands-on learning and manipulatives on student achievement of middle school students in mathematics. Many factors could improve mathematics education, but the implementation of different instructional strategies is one that could be done rather simply by individual classroom teachers. In this study, there were two groups of students, an experimental and control. The experimental group participants received hands-on instruction with use of math manipulatives while the control group received instruction on the same content, but without the use of manipulatives.

Research Questions

Research Question 1: Will there be a significant difference in mathematics achievement of seventh-grade students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

H₁₀: There will be no significant difference in mathematics achievement of seventh-grade students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction) while controlling for initial group differences in mathematical achievement.

Research Question 2: Will there be a significant difference in mathematics

achievement of low-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

H2₀: There will be no significant difference in mathematics achievement of low-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction).

Research Question 3: Will there be a significant difference in mathematics achievement of average-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

H3₀: There will be no significant difference in mathematics achievement of average-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction) while controlling for initial group differences in mathematical achievement.

Research Question 4: Will there be a significant difference in mathematics achievement of high-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction)?

H4₀: There will be no significant difference in mathematics achievement of high-achieving seventh-grade mathematics students based on the instructional model used to teach mathematics (hands-on learning with manipulatives versus traditional instruction).

Review of Methodology

This was a quasi-experimental study, and used a non-equivalent control-group design to evaluate pretest and posttest results of two groups of seventh-grade mathematics students from a Northwest Georgia middle school. During the 4-week study, the experimental group received instruction on the concepts of data analysis and probability through use of hands-on learning and math manipulatives. The control group was taught the same concepts, but in a more traditional form, without use of mathematics manipulatives as learning tools. Both groups completed a pretest which was used to determine if there were initial group differences prior to the treatment. They also both completed a unit posttest, which was used to assess whether significant differences in achievement existed, based on the instructional model used to teach mathematics.

Participants

The participants of the study were seventh-grade mathematics students from a middle school in Northwest Georgia. The participating school has approximately 700 students enrolled with the following demographics: 90% Caucasian, 4% Black, 2% Hispanic, 2% Asian, and 2% multiracial. Approximately 61% of students attending the participating school receive free and reduced lunch. Participants included 145 male and female mathematics students in the designated grade level. The experimental group, those receiving instruction with the use of manipulatives, consisted of 80 students, eight of whom were inclusion students who were accommodated by an Individualized Education Plan. The other 60 students served as the control group including 12 inclusion

students. There were four mathematics teachers who also participated in the study, all of whom have at least three years of teaching experience in the area of mathematics.

Procedure

Control and experimental groups were formed out of nine total seventh-grade mathematics classes. A pretest was given to all participating students in both the control and experimental groups. The four-week unit on data analysis and probability was then taught to all classes, based on mathematical content standards set forth by the state of Georgia. The control group did not receive instruction with the use of math manipulatives, but the experimental group did. These manipulatives included but were not limited to number cubes, fruit loops cereal, spinners, colored discs, and coins. Once the unit was complete, a posttest was given to all participating students and collected by the participating teachers. All pretests and posttests were then graded and recorded by the researcher in a Microsoft Excel spreadsheet. Analyses were made comparing the control to experimental group. Data were also sorted so that subgroups could be considered based on existing performance level (low, average, high), which was determined by the performance level obtained on the math portion of the 2011-2012 Georgia CRCT.

Performance levels established by the Georgia CRCT are based on ranges of scores. Students scoring in the level one range have not shown evidence of meeting the standards set forth by the state of Georgia. Students scoring in the level two range are considered to have shown evidences of meeting the standards. Students scoring in the level three range have shown evidences of meeting and exceeding the standards set forth

by the state. These levels were used to identify low, average, and high-achieving students based on level one, level two, or level three achievement respectively.

Summary of Results

Statistical testing was performed on both the pretest and posttest scores gathered during the study. A Mann-Whitney U test was conducted in Microsoft Excel on pretest scores of the control group and the experimental group to establish any initial group differences. The Mann-Whitney U test revealed that there were significant differences between the control and experimental groups ($p = .02$). An ANCOVA was then run in VassarStats to identify if there were significant differences in posttest scores of all participants in the control group versus all participants in the experimental group. Results showed that there were no significant differences in posttest scores between the control and experimental groups ($p = .79$). Prior to evaluation of posttest scores by subgroups (low-control versus low-experimental, average-control versus average-experimental, high-control versus high-experimental), three separate Mann-Whitney U test were run to establish initial differences between subgroups in the control and experimental groups. Between low-achieving math students in the control and experimental groups, there were no initial group differences ($p = .58$). Between average-achieving math students in the control and experimental groups, there were initial group differences ($p = .05$). Between high-achieving math students in the control and experimental groups, there were no initial group differences ($p = .72$). Since no existing differences were identified prior to the treatment for the low-achieving or high-achieving groups, two separate Mann-Whitney U test were performed to evaluate the second and

fourth research questions. An ANCOVA was run to evaluate the third because initial differences were found between the average-achieving subgroup. Results of the two Mann-Whitney U tests revealed that there were no significant differences in posttest scores between the low-achieving control students versus low-achieving experimental students ($p = .55$) or high-achieving control students versus high-achieving experimental students ($p = .98$). Furthermore, the ANCOVA revealed that there were not significant differences in posttest scores between average-achieving control students versus average-achieving experimental students ($p = .68$).

Discussion

Prior studies, as noted in chapter two, have revealed mixed findings in regards to the effectiveness of using mathematics manipulatives to promote student understanding of mathematical concepts. Studies targeting students with disabilities conducted by Cass et al. (2003) and Bouck and Flanagan (2010) showed a positive correlation between the use of manipulatives and mathematical performance. In two separate studies, Moch (2001) and Cain-Caston (1996) found that elementary students who were exposed to mathematics manipulatives also showed greater performance than their peers who were not exposed to math manipulatives. However, other studies have revealed different results, indicating that manipulatives may not be the answer to enhancing mathematical instruction and student performance. McNeil and Jarvin (2007) found that students who had limited cognitive resources did not respond positively to the use of manipulatives, due to the increase in brain power needed to transfer knowledge from the concrete to the abstract. In addition, Alsup and Sprigler (2003) explored using three different

approaches, traditional, reform-based including use of manipulatives, and a mix of the latter two when teaching mathematics to eighth-grade students, and found that the reform-based method when used alone was the least beneficial to students.

The results of this study revealed that there were no significant differences between the control group who received more traditional-based instruction and the experimental group who received instruction through hands-on learning and use of manipulatives. These results are supported by mixed findings of past literature that have shown positive and negative results of using math manipulatives as instructional tools. When considering the groups as a whole, experimental versus control, there were students of various ability levels. With past studies, the use of manipulatives have had different effects on achievement depending on the type of student involved in the process. It should not be declared that math manipulatives were not beneficial to individual students, as many students in the experimental group showed positive gain between pretest and posttest scores, possibly due to the exposure they had to math manipulatives. The result of no significant difference in posttest scores was in reference to comparison of whole groups and could be explained by the various existing achievement levels that were represented within each of the control and experimental groups.

The results of the study also implied that one instructional model was not better than the other in terms of teaching students within various mathematical performance levels (low-achieving, average-achieving, high-achieving). While the use of manipulatives may be helpful for some students, results of the study did not show a significant difference in overall achievement of the experimental group who received this

type of instruction. As mentioned previously, with low-achieving students, or students with disabilities, manipulatives have proven to be both helpful and a possible hindrance in terms of learning and achievement. Students who were considered in the low-achieving subgroup all had scores on their standardized tests in mathematics that did not meet the state of Georgia's set performance standard. However, the reasoning behind why they did not meet cannot be summed up by one reason. Mathematics involves multiple skills, and though a student does not succeed in one area of mathematics, does not mean he/she is not fluent in other areas. The results of the study, showing no significant differences in posttest scores of low-achieving students in the control versus experimental group, may have been a result of the quality and type of manipulative used in this study, compared to the type of manipulative that may have served students best, depending on the area in which they struggle mathematically. For instance, if a student struggles with comprehension and reasoning, a particular manipulative may not make a difference in their learning because it does not address the weakness in their learning.

In regards to students who perform above average in mathematics, the study indicated that there were no significant differences in scores on the unit posttest of those high-achieving students who received instruction with the use of manipulatives and high-achieving students who received more traditional instruction with no manipulatives during instruction. Students who are higher-achieving learners in mathematics likely think more abstractly than low-achieving or average-achieving students. Since math manipulatives are concrete tools usually used to connect the concrete to the abstract, it

would be understandable that they may not have as much of an effect on scores of higher-achieving math students who can process abstract ideas directly.

As derived in the study by Alsup and Sprigler (2003) which indicated that a mixed approach to instruction of mathematics may lend the greatest benefit, the results of the study support the idea of differentiation. All students have different needs in order to maximize their learning, and one type of instruction can be just as effective as another. The topic, time-frame, type of student being educated, and objective of the lesson can all be factors that play a role in student learning. Combining multiple methods of instruction within a lesson reaches more students and makes instruction more effective. Cooperative learning and use of technology are both forms of differentiating instruction and were both used in this study by the control and experimental groups. Though one group utilized math manipulatives during instruction, there were no significant differences found in achievement among the groups, proving that a plethora of instructional strategies prove beneficial in enhancing instruction.

Limitations

There are many factors that can affect change in achievement levels of students which will be limitations to this study. Some of these factors are within the control of the classroom teacher, while others are not. Environmental factors such as availability of resources outside of school and students' motivational levels both play a role in the success of students' educations, but are variables that cannot be controlled by educators. Factors related to the learning environment such as instructional strategies, classroom management, teacher attitude towards students and learning, and years of experience can

all impact students positively and negatively. Related to the school atmosphere, but not directly to teachers are factors such as school leadership and guidance, adequate supplies and facilities, and parental support. It can be difficult to conclude if there is a particular one that had the most impact or can be determined as the cause of the change.

The sample chosen could have been a limitation to the study. This study was limited to seventh-grade students from one middle school in North Georgia. Though the number of participants from these schools produces a representative sample of the local population, it may not accurately represent seventh-grade students from other parts of the United States. In addition, to make generalizations about middle school students, other grade levels would need to have been represented in the sample. A much larger sample from various locations in the country would be needed to fully support the findings. Another consideration with the sample of the study is the socioeconomic levels of the students and the percentage of minority students represented. The school in the study was a Title I school, with the majority of students receiving free or reduced lunch. Most students are from low- to middle-class social status. A more diverse number of students in terms of race and ethnicity would be needed to have a more representative sample to make generalizations.

Other limitations to the study could have been the timing of the study and the mathematics manipulatives used for instruction. The study took place at the end of the school year, after CRCT testing. As a trend at the participating school, students tend to be absent more, affecting the amount of instructional time they receive in the mathematics classroom after that testing is conducted. In addition, the length of time of the study, could limit it, as more time may give a better representation of the

effectiveness of use of manipulatives. With regards to manipulatives, the quality of the manipulatives used in the study could also be a limitation, as some math manipulatives may be more useful and productive than others.

The focus of this study was to determine if the use of a particular instructional strategy has an effect on student performance, based on achievement levels. While the instructional strategy may have played a large role in any change that may have occurred, many other factors that cannot necessarily be measured can lead to student achievement. Classroom teachers play a significant part in the success of students. Teacher differences or similarities between the control and experimental group could have been a factor. Their attitudes towards students, the environment they create for students, and their philosophy of education are just some of the factors that have positive or negative effects on student learning, but cannot always be measured. In order to help control these extraneous variables, teachers who participated in the study were certified teachers in the state of Georgia with at least 3 years of classroom teaching experience in mathematics. Furthermore, teachers at the participating school had received professional development training and continue to receive guidance through the system-wide math coach on a model using hands-on learning with manipulatives.

Additional specific threats to the internal and external validity of this research study included maturation, selection threat due to non-equivalent groups, the novelty effect, and pretest and/or posttest sensitization (Gall et al., 2007). Though these threats cannot be completely eliminated, the study was designed in a way to minimize these threats. Internal threats of concern included maturation and selection threat due to non-equivalent groups. Maturation likely occurred as participants underwent physical and

psychological changes during the research period (Gall et al., 2007). In addition, participants may have matured intellectually through remediation and additional instruction outside of the classroom. While uncontrollable, the treatment occurred and data was collected in a limited amount of time to reduce the number of developmental changes that participating students may have undergone during the study to help lessen the maturation threat. A period of 4 weeks was needed for teachers to properly teach a seventh-grade mathematics unit and perform assessments. Furthermore, a control group consisting of students of the same age was used.

The use of non-equivalent groups posed a threat because there was a possibility that group differences on the posttest are the result of pre-existing differences rather than the treatment (Gall et al., 2007). To minimize this threat, similar populations of students were used for the control and experimental groups. In addition, a pretest was administered and a Mann-Whitney U test was used to determine if there were initial differences between the two groups. Then, an analysis of covariance was used to statistically reduce the effects of initial group differences (Gall et al., 2007).

Introduction to a new treatment known as the novelty effect can be a factor that impacts experimental research studies (Gall et al., 2007). Each group in this study had been previously exposed to the treatment that they will receive during the study. Students in the control and experimental groups had been exposed to both types of instruction that was used during the study, so neither group experienced a new method of learning, though each group was taught using different methods.

Since a pretest and posttest were conducted, pretest and posttest sensitization were possible threats (Gall et al., 2007). However, both groups of students were accustomed to

completing pretest and posttest assessments throughout the academic year which should have decreased how much of an impact this threat had on the study. Unit pretest and posttest were conducted by the participating teachers on a regular basis to measure student understanding.

Applications

Mathematics has been and continues to be a content area in America's educational system that is held to a high standard and is pinpointed in terms of accountability and success rates. Many initiatives have existed through the years, with the most current being an adoption of common core curriculum by most states in America (Common Core State Standards Initiative, 2012a). According to the Common Core State Standards Initiative (2012a), the mathematics standards produced by common core will ensure the American's competitive edge is maintained, so that all students are prepared with skills and knowledge needed to compete with other students, local and abroad. In order to reach all students, measures are going to have to be taken by teachers that enable and encourage all types of learners to achieve. This will involve planning rigorous lessons that incorporate best practices and multiple teaching strategies. The Common Core Initiative points out that though standards will be set, teachers continue to devise their own lesson plans and tailor instruction to meet the needs of students in their classrooms (Common Core State Standards Initiative, 2012a). These lessons will require various forms of instruction, including but not limited to the use of concrete objects to represent mathematical situations.

With increased demand on educators and administrators to provide high quality education in the area of mathematics, this study shows that multiple instructional methods may be necessary to be most effective with students. As class sizes continue to increase, there will be students at many different levels and with various amounts of prior knowledge. Teachers can see from the results of the study that one particular instructional method is not the answer to increase mathematical achievement. As stakeholders, administrators and educators consider changes and implementations in their schools to increase student achievement, results such as these can be productive in the decision-making process.

Recommendations for Future Research

There are a few recommendations for future research on using math manipulatives as instructional learning tools. First, a larger sample should be used to represent the middle school population. While the seventh-grade students in the study were middle school students, other grade levels should be considered, and a greater number of participants should be used in order to generalize findings. Furthermore, inclusion of many schools in a study would also give better insight into the effectiveness of the use of math manipulatives. In addition to a larger sample, a greater time period could also be beneficial, as more concepts would be taught during a longer period of time. This could help identify if the effectiveness of manipulatives as an instructional tool is more helpful when teaching certain mathematical concepts over a longer period of time.

Conclusion

According to the Common Core State Standards Initiative (2012b), for more than 10 years, mathematical research studies in high-performing countries have concluded that in order for mathematics achievement to improve in the United States, a substantial change must occur in the curriculum. More focus must be placed on concepts being taught. As a result, a set of common standards has been developed to meet this challenge, and 45 states have already adopted the standards as part of their state curriculum (Common Core State Standards Initiative, 2012b). With the new demands of core curriculum, the job of all educators will become more challenging, especially that of mathematics educators. It will be even more critical for educators to find teaching methods and instructional models that promote understanding for the students in their classrooms. Research in mathematics education must continue in order for educators to gain insight into effective teaching methods. The results of this study reiterate that there is not a “one size fits all” when it comes to the education of students in the mathematics classroom. Multiple approaches must be implemented in order to provide the most success for today’s students.

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APPENDICES

Appendix A: Data Analysis and Probability Unit Lesson Plans

- Lesson 1
 - Probability Pretest
 - Worktext pp. 282, 73
- Lesson 2
 - BrainPop Basic Probability Movie
 - <http://www.brainpop.com/math/probability/basicprobability/preview.weml>
 - BrainPop Activity Sheet
 - Experimental group use cards, tiles, coins, and marbles
 - Worktext pp. 76, 79
- Lesson 3
 - BrainPop Basic Probability Movie (watch again)
 - Fruit Loop Lab
 - Experimental group uses Fruit Loops cereal
- Lesson 4
 - Probability Puzzles
- Lesson 5
 - BrainPop Introduction to Independent & Dependent events
 - <http://www.brainpop.com/math/probability/independentanddependentevents/preview.weml>
 - Experimental group use number cubes, colored chips, deck of cards
- Lesson 6
 - Puzzles, Twisters, Teasers worksheet
- Lesson 7
 - BrainPop Compound Events
 - <http://www.brainpop.com/math/probability/compoundevents/preview.weml>
 - Puzzle worksheets (E49, E50, E52, E53)
 - Experimental group uses spinners
- Lesson 8
 - Introduction to Experimental Probability
 - Worktext p. 391

- Lesson 9
 - Review Experimental Probability
 - Lesson 11-2 Packet
- Lesson 10
 - Introduction to “sample space”
 - Lesson 11-3 packet
 - Experimental group uses spinners, number cubes
- Lesson 11
 - Introduction to Combinations
 - Worksheet 11-6
- Lesson 12
 - Introduction to Tree Diagrams
 - Clothes Combos, Card Sort: Pet Peeves
 - Experimental group will use real clothes
- Lesson 13
 - Pie Slingers Probability unit task
- Lesson 14
 - Probability Posttest

Appendix B: Pretest/Posttest Instrument

Unit 1: Probability

Choose the **one** correct answer for each question.

1. Marcella has three hats, two pairs of gloves and four scarves at home. How many different combinations of one hat, a pair of gloves, and one scarf can she wear to school on a particular morning?
a) 12 b) 9 c) 10 d) 24
2. What is the theoretical probability of getting a four on one roll of a number cube?
a) $\frac{4}{12}$ b) $\frac{1}{6}$ c) $\frac{4}{6}$ d) $\frac{1}{12}$
3. A set of cards includes 15 green cards, 10 blue cards, and 10 orange cards. What is the probability that a card randomly chosen will be orange?
a) $\frac{10}{25}$ b) $\frac{1}{35}$ c) $\frac{2}{7}$ d) $\frac{1}{10}$
4. If a family has five girls in a row, what is the theoretical probability that the next child will also be a girl?
a) $\frac{1}{32}$ b) $\frac{1}{16}$ c) $\frac{1}{8}$ d) $\frac{1}{2}$
5. What is the probability of rolling a fair number cube and getting a 6 three times in a row?
a) $\frac{1}{6} \times \frac{1}{6} \times \frac{1}{6}$ b) $\frac{1}{6} \times \frac{1}{6} \times \frac{1}{3}$ c) $\frac{1}{6} \times \frac{1}{6}$ d) $\frac{1}{6} \times 3$
6. Which answer gives the sample space for the outcome of rolling a single number cube?
a) $\{0,1,2,3,4,5,6\}$ b) $\{1,2,3,4,5,6\}$
c) $\{6\}$ d) The number facing up on a given roll.
7. Sally wants to create a spinner with three sectors. The first is 25% of the circle. The second sector is 40% of the circle. What is the percent of the circle for the third sector?
a) 30% b) 35% c) 40% d) 33.3%
8. DJ was working on his probability homework and could not figure out how to solve the probability of rolling a 2 and a 3 on two rolls of a fair number cube, $P(2 \text{ and } 3)$. Which answer shows how to solve the problem?
a) $\frac{1}{6} + \frac{1}{6}$ b) $\frac{2}{6} + \frac{3}{6}$ c) $\frac{1}{12} \times \frac{1}{12}$ d) $\frac{1}{6} \times \frac{1}{6}$

9. James rolls a fair number cube and gets a 3. He rolls it again and gets a 6. Is this an example of an independent or dependent event? Why?
- Independent because the first roll does not affect the outcome of the second roll.
 - Dependent because the first roll does not affect the outcome of the second roll.
 - Independent because the first roll does affect the outcome of the second roll.
 - Dependent because the first roll does affect the outcome of the second roll.
10. There are 5 options on the dessert menu at a restaurant: apple pie, strawberry shortcake, brownie sundae, raspberry cheesecake, and blackberry cobbler. Erin and Ellen like all the choices equally, so they each choose a dessert at random. What is the probability that Erin will choose apple pie and Ellen will choose strawberry shortcake for dessert?
- 0.04
 - 0.2
 - 0.05
 - 0.96
11. A state offers specialty license plates that contain 2 letters followed by 3 numbers. License plates are assigned randomly. Find the number of license plates that can be issued using this system.
- 98
 - 676,000
 - 36
 - 67,000
12. The ski report predicts a $\frac{3}{5}$ chance of having snow. What is the probability of not having snow?
- $\frac{1}{2}$
 - $\frac{2}{5}$
 - $\frac{3}{5}$
 - 1
13. Josh works at a local deli making sandwiches. Each sandwich has 1 type of cheese and 1 type of meat on the bread. The deli offers white (Whi), wheat (Whe), and rye (Rye) bread. The meat choices are turkey (T) and ham (H), and the cheese choices are American (A) and Swiss (S). Which shows the tree diagram for all sandwich possibilities?
- | | | | | | |
|------|---|------|---|------|---|
| Whi | | Whe | | Rye | |
| └─┬─ | | └─┬─ | | └─┬─ | |
| T | H | T | H | T | H |
| └─┬─ | | └─┬─ | | └─┬─ | |
| A | S | A | S | A | S |
 - | | | | | | |
|------|---|------|---|------|---|
| Whi | | Whe | | Rye | |
| └─┬─ | | └─┬─ | | └─┬─ | |
| T | H | T | H | T | H |
| └─┬─ | | └─┬─ | | └─┬─ | |
| A | S | A | S | A | S |

16. Using the information from problem #13, find $P(\text{a sandwich with rye bread})$.
a) $1/12$ b) $1/6$ c) $1/3$ d) $7/12$
17. Using the information from problem #13, find $P(\text{a ham sandwich})$.
a) $1/12$ b) $1/4$ c) $1/2$ d) $1/6$
18. Using the information from problem #13, find $P(\text{a sandwich with Swiss cheese})$.
a) $1/2$ b) $1/15$ c) $6/21$ d) $1/21$
19. Using the information from problem #13, find $P(\text{a ham sandwich on wheat bread})$.
a) $1/6$ b) $1/6$ c) $1/2$ d) $1/3$
20. Using the information from problem #13, find $P(\text{soup})$.
a) 1 b) $1/7$ c) $1/12$ d) 0

Appendix C: Cronbach's Alpha Coefficient Results

Cronbach's Alpha = 0.7054

Omitted Item Statistics

Omitted Variable	Adj. Total Mean	Total StDev	Squared Item-Adj. Total Corr	Multiple Corr	Cronbach's Alpha
2	10.417	3.636	0.2725	0.3148	0.6956
3	10.688	3.493	0.4681	0.3160	0.6752
4	10.444	3.664	0.1758	0.2537	0.7024
5	10.708	3.631	0.1751	0.2058	0.7041
6	10.528	3.695	0.0687	0.1627	0.7120
7	10.403	3.640	0.2771	0.2047	0.6955
8	10.910	3.522	0.4245	0.2698	0.6801
9	10.597	3.519	0.4397	0.2848	0.6789
10	11.007	3.475	0.1859	0.0758	0.7217
11	10.972	3.649	0.1646	0.1274	0.7042
12	10.493	3.589	0.3339	0.3374	0.6898
13	10.597	3.529	0.4175	0.2931	0.6810
14	10.799	3.644	0.1476	0.1680	0.7067
15	10.743	3.553	0.3348	0.2048	0.6885
16	10.729	3.544	0.3542	0.3331	0.6866
17	10.792	3.544	0.3552	0.2596	0.6865
18	10.667	3.486	0.4877	0.4271	0.6733
19	10.729	3.689	0.0563	0.1434	0.7153
20	10.528	3.552	0.4009	0.2832	0.6835

Appendix D: Experimental Group Participants' Data

Student ID	Group	CRCT Performance Level	Pretest	Posttest
1	E	1	40	40
2	E	1	70	75
3	E	1	15	45
4	E	1	50	40
5	E	1	25	40
6	E	3	80	75
7	E	3	85	95
8	E	3	45	60
9	E	3	55	90
10	E	3	65	80
11	E	3	45	70
12	E	3	70	95
13	E	3	35	70
14	E	3	50	70
15	E	3	55	80
16	E	3	40	60
17	E	3	75	10
18	E	3	80	95
19	E	3	65	90
20	E	3	60	75
21	E	3	65	75
22	E	3	65	70
23	E	3	35	55
24	E	3	75	90
25	E	3	65	65
26	E	3	75	65
27*	E	3	75	75
28*	E	3	40	80
29	E	3	35	50
30	E	3	50	55
31	E	3	40	70
32	E	3	70	75
33	E	3	70	75

Student ID	Group	CRCT Performance Level	Pretest	Posttest
34	E	3	50	80
35	E	3	15	45
36	E	3	45	70
37	E	2	25	30
38	E	2	45	60
39	E	2	25	50
40	E	2	70	65
41	E	2	30	20
42	E	2	60	70
43	E	2	60	80
44	E	2	50	60
45	E	2	60	65
46	E	2	45	80
47	E	2	45	45
48	E	2	65	55
49	E	2	60	65
50	E	2	50	65
51	E	2	50	75
52	E	2	55	65
53	E	2	40	55
54	E	2	40	30
55	E	2	30	55
56	E	2	65	55
57	E	2	55	60
58	E	2	60	70
59	E	2	45	60
60	E	2	50	50
61	E	2	50	85
62	E	2	65	45
63	E	2	70	70
64	E	2	50	55
65	E	2	45	70
66	E	2	35	50
67	E	2	60	50
68*	E	2	60	35
69*	E	2	55	40

Student ID	Group	CRCT Performance Level	Pretest	Posttest
70*	E	2	35	60
71	E	2	55	75
72	E	2	35	50
73	E	2	40	70
74	E	2	80	90
75	E	2	20	35
76	E	2	70	50
77	E	2	25	50
78	E	2	45	65
79	E	2	25	45
80	E	2	45	50

Appendix E: Control Group Participants' Data

Student ID	Group	CRCT Performance Level	Pretest	Posttest
81	C	1	40	50
82	C	1	45	85
83	C	1	10	30
84	C	1	35	50
85*	C	1	40	55
86*	C	1	25	40
87	C	3	35	75
88	C	3	55	80
89	C	3	55	55
90	C	3	60	90
91	C	3	85	90
92	C	3	55	75
93	C	3	70	90
94	C	3	75	90
95	C	3	45	70
96	C	3	65	85
97	C	3	40	55
98	C	3	70	65
99	C	3	40	0
100	C	3	70	80
101	C	3	40	75
102	C	3	70	70
103	C	3	40	50
104	C	3	40	60
105	C	2	60	70
106	C	2	40	45
107	C	2	35	50
108	C	2	30	50
109	C	2	35	70
110	C	2	30	60
111	C	2	30	60
112	C	2	40	85
113	C	2	25	55

Student ID	Group	CRCT Performance Level	Pretest	Posttest
114	C	2	30	65
115	C	2	55	15
116	C	2	40	35
117	C	2	50	40
118	C	2	35	40
119	C	2	40	55
120	C	2	30	35
121	C	2	70	35
122	C	2	65	55
123	C	2	55	50
124	C	2	40	55
125	C	2	45	65
126	C	2	35	90
127	C	2	40	50
128	C	2	70	75
129*	C	2	35	65
130*	C	2	45	25
131*	C	2	50	45
132*	C	2	35	40
133*	C	2	45	35
134*	C	2	55	45
135*	C	2	70	50
136*	C	2	20	40
137*	C	2	45	55
138*	C	2	55	45
139	C	2	40	80
140	C	2	30	80
141	C	2	50	55
142	C	2	35	70
143	C	2	45	65
144	C	2	25	60
145	C	2	60	80