THE EFFECT OF ENHANCED VISUALIZATION INSTRUCTION ON FIRST GRADE STUDENTS' SCORES ON THE NORTH CAROLINA STANDARD COURSE ASSESSMENT

by

Amber Cole Thompson

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

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APPROVED BY:

DR. JERRY WESTFALL Ph.D., Committee Chair

DR. MATTHEW TOWLES Ph.D., Committee Member

DR. WILLIAM MCDANIEL Ed.D., Committee Member

DR. SCOTT B. WATSON Ph.D., Associate Dean, Advanced Program

ABSTRACT

Visualization was once thought to be an important skill for professions only related to engineering, but due to the realization of concurrent design and the fast pace of technology, it is now desirable in other professions as well. The importance of learning basic knowledge of geometrical concepts has a greater impact than it did prior to the 21st century. This study's purpose was to test the effect of enhanced visualization instruction on the visualization skills measured by the North Carolina standard course test for first grade students. This quasi-experimental study was conducted using the non-randomized subjects, non-equivalent control group design. Nine elementary classrooms with a total of 157 students participated. The standard end of course test scores of the participants were analyzed using a two-way ANCOVA to establish whether a significant difference existed among the sample means based on instructional delivery method and gender and instructional delivery method and race. A pre-test was used to control for differences between groups. A Tukey's HSD test was used to evaluate multiple comparisons for delivery method. Results indicated that instructional delivery had a significant effect on post-test scores. Participants who took part in a classroom with instruction enhanced by multimedia or manipulatives scored higher than those who received instruction without any enhancements. Participants who received instruction with both multimedia and manipulatives had the highest scores. Gender and race were not significant factors in the students' success. Discussion of further research is also incorporated.

Descriptors: First Grade; Gender Differences; Geometry; Minority Differences; Model; Partnership; Three-Dimensional Modeling; Two-Dimensional Drawing; Visualization

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List of Abbreviations

3D – Three-Dimensional

ANCOVA – Analysis of Covariance

CAD – Computer-Aided Design

EOC – End of Course

EOG – End of Grade

K-12 – Kindergarten through Twelfth Grade

NC – North Carolina

NCBE – North Carolina Board of Education

NCDPI – North Carolina Department of Public Instruction

NCSBCC – North Carolina State Board of Community Colleges

NCSCS – North Carolina Standard Course of Study

NCTM – National Council of Teachers of Mathematics

PSVT – Purdue Spatial Visualization Test

STEM – Science, Technology, Engineering, and Math

VHGT – Van Hiele Geometry Test

CHAPTER 1: INTRODUCTION

The demand for learning good visualization skills at earlier ages is evident when considering elementary school math competencies in the North Carolina Standard Course of Study (NCSCS) (2003). With the onset of advancements in graphics and multimedia, our approach to teaching visualization skills is behind the times (Boakes, 2009; Moorhead, et al., 2006). The literature reports a variety of disciplines requesting the need to increase visualization skills for students and workers to better understand knowledge content (Kozhevnikov, Motes, & Hegarty, 2007; Titus & Horsman, 2009). To some extent the North Carolina (NC) curriculum has addressed this issue by introducing three-dimensional shapes through geometrical principles at an early grade. The introduction of three-dimensional shapes forces students to raise the level of visualization skills and the understanding of higher order geometrical mathematical concepts (Titus & Horsman, 2009).

The focus of this study was to examine the void in the literature about how students respond to three-dimensional shapes and their physical properties at the first grade level. The National Council of Teachers of Mathematics (NCTM) (2004) calls for all "students to become familiar with shape, structure, location, and transformations as they develop spatial reasoning" (p. 97). The organization and development of these skills are necessary in everyday activities for children as well as adults (NCTM, 2004). The purpose of this study was to examine different instructional delivery methods that intentionally focus on developing visualization skills in first grade students.

Background

The North Carolina Standard Course of Study (NCSCS, 2003) aligns with the NCTM and calls for first grade students to learn the basic principle of visualizing shapes. Students are required to identify three-dimensional geometric shapes, demonstrate an understanding of the properties of each shape, and synthesize the relationship of basic shapes to their use in everyday life. Students are introduced to three-dimensional shapes for the first time at the first grade level. Prior to the first grade, students learn about two-dimensional shapes that do not have the same characteristics as their three-dimensional counterparts (NCSCS, 2003).

In order to fully master the creation and manipulation of three-dimensional geometric shapes, students must be able to form mental images of the shapes (Lieu & Sorby, 2009). The mental images can then be operational in more advanced cognitive processes of adding, subtracting, and unioning the geometric shapes to form more complex configurations, which is similar to what is required in understanding the Boolean Coordinate System of three-dimensional modeling (Lieu & Sorby, 2009). The differences in how and when visualization skills develop based on gender and race is unclear in the research which is why the topics were chosen to be further developed by this study.

Introducing pre-engineering concepts in first grade might possibly increase the innovative aptitude of students because aspects of engineering are closely related to innovation (Jorgensen & Kofoed, 2007). Visualization skills are desired by business and industry in the global market despite what profession students pursue later due to the concurrent design aspect of global industrialization (Lundberg, 2010). Fabrication of an innovative environment is perhaps the only distinction United States schools have over other schools in developed countries (Lundberg, 2010; Feldman, 2010). Resourcefulness and creativity are qualities sought after in the manufacturing world. By fostering these qualities and channeling students to increase skills in these areas, the United States may stay competitive in the social, technological, and economic market (Lundberg, 2010; Feldman, 2010).

Under the current curriculum, first grade students are applying introductory engineering principles in the classroom. There is great importance in being able to link the first grade objective to its higher order use to increase visualization skills at a younger age, thereby increasing the innovative activity in the classroom. The mathematics goal three for NCSCS (2003) entails the need for students to compare and contrast differences in the geometric shapes and build problem solving skills using spatial visualization techniques. Limited empirical support can be found for effective ways to teach these skills (Halat, 2006; Guven & Kosa, 2008; Aslan & Arnas, 2007; Van der Sandt, 2007; Brooks, 2009; Van Garderan, 2006; Ernst & Clark; 2007; Scribner & Anderson, 2005). In this study, participants were introduced to multimedia developed with the use of a three-dimensional modeling system and manipulatives created by a three-dimensional printer. Three-dimensional modeling systems provide pictorial projections of objects in a three-dimensional form which is easier to visualize than the two-dimensional drawings configured by hand or a two-dimensional drawing system (Garmendia, Guisasola, & Sierra, 2007; Gow, 2007; Guven & Kosa, 2008). In addition, three-dimensional modeling systems can rotate objects in a manner where all sides and edges can be viewed (Guven & Kosa, 2008; Gow, 2007). Three-dimensional printers provide easy access to prototypes of any solid model (Gow, 2007). Using these technologies to create multimedia and manipulatives allowed students to see how a two-dimensional shape, which they were already familiar with, transformed into a three-dimensional geometric object. The prototypes created from the solid models served as the manipulatives introduced to the students allowing them hands-on experience with each shape which helped increase the visual learning experience (Van Hiele, 1986; Olkun & Tuluk, 2004; Brook, 2009). Research shows how multimedia and manipulatives can increase learning and help create a more innovative learning environment, but a lack of supplies and knowledge about using these tools can inhibit intellectual growth (Kaufhold, Alverez, & Arnold, 2006; Brooks, 2009, Capraro & Capraro, 2006; Ernst & Clark, 2007). This study helped surpass these barriers by versing teachers in proper terminology and providing to every student instructional props that may have been priced out of the normal classroom budget.

By engaging students in a more scientifically advanced approach to learning, they were exposed to technologies that would have, otherwise, been unavailable at that level. A partnership between a Western NC Community College Mechanical Drafting Technology program and the first grade classrooms of a Western NC school district benefitted students, provided professional development for teachers, and supplied each classroom with instructional materials unique to the curriculum. By introducing new delivery methods and instructional materials to first grade teachers, this study served as an example of how partnerships can be developed between higher learning institutions and elementary schools across the nation. Without such partnerships, elementary schools are limited in the type of instruction that can be delivered based on the knowledge of the teacher (Van Driel, Verloop, Van Werven, & Dekkers, 1997; Scribner & Anderson, 2005). Elementary teachers are required to provide instruction in multiple academic areas and are, likely, not experts in all, especially geometric concept domains (Malinsky, Ross, Pannells, & McJunkin, 2006; Kozhevnikov, Motes, & Hegarty, 2007; Van der Sandt, 2007). Current research has been conducted on visualization skills in older children, and it is clear that the demand for visualization skills is apparent in multiple disciplines (Boakes, 2009; Capraro & Capraro, 2006; Kozhevnikov, Motes, & Hegarty, 2007; Moorhead, et al., 2006; Titus & Horsman, 2009). Furthermore, achievement gaps in STEM education are clearly seen in traditionally underserved middle and high school students; however, there is still debate about why the shortfalls are present and what should be done to fill the gap (Liu & Wilson, 2009; Chatterji, 2005; Neuville & Croizet, 2007). There is additional discussion about when the achievement gaps first appear in relation to gender and race (Downer & Pianta, 2006; Mendick, 2005). This study contributed to the literature because it specifically addresses instructional methods that helped increase visualization skills in first grade students and provided some insight on gender and race differences at an early age.

Purpose Statement

The purpose of this quasi-experimental study was to test the effect of different instructional delivery methods (regular, with manipulatives, with multimedia, and with both, manipulatives and multimedia) on first grade students' visualization skills as measured by the NC standard course tests and to examine the impact the different instructional methods had on the achievement of participants of different gender and race. This quantitative study was conducted using the non-randomized subjects, non-equivalent control group design approach (Gall, Gall, & Borg, 2010). Participants were divided into four groups by instructional delivery method, the control group received regular instruction and the three experimental groups received the treatment in the form of different delivery methods. All groups took a standard pre-test. One experimental group received regular instruction with manipulatives added. The second experimental group received regular instruction with multimedia added, and the third group received regular instruction with both, manipulatives and multimedia, added. The independent variables were the delivery method participants received, the gender of each participant, and the race of each participant. The dependent variable was the end of course post-test assessment scores. First grade students from a rural school district in Western NC were studied. Introducing these first grade students to three-dimensional objects and their properties by using different techniques may have helped develop and support the innovative aptitude of each child. Object visualization skills are necessary in technical areas of STEM and according to recent research, may play a large role in other areas as well (Moorhead, et al., 2006).

Significance of the Study

This study had an impact on the STEM community because it provided insight on how early students can be taught skills that will enhance proficiency in visualization. The art of drafting, which is an expression of visualization, is usually introduced to the middle school aged children. Findings from this study suggest children at the first grade level may be adept in this skill. Limited prior research has been conducted in the area (Lin & Dwyer, 2010; Boakes, 2009; Capraro & Capraro, 2006; Kovas, Haworth, Petrill & Plomin, 2007). Furthermore, introducing students to concepts of three-dimensional modeling and part prototyping may have helped them understand product simulation and development. In the long-term, students will be able to relate to part creation in a new way and open future avenues to pursue areas of STEM as a profession of choice. Short-term significance includes a basic skill level students developed as first graders which will lead to more immediate understanding in grades to come. In NC, each subsequent grade curriculum covers geometry topics as part of the standard curriculum. It is imperative that students progress each year with a higher cognitive level of geometrical experience. By second grade, students are introduced to perimeters of shapes. Without the knowledge of shape parameters and terminology to describe each, students will not be fully aware of the mathematical concept. By third grade, students are learning about fractions through the use of solid figures. Again, without being able to describe the solid figure and its properties, students will fall short. In fourth grade, geometry is mixed with Algebraic expressions as students are asked to solve for area and volume given only one related variable. Students must commit to memory the faces, edges, and vertices of solid objects to be able to solve the problems. Learning the proper terminology and descriptions of solid models in the first grade will prepare students for the duration of elementary school competencies.

The type of instruction discussed in this study was made possible by a partnership between a Western NC community college Mechanical Drafting Technology program and Western NC school district. By examining the effectiveness of this partnership, other K-12 partnerships can be considered and encouraged in various service areas across the United States. The schools will benefit because it will allow teachers to be trained on a different approach to teaching mathematical objectives (deCastro & Karp, 2009). The joint venture between the colleges and the schools will help ensure teachers get sustained support for other math and science objectives. In addition, for this study, each first grade classroom was provided enough manipulatives, three-dimensional prints of the geometric figures, for each student. The multimedia, a series of videos created with a three-dimensional modeling system, was original to the NC curriculum and developed by the researcher, who is a professional in the drafting field and lead instructor of the

Mechanical Drafting Technology program at a Western NC community college. Similar supplies and materials could cater to different curriculums for other states.

Research Questions

By using enhanced visualization instruction, teachers were able to change their teaching strategies to help promote visualization skills. Combining the mathematics competency of geometric shapes with the enhanced visualization instruction was a new method that possibly nurtured both visualization and innovation. The research questions for this study were:

1) Did participants' tests scores measured by the standard course assessment significantly differ based on instructional method and gender (male or female)?
2) Did participants' tests scores measured by the standard course assessment significantly differ based on instructional method and race (participants' self-disclosed ethnicity)?

Research Hypotheses

There were six null hypotheses to test for from the research questions. All hypotheses were tested while controlling for between group differences using pre-test scores. The following were the null hypotheses:

Question 1:

H_{o1}: There is no significant difference in the means of participants' test scores based on the instructional delivery method (regular instruction, regular instruction with manipulatives, regular instruction with multimedia, and regular instruction with both, manipulatives and multimedia) and gender (male or female) while controlling for differences between groups with a standard pre-test.

H_{o2}: There is no significant difference in the means of participants' test scores based on instructional delivery method (regular instruction, regular instruction with manipulatives, regular instruction with multimedia, and regular instruction with both, manipulatives and multimedia).

H_{o3}: There is no significant difference in the means of participants' test scores based on gender (male or female).

Question 2:

H_{o4}: There is no significant difference in the means of participants' test scores based on the instructional delivery method (regular instruction, regular instruction with manipulatives, regular instruction with multimedia, and regular instruction with both, manipulatives and multimedia) and race (participants' self-disclosed ethnicity) while controlling for differences between groups with a standard pre-test.

H_{o5}: There is no significant difference in the means of participants' test scores based on instructional delivery method (regular instruction, regular instruction with manipulatives, regular instruction with multimedia, and regular instruction with both, manipulatives and multimedia).

H_{o6}: There is no significant difference in the means of participants' test scores based on race (participants' self-disclosed ethnicity).

Identification of Variables

The independent variables for this study were the instructional methods participants received (regular instruction, regular instruction enhanced by manipulatives, regular instruction enhanced by multimedia, and regular instruction enhanced by both, manipulatives and multimedia), the gender of each participant, and the race of each participant. The four levels of delivery methods were regular instruction, regular instruction enhanced by manipulatives, regular instruction enhanced by multimedia, and regular instruction enhanced by both, manipulatives and multimedia. Regular instruction is defined by the current normal teaching strategy of first grade teachers without any enhancements provided by the study process. Regular instruction enhanced by manipulatives is defined by the current normal teaching strategy of first grade teachers with the addition of manipulatives which are three-dimensional solid objects in standard geometric shapes created by a three-dimensional printer and pattern developments of the geometric shapes. Regular instruction enhanced by multimedia is defined by the current normal teaching strategy of first grade teachers with the addition of multimedia which is a series of videos identifying, describing, drawing, and building basic geometric figures using a parametric solid modeling system. Regular instruction enhanced by both, manipulatives and multimedia, is the current normal teaching strategy of first grade teachers with a combination of the manipulatives and multimedia introduced as part of the study process. The independent variable, gender, has two levels, and each participant's gender is defined as either male or female. Race in this study had four levels, Caucasian, African American, Hispanic, and Multiracial. Race is defined by the ethnic background the participant self discloses himself or herself to be considered. The curriculum materials for enhanced visualization instruction were developed by me, the researcher. The researcher is an experienced drafting and teaching professional having taught visualization skills to high school and adult students for 12 years. The curriculum materials aligned with the objectives for NC standard course of study Mathematics Competency Goal Three and were taught by the regular classroom teacher during the study.

The dependent variable was the end of course assessment scores on the NC standard course of study Mathematics Competency Goal Three measured by the standard course assessment (NCDPI, 2010). Created by the NC Department of Public Instruction (2010), the assessment measures on a grading scale of zero to 100. The highest score is 100.

Definition of Terms

Terminology in the STEM fields, particularly drafting and design, can be misunderstood by individuals who do not have prior knowledge or experience. Many terms can be used interchangeably which can increase confusion. To ensure the interpretation of each term the description can be found in this section.

Contextual Model of Innovation. The contextual model of innovation calls for the "liquid networking and the capacity for collision which means that new ideas need to come into contact with other ideas, often in the form of controversy" (Lundberg, 2010, p.17). Lundberg describes the contextual model of innovation as "cultivating a broader social capacity for organizational innovation, so that all the members of an organization can contribute to the goal of advancing innovation" (p.18).

Innovation. The National Commission on Entrepreneurship (2003) (as cited in Badran, 2007) explains innovation through its proximity to creativity which is "the process of uncovering and developing an opportunity to create value through innovation. Being innovative is closely related to being creative. Seeing possibilities, seizing opportunities, creating new ventures, markets or products are all part and parcel of innovation" (p.575).

Model. Lieu and Sorby (2009) describe a model as "a mathematical representation of an object or a device from which information about its function, appearance, or physical properties can be extracted" (p.1-33).

Three-Dimensional Modeling. Three-dimensional modeling can be described as "mathematical modeling where the appearance, volumetric, and inertial properties of parts, assemblies, or structures are created with the assistance or computers and display devices" (Lieu & Sorby, 2009, p.1-33).

Two-Dimensional Drawing. Two-dimensional drawing allows the drafter to place a three-dimensional object on a two-dimensional sheet of paper. Lieu and Sorby (2009) define two-dimensional drawing as "mathematical modeling or drawing where the appearance of parts, assemblies, or structures are represented by a collection of two-dimensional geometric shapes" (p.1-33).

Visualization. Visualization is "the ability to create and manipulate mental images of devices or processes" (Lieu & Sorby, 2009, p.1-33).

Assumptions and Limitations

Assumptions. The researcher assumed that participants had not been previously introduced to visualization techniques outside of their regular class instruction in previous grades. The study was directed toward first grade students because of the NC standard course of study competencies. Research was prevalent based on the need to increase skills at all levels. First grade students were chosen because of the newness of the content to them at this age. In addition, there was the assumption that all first grade teachers delivering instruction for this study would follow the proper training and procedures for introducing the manipulatives and multimedia in the classroom.

Limitations. Although this study presented valuable information for curriculum and instruction purposes, it was limited by the population sample. The sample for this study was chosen as a sample of convenience from local elementary schools within the service area of a Western NC community college. Results of the study may not represent the general population. Also, this study was designed around the NC state curriculum for first grade students. Curriculum varies by state which could pose additional limitations in generalization of results.

Other possible limitations to this study came in the repeatability of the process. Costly equipment and software was used. Colleges may not have the resources or equipment budget to develop this kind of relationship with elementary schools. Depending on the type of plastic used, the three-dimensional prototypes similar to those used in this study could be expensive to develop, and the software that was used in this study is used exclusively by drafters and designers.

Since the design was quasi-experimental, there were innate threats to validity; however, to control for situations such as the Hawthorne effect, no special attention was given to participants during the study (Gall, Gall, & Borg, 2010). The participants did not know of any differences in instruction from one class to the next. Teachers were only versed in the instructional method they were to deliver. The four types of instruction were not discussed during training of the teachers' roles in the study. The classrooms were randomly assigned to instructional delivery method groups. Teachers delivering regular instruction were not trained on the different enhancements. Teachers delivering regular instruction with manipulatives were only trained on the use of manipulatives. Teachers delivering regular instruction with multimedia were only trained on the use of multimedia, and teachers delivering regular instruction with both multimedia and manipulatives were trained on both. Teachers were asked not to discuss instructional methods during the study time to eliminate any effect the enhanced information may have on teaching strategies and study results.

A pre-test was used to control for differences between groups and ensure homogeneity of variances. External differences between groups should have been minimal because the participants were from the same school system and geographic location. The students should have had similar backgrounds and experiences. The pre-test was similar to the post-test in format and had many of the same questions; the time distance between the pre-test and the post-test limited sensitization.

Research Plan

This study was a quasi-experimental study using non-randomized subjects, non-equivalent control group design approach (Gall, Gall, & Borg, 2010). Participants were divided into four groups by instructional method, the control group received regular instruction, and the three experimental groups received the treatment in the form of different delivery methods. All participants from each group took part in a pre-test. One group received regular instruction with manipulatives added. The second experimental group received regular instruction with multimedia added, and the third group received regular instruction with both, manipulatives and multimedia, added. The scores were analyzed using descriptive statistics to check for normal distribution and the assumption of homogeneity of variances was tested using the Levene’s Test (Howell, 2011). A two-way ANCOVA was used to control for differences between groups and establish whether a significant difference existed among the different sample means based on delivery method and gender main effects and delivery method and race main effects (Stevens, 1996). A follow up test was conducted to evaluate pairwise differences among the delivery method interaction effects using the Tukey's HSD test (Howell, 2011).

CHAPTER 2: LITERATURE REVIEW

Efforts have been underway in the last two decades to increase science and math skills at an early age in order to increase technology and engineering expertise (Garmendia, Guisasola, & Sierra, 2007; Badran, 2007). The United States is experiencing a time of transition in its manufacturing areas (Feldman, 2010). Low-skilled jobs are rapidly moving overseas. Unemployment has skyrocketed since the shutdown of many companies in recent history, and a state of recession lingers in the economy. Industry has been left desolate all over the country (Feldman, 2010). In many cases, the problem is under-trained individuals in technological areas. The global market calls for highly innovative thinkers who bring creativity into the design process (Badran, 2007;Van Driel, Verloop, Van Werven, & Dekkers, 1997; Feldman, 2010).

Visualization has been linked to problem solving, critical thinking, creativity, and innovation which are soft skills sought after in nearly every industry (Feldman, 2010). There is recent research on increasing visualization skills in high school and college students, but little has been directed toward elementary students, especially, as early as first grade (Chatterji, 2005; Downer & Pianta, 2006). Kelly (2004) reported that first grade and every sequential grade after are essential in creating an equal playing field for minorities, especially African-Americans. Once students reach the middle and high school level, mathematics courses are chosen directly based on prerequisites. In his longitudinal study, Kelly (2004) found that in high school "white students are almost twice as likely to be in the top two mathematics sequences as are black students (22.1 percent versus 11.9 percent)" (p.56).

Problem Statement

The problem addressed in this study was that under traditional methods of instruction, students were not currently gaining the knowledge and understanding they could have been if current engineering technologies in the form of three-dimensional software and prototyping were used in a way that supplemented regular instructional methods (Garmendia, Guisasola, & Sierra, 2007; Gow, 2007; Guven & Kosa, 2008). Currently, students and teachers are not seeing the significance of the geometric mathematical competency as it relates to pre-engineering concepts and the higher order geometric concept domains (Boakes, 2009; Capraro & Capraro, 2006; Kozhevnikov, Motes, & Hegarty, 2007; Moorhead, et al., 2006; Titus & Horsman, 2009; Paar, 2005).The mathematics goal three for NCSCS (2003) entails the need for students to compare and contrast differences in the geometric shapes and build problem solving skills using spatial visualization techniques. These two goals are unique and necessitate a different approach in pedagogy than what has traditionally been provided by most teachers (Malinsky, Ross, Pannells, & McJunkin, 2006; Kozhevnikov, Motes, & Hegarty, 2007; Van der Sandt, 2007; Moorhead, et al., 2006).

In this quasi-experimental study, first grade students were asked to participate in a classroom with enhanced visualization instruction designed to fit the NC standard curriculum of study to increase students' visualization skills, thereby increasing their test scores on the standard end of course assessment. The study was a non-randomized subjects, non-equivalent control group quasi-experimental study. Students were not randomly assigned to groups and stayed in their regular classrooms during the instructional period in which the treatment took place; however, classroom assignments for selecting the different delivery groups were random. The purpose of this study was to introduce first grade students to three-dimensional objects and their properties by using different techniques that helped develop and support the innovative aptitude of each child. Combining the mathematics competency of teaching geometric shapes with a contextual approach was an enhanced instructional technique that could have facilitated both visualization and innovation. The contextual model of innovation was used as a basis for developing a visualization curriculum to encourage growth of ideas in students who were for the first time in their school careers being introduced to three-dimensional objects. Object visualization skills are necessary in technical areas of STEM, and there should be a grounded effort to enhance them at an early age (Kozhevnikov, Motes, & Hegarty, 2007). This study provided empirical evidence about promoting visualization skills in first grade students and the differences in achievement that might have occurred between student gender and race. The methodology chapter introduces the participants, setting, instrumentation, procedures, research design, and data analysis for this quasi-experimental study. The findings chapter presents the actual data collected and statistically analyzed. The discussion chapter discloses information about the findings, builds upon the literature found in this section, and points out the need for future research.

The work of Piaget is presented to help build a framework for how children learn and develop spatial and visualization skills. Piaget (1969) held that children build their own knowledge based on active participation and interpretation of learning events. In their early years, children define objects by whether they can be seen and their ability to act on them (Miller, 2011). The structuralism approach Piaget took to thought organization is parallel to the make-up of geometric shapes into tangible more complex objects. In the same way that Piaget thought children organized their thoughts into smaller parts that related to a bigger picture of their mental structure, geometric shapes fit together to form a whole product. Without the geometric shape to serve as a building block, the end product would not exist.

Building upon Piaget's developmental theory, Van Hiele (1986) focused his theory directly on mathematics education in geometry. Van Hiele (1986) also described his theory with operational levels. The Van Hiele theory includes "five levels of reasoning in geometry. These levels are level one, Visualization, level two, Analysis, level three, Ordering, level four, Deduction, and level five, Rigor" (Halat, 2006, p.175). Van Hiele (1986) concluded that in order for a student to achieve a prescribed operational level, the teacher must also be at that level or above.

Previous studies using the Van Hiele theory, such as Aslan and Arnas (2007) and Halat (2006) focused on how children identify two-dimensional shapes. Aslan and Arnas (2007) found that the older the student was, the more likely the student would describe the shape according to its properties. Although findings from the Aslan and Arnas (2007) and Halat (2006) are current and do contribute to the literature, there is still the question of how to provide support that promotes visualization skills in elementary age students. Perhaps the largest void in the literature is how students respond to identifying three-dimensional shapes and defining the properties of each.

Similar to Halat (2006), Van der Sandt (2007) studied the relationship between the teacher's level of geometric thinking based on the Van Hiele theory and the student's level of achievement in geometry in the seventh-grade. Van der Sandt (2007) found that preparing teachers in the content area was very important, but was, perhaps, not enough. In the two year study, Van der Sandt (2007) gave questionnaires to 18 teachers and 224 pre-service teachers to find their Van Hiele level. All pre-service teachers scored no higher than level two with the majority achieving a low level of acquisition. "The 18 seventh-grade mathematics teachers only achieved a low degree of acquisition for both Van Hiele level three (the relevant level for grade seven) and Van Hiele level four (level relevant for high school mathematics)" (Van der Sandt, 2007, p. 4). All students participating in the Van der Sandt (2007) study completed the seventh-grade with a low level of acquisition as well. Van der Sandt's (2007) research has two important implications, teachers are not versed in teaching mathematical concepts of geometry and visualization, and students need the enhanced instructional support they are not currently getting from traditional instruction.

Theoretical Framework

Piaget is one of the pioneer researchers in seeking to understand the development of visualization skills and spatial learning in children. Piaget (1969) discussed the importance of active learning and hands-on experiences in the learning environment. Piaget's theory focused on four stages of development (Hansen & Zambo, 2005). In the primary stage of development for birth to toddler, children respond to objects by their ability to see them and act upon them (Miller, 2011). The next stage of cognitive development includes a more "abstract cognitive map of the relations among objects in the environment" (Miller, 2011, p. 33). Piaget (1971) defines the preoperational period as taking place between the ages of two to seven. Children are more focused in the thought process and are able to use mental images to differentiate between objects that have different characteristics, but are categorized by type, for example, the triangle (Hansen & Zambo, 2005). Because of the great differences in ability from a two year old and a seven year old, more modern theorists and Piaget, himself, moved away from stages to more operational levels of learning (Miller, 2011). What does this mean to the modern day educator? Miller (2011) states that the emphasis should not be on how advanced the child is at a particular subject, but the means it takes to acquire knowledge of the subject matter. "Another important notion is that learning is most likely to occur when the child actively participates" (Miller, 2011, p. 72).

Van Hiele (1986) built upon the developmental theory, but his focus was mathematics education, specifically geometry. As a Montessori teacher, Van Hiele (1986) was influenced by the Gestalt theory. As he established his own philosophy, he also used operational levels to describe a child's progress (Van Hiele, 1986). The Van Hiele theory includes "five levels of reasoning in geometry. These levels are level one, Visualization, level two, Analysis, level three, Ordering, level four, Deduction, and level five, Rigor" (Halat, 2006, p. 175). Van Hiele (1986) concluded that student success in gaining understanding at each stage would require the teacher to be at that level or above on the subject. Van Hiele's levels of geometry have been investigated by many researchers such as Wirszup (1976), Usiskin (1982), Fuys, Geddes, and Tischler (1988), Halat, (2006) and Guierrez and Jaime (1988) over the last three decades. Van Hiele's levels have been found valid at the secondary level and have been used in elementary studies (Aslan & Arnas, 2007; Halat, 2006).

Aslan and Arnas (2007) studied the way children ages three to six recognized geometric shapes. Their experimental study was conducted with four groups, separated by age, of 100 Turkish students who were asked to identify two-dimensional shapes of circles, squares, rectangles, and triangles. The study was based on the Van Hiele Theory (Aslan & Arnas, 2007). Once the shapes were identified, the children were asked why they chose each shape as a circle, square, rectangle, or triangle. The children's responses were recorded and categorized as to whether the shape was identified visually or by the shape's properties (Aslan & Arnas, 2007).

The NC first grade assessment is conducted in much the same way as the Aslan and Arnas (2007) study. By asking students to verbally explain the shapes, they are exhibiting a higher level of cognitive query. Aslan and Arnas (2007) found that older students were able to define the shapes through statements about their physical properties, whereas, younger students may have described the shape in a different way. Aslan and Arnas (2007) noted that "while 84 percent of the property responses were correct, only 63 percent of the visual responses were correct" (p. 90); however, overall there was no statistically significant difference between the mean scores of correct answers in any of the four groups studied. Aslan and Arnas (2007) mainly focused on preschool and kindergarten age children who identified shapes based on their previous learning experiences. They did not provide instruction for the participants to teach them about the shapes. Another difference was that Aslan and Arnas (2007) used two-dimensional shapes as a basis for their study. Literature about students' responses to three-dimensional shapes and their properties is certainly less common because the research is not yet available (Khairulanuar, Nazre, Jamilah, Sairabanu, & Norasikin, 2010).

Halat (2006) also based his research on the Van Hiele Theory of teaching and learning geometry. Halat's (2006) quasi-experimental study used 150 sixth-grade geometry students as participants. Halat (2006) focused on finding the relationship of mathematical proficiency in geometry to gender and motivation. Participants were given a pre-test and post-test of the Van Hiele Geometry Test (VHGT) (Halat, 2006). Halat (2006) found no statistically significant difference in participant's scores in either gender or motivation. He did find that "none of the sixth-grade students in the study progressed beyond level-II (analysis)" (p. 179) of the VHGT. Again, Halat's (2006) research clearly adds to the recent literature, but focuses on middle school students instead of the elementary level. Halat (2006) also used two-dimensional shapes in the learning process instead of their three-dimensional counterparts. The insignificance of the role of gender in Halat's (2006) study is worth noting here as well.

Review of the Literature

This section outlines the major components of research that provide evidence as to the need for further research on promoting visualization skills in first grade students. There are few specific findings on the aspect of three-dimensional geometric concept domains for first grade students. Because this is new territory, the literature reviewed came from similar situations in older children and related literature. Topics about STEM and differences in achievement based on gender and race were of particular importance. The literature reviewed were scholarly articles primarily found through Liberty University Library portal and databases such as ERIC and PsycINFO. The literature review is meant to inform the reader about the value of visualizations skills to all individuals and what it means to provide longevity in engineering endeavors throughout the US to maintain a certain quality of life that would otherwise be unavailable compared to what is has been over the last century. The literature review spans the larger picture of how visualization is related to design and innovation, and also probes for more specific findings on how strong visualization skills can be developed in a specific group of children who are for the first time in an organized setting using critical thinking skills to analyze solid objects.

The Concurrent Design Process

Higher order visualization skills have always been required in the areas of engineering and manufacturing due to the nature of product development and production (Garmendia, Guisasola, & Sierra, 2007; Branoff, et al., 2005). Consumers often take for granted that their cars will start when the key is turned or that coffee will be made upon the push of a button. These products and thousands more are created each day to benefit the common person. The last two decades have spawned a new way to develop products (Lieu & Sorby, 2009). Three-dimensional parametric solid modeling programs changed the way new products are created (Gow, 2007). Since the introduction of three-dimensional parametric solid modeling systems to the market, other industries such as gaming and advertising have utilized the same concepts to create more visually enhanced products or services of their own (Lieu & Sorby, 2009). These industries do not require the accuracy engineering industries need, but the scientific visualization software created for these industries use the same basic structure of the Boolean coordinate system (Lieu & Sorby, 2009).

Three-dimensional visuals do help people, who are not technically trained, see objects more clearly; however, because of the advanced pictorial representation, some experts argue that the need to teach visualization skills does not have the high priority it once had before the rise of three-dimensional parametric solid modeling systems (Garmendia, Guisasola, & Sierra, 2007; Gow, 2007; Scribner & Anderson, 2005). "Since the advent of computer-aided design (CAD) systems in the early 1980s, nearly all US engineering schools eliminated courses in descriptive geometry, and most schools also eliminated manual drafting and sketching in their introductory graphics courses" (Ault & John, 2010, p.13). Since this change in curriculum took place, Ault and John

(2010) report that even in areas of engineering, visualization skills are noticeably lacking.

The concurrent design process is a network process where product development is considered by all stakeholders from the engineer to the consumer (Branoff, et al., 2005). Anyone involved at any point in the life cycle of the part can access part drawings and make changes at any time. The three-dimensional parametric modeling system acts as a nucleus in this network. "3D CAD software is currently accepted among researchers and practitioners as the primary medium for communicating and implementing innovative research and design ideas in industry, as well as a means of increasing competitiveness in the global market place" (Ferguson, Ball, McDaniel, & Anderson, 2008, p.3). The system's associative properties allow for dynamic updates in real time. Globalization of product development and distribution would not be possible without such systems (Lieu & Sorby, 2009; Feldman, 2010). Before concurrent design, manufacturers used a linear design process where one group or department was responsible for only one aspect of the product development at a time (Branoff, et al., 2005). This type of design process was limited in seeing the whole life of the part from creation to disposal. Because communication was less feasible between groups, product development was often inefficient and short sighted (Branoff, et al., 2005; Feldman, 2010). With the parametric solid modeling system, companies can communicate world- wide without difficulty. The drawing, itself, is a form of communication which helps overcome former language barriers.

The concurrent design process is driven by everyone in the company where communication takes place through the three-dimensional parametric solid modeling system. Opening the lines of communication can increase efficiency and even spark innovation within, but it may cause problems for those who do not have enough skill in visualizing the part (Branoff, et al., 2005; Gorska, & Sorby, 2008; Lundberg, 2010). The concurrent design process actually increases the need for visualization skills especially in non-traditional areas such as financing, marketing, and sales (Branoff, et al., 2005; Gow, 2007). Schools of engineering are still leading the way to help close the gap of visualization inadequacies. Researchers are using the very same technology that they are teaching for product development but in a new way to develop instructional methods that will enhance visualization skills in their students (Jorgensen, & Kofoed, 2007; Ault & John, 2010; Lieu & Sorby, 2009). "In general, these methods involve increased sketching of 3D objects, use of manipulatives (3D objects), and computer graphics animations of rotating 3D objects" (Ault & John, 2010, p.16). This study parallels the research design sought by engineering instructors, but the audience is much different. From the literature review, it is apparent that there is a need for increased visualization skills. If positive results are seen by implementing manipulatives and multimedia in college settings, then the same should be true at a lower level when tied in appropriately to the curriculum.

The Importance of Innovation

The concurrent design process opens channels for innovation by including a diverse group of individuals instead of just the engineering and production departments. Ferguson, Ball, McDaniel, and Anderson (2008) discussed the "relevance of competitive pressures and technological advances compelling industries to become more innovative, efficient, and productive through new technologies that will enable innovative rapid product development" (p.3). Contemporary research shows that innovation is more of a product of social interaction than individual talent (Lundberg, 2010). Most often, significant ideas come from a slow fade of give and take among many people. This type of social contestation to provide innovative clusters is based upon the contextual model of innovation.

Badran (2007) suggested there are spikes in innovation followed by a dwell period without much change. Badran (2007) proposed that understanding the human and the environment leads to innovation. Badran's (2007) focus was on engineering education since engineers are considered to be the leaders in innovation by coming up with new products and improving usage of existing products. Badran (2007) advocated that all engineered products are strategies to make human life easier. Engineering is technology based; therefore, innovation must be technology based (Badran, 2007;Van Driel, Verloop, Van Werven, & Dekkers, 1997). Using technology in the classroom as part of the curriculum is a natural step in the emergence of new developments.

Jorgensen and Kofoed (2007) discussed teaching students to be innovative through problem based learning and continuous improvement which they specifically defined by a list of characteristics considered by experts in the area to represent innovation. Their study focused on student views to particular situations. The researchers designed the study so the students could guide the research process (Jorgensen & Kofoed, 2007). Jorgensen and Kofoed (2007) explained that innovation is not simply taught; it is a continuous process of improvement. Students can be taught to critically think about new solutions even when results have been met. When designing with parametric solid modeling systems, multiple solutions are easily formed, manipulated, and, in many cases, tested before a prototype is created (Lieu & Sorby, 2009; Branoff, et al., 2005).

Ferguson, Ball, McDaniel, and Anderson (2008) studied the effects of adding three-dimensional dissection manipulatives to an introductory college course of

Technology Systems. Their study included two groups of students who either took part in a class where instruction was conducted with or without manipulatives (Ferguson, et.al., 2008). The course had both STEM and non-STEM majors. According to the results, the experimental group with manipulatives had a higher growth in visualization skill (Ferguson, et.al., 2008). It is important to note that the two groups were unequal in academic skill (Ferguson, et.al., 2008). The control group without manipulatives had a higher pre-test mean than did the manipulatives group; however, the manipulatives group averaged 7% higher growth than did the control group without manipulatives at only a 2% growth (Ferguson, et.al., 2008). This evidence shows that manipulatives in the form of three-dimensional solid models can help provide a means to close the gap in visualization abilities in diverse majors, not just engineering.

By involving students in a higher level learning process involving three-dimensional shapes, teachers can increase visualization skills necessary for skilled and non-skilled trades and promote innovative environments in the classroom. Teaching students enhanced visualization skills at an early age will help build the foundation for more efficient and inventive design facets later (Van Driel, Verloop, Van Werven, & Dekkers, 1997). By using the same technology as industry, students will become more familiar with design concepts and will likely embrace advanced visualization with ease in years to come (Van Driel, et al., 1997). Studies show that instructional delivery methods implementing advanced technologies can have a positive effect on assessment outcomes, but there is still debate about the combination of enhancements that work, the length of treatment time, and the age appropriateness of the content and materials. This study does investigate each of these variables to hypothesize answers based on significance in the results. Regardless of the instructional method, teachers must thoroughly understand the material before they are able to teach it to others and develop their own advanced instructional techniques.

Instructional Delivery Methods

Instructional delivery methods can provide an atmosphere in the classroom that is conducive to learning. Providing the right mixture of instructional tools and strategies can be challenging even for the most seasoned teachers. A common characteristic found among teachers is intrinsic motivation to help their students succeed; however, teachers, or anyone else, cannot progress beyond their scope of knowledge (Malinsky, Ross, Pannells, & McJunkin, 2006). This study questioned the visualization skills of students in the first grade, but students can only be expected to learn as much as the teacher is capable of sharing. The direct purpose of this study was to increase visualization skills in students; an indirect and less obvious focus of this study was to help teachers become more aware of accurate geometric terminology and principles. Elementary school teachers have to deliver instruction on many subjects each day. Much emphasis is placed on reading, writing, and number sense which is a valid way to spend classroom time, and a plethora of training and support is available for these topics (Malinsky, Ross, Pannells, & McJunkin, 2006; Van Driel, Verloop, Van Werven, & Dekkers, 1997). Teachers spend more time on what they know and what they have been trained on in professional development. Conversely, that means less time for objectives like geometry, and many may tend to move through competencies they have less support for at a quicker pace (Kozhevnikov, Motes, & Hegarty, 2007). In this study, teacher support was provided and subtle professional development on geometric concept domains was incorporated into the research design and treatment strategy with the intention of helping teachers improve content knowledge.

Van Driel, Verloop, Van Werven, and Dekkers (1997) discussed the importance of content knowledge of the curriculum in relation to providing an innovative environment. Their study ties in directly with the problem statement of how first grade teachers may be inadequately prepared to provide the type of environment needed to promote necessary skills because of the lack of knowledge of pre-engineering visualization concepts. Van Driel et al. (1997) proposed that practical knowledge and personal experiences pave the way for enhanced pedagogical practices which will more likely stimulate an innovative environment. First grade students in North Carolina are required to learn about geometric shapes as math competency goal three for the state curriculum. Teachers at this age level are usually not versed in the importance of this modest objective (Malinsky, Ross, Pannells, & McJunkin, 2006; Kozhevnikov, Motes, & Hegarty, 2007). Introducing this pre-engineering concept early can increase the aptitude of students who will likely need visualization skills despite what profession they later choose to pursue because of the concurrent design aspect of global industrialization (Lundberg, 2010; Lieu & Sorby, 2009; Feldman, 2010).

Students need to have hands-on experiences with the shapes (Boakes, 2009; Brooks, 2009). Another difficulty with teaching geometric shapes in the first grade may be lack of supplies (Kaufhold, Alverez, & Arnold, 2006; Olkun & Tuluk, 2004). Many classrooms may not be equipped with a set of geometric figures for each child. One of the objectives in the competency is to draw the geometric shapes. Again, appropriate supplies such as drafting paper and equipment may be limited (Kaufhold, Alverez, & Arnold, 2006). Even if the supplies are readily available, teachers may not have the background knowledge to fully engage the student in the task (Brooks, 2009). With the help of rapid prototyping, a process easily accessible in most college engineering programs, the geometric shapes can be effortlessly modeled and built in a three-dimensional printer. Specialty drafting supply sources can be shared, and teachers can gain support from more experienced colleagues. Support can come with shared curriculum materials such as multimedia and manipulatives similar to those created for this study.

Olkun and Tuluk (2004) studied the use of manipulatives and different forms of social interaction in teaching for understanding in geometry for pre-service teachers. Their goal was “to move the students toward more formal use of the concepts and higher level of thinking” (as cited by Van Hiele, 1986 in Olkun & Tuluk, 2004). As often the case in most classrooms, Olkun and Tuluk (2004) did not have enough manipulatives for each student in the class; thus, they were limited by demonstrating the props instead of students having one-on-one time discovering the geometric shapes for themselves. As with others studies reported on, Olkun and Tuluk limited their geometric exploration to two-dimensional shapes instead of three-dimensional solid objects.

Manipulatives can be thought about as tangible objects, but multimedia comes in different forms. In one study, Capraro and Capraro (2006) used children’s literature to enhance achievement in middle school student’s end of year geometry test scores. Capraro and Capraro (2006) completed a quasi-experimental study of 105 sixth-grade students. Out of the three groups, one story and two non-story, the data showed a statistically significant difference in participant’s scores between the story group and the non-story groups (F =28.60, 4; $p = 1.50\times10^{-15}$; R^2 =.549) (Capraro & Capraro, 2006, p.29). In addition to the story, the participants were given real props to study and measure for geometric properties such as circumference, diameter, and radius. These concepts were outlined in the children’s stories read to the students in class; therefore, they were able to understand the concept better when they actually were on task (Capraro & Capraro, 2006).

Using enhancements in the form of manipulatives and multimedia were found to be helpful instructional tools; however, the need is still very apparent. Baki, Kosa, and Guven (2011) reported on why "it is important to find a better way to teach mathematics and geometry than the use of current methods, which do not pay sufficient attention to spatial reasoning" (p.292). In their literature review, Baki, Kosa, and Guven (2011) discuss different previous studies that were successful in increasing visualization skills and spatial reasoning when implementing manipulatives and graphic software for engineering courses. They also report that non-engineering courses were not as successful. This framework may point to non-engineering teachers' personal experience and ability in visualization, which lead them to conduct their study on increasing the visualization skills of pre-service mathematics teachers (Baki, Kosa, & Guven, 2011). Baki, Kosa, and Guven (2011) had three groups in their study: One group received traditional instruction, the second group received instruction with manipulatives, and the third received instruction with three-dimensional multimedia. They found a significant difference in scores of the two experimental groups who received the instructional enhancements (Baki, Kosa, & Guven, 2011). The Baki, Kosa, and Guven (2011) study was very similar to the design approach and the results of this study. The uniqueness of this study is that it was conducted with much younger participants, but as stated before, the same results should be expected. One important concept to keep in mind that follows the Van Hiele (1986) structure is that students are only going to achieve the level of knowledge in which their teacher has achieved. Teacher training then becomes a priority for many schools and especially for those teachers with non-STEM backgrounds.

The Role of Gender and Racial Differences in Mathematics

Achievement gaps in STEM education are clearly seen in traditionally underserved middle and high school students; however, there is still debate about why the shortfalls are present and what should be done to fill the gap (Liu & Wilson, 2009; Chatterji, 2005; Neuville & Croizet, 2007). There is further debate about when the achievement gaps first appear (Downer & Pianta, 2006; Mendick, 2005). Silverman, Choi, and Peters (2007) suggest that gender differences in visualization dates back to the hunting and gathering era. Gender roles in that era were discussed as having a lasting effect on evolution of society and the separation of job norms for men and women (Silverman, Choi, & Peters, 2007). This occurrence proposes that differences in visualization do not come from skill, but through evolutional development (Silverman, Choi, & Peters, 2007). In their research, Silverman, Choi, and Peters (2007) tested over 250,000 participants from over 200 countries. Participants were given visual stimuli to study, and then, asked to look at a separate slide with the same visual stimuli to see which pictures had changed position (Silverman, Choi, & Peters, 2007). Findings from 40 countries, that met the minimum number of participants of both male and female, were analyzed showing consistent results that men outscored women in all nationalities represented (Silverman, Choi, & Peters, 2007).

Other studies are not as profound, but do suggest that a difference in visualization ability among males and females occurs in mass across cultures. Janssen and Geiser (2012) discussed male dominance in different cultural societies may have a "strong biological basis for male-female differences in spatial cognition, although environmental factors as well as the interplay between nature and nurture also play a significant role for the development of sex differences across the life span" (p.535). Instead of answering the question of why gender differences across cultures are apparent, Janssen and Geiser (2012) chose to look at strategies to even these abilities among cultures that are disadvantaged. Janssen and Geiser (2012) gave adolescent and adult participants from two countries, one developed and one underdeveloped, a visualization test. Afterwards, they surveyed the participants to see what type of strategy they used to find a solution to the problems (Janssen & Geiser, 2012). Janssen and Geiser (2012) found that those from the developed country used a holistic approach to visualization which allowed them to mentally visualize the shapes as a whole which is consistent with former research in that males use a holistic approach more often than females. Knowing that intentional strategies like the holistic approach can help increase visualizations skills supports the need to provide different instructional methods that could enhance visualization abilities in disadvantaged students.

The scope of this study does include gender and racial differences in spatial visualization skill, but the focus is on elementary age students, specifically first grade. Research aligning with this group of participants was narrow and findings were harder to pinpoint consistency in the literature. Take for instance, Chatterji's (2005) study on mathematical achievement gaps in kindergarten and first grade students. Chatterji (2005) also focused on the differences in achievement based on race, gender, and socio-economic background. His findings showed that kindergarteners exhibited clear achievement gaps relative to these factors; however, by the end of the first grade, Hispanic students leveled out while achievement gaps of African American and females were still significant (Chatterji, 2005). Chatterji (2005) linked achievement to class size, school size, and the community environment to reasons for low achievements from these groups. There were 2300 participants from 182 schools in Chatterji's (2005) study, but the study focused on the entire mathematic curriculum instead of specialized areas. Some experts argue that certain aspects of mathematics such as geometry and spatial concepts may be more favorable for girls' abilities rather than boys (Kovas, Haworth, Petrill, & Plomin, 2007; Liu & Wilson, 2009).

Similar to Chatterji (2005), Downer and Pianta (2006) looked at achievement gaps for students in the first grade. Both studies related gaps to previous and unchangeable conditions of the students such as family life, race, and gender. While these factors are vital to educational research, the researcher intended to look at instructional strategies that could possibly help fill those gaps at the current time no matter what the preceding life experiences were for the student. It is important to note that Downer and Pianta (2006) discussed the environment of the classroom as a predictor of cognitive development. Creating an innovative environment with enough materials and use of multiple delivery methods can possibly raise academic competence in students across culture and gender.

Guay, et al. (2010) discussed that the achievement of students may be based on motivation. Even in elementary school, differences in intrinsic and extrinsic motivation can factor into student success (Guay, et al., 2010). They "argue that intrinsic motivation may develop before identified regulation, because children are involved in a variety of tasks, becoming more interested in some and less interested in others (Guay, et al., 2010, p.713). Out of 425 participants, 225 being girls and 200 boys, Guay, et al. (2010) found that girls were significantly more likely to be intrinsically motivated in areas of reading and writing, while boys were more intrinsically motivated in areas of math.

Achievement gaps may not be based on minority or gender status at all. Jordan, Kaplan, Locuniak, and Ramineni (2007) and Howell and Kemp (2010) discuss the development of number sense in relation to mathematic achievement. Jordan et al. (2007) found that "background characteristics of income status, gender, age, and reading ability did not add explanatory variance over and above number sense" (p. 42). Number sense is a large part of mathematics, but is not a specific factor on a student's ability to identify, describe, draw, and build basic geometric figures.

The US is not the only country concerned about the spatial visualization skills of students (Silverman, Choi, & Peters, 2007; Janssen & Geiser, 2012). Over the last five decades, global studies have shown noticeable spatial visualization ability differences between gender and race all over the world (Voyer, Voyer, & Bryden, 1995; Kimura, 1999). To understand more about this phenomenon, researchers developed several visualization tests over the years (Gorska & Sorby, 2008). The test most commonly used in engineering programs found in US universities is the Purdue Spatial Visualization Test (PSVT) (Guay, 1977; Ault & John, 2010; Titus & Horsman, 2009). The PSVT tests students' descriptive geometry abilities to see objects rotated from their original form, to perceive how an object will take shape from a development, and to visualize a perspective view of an object from a given point (Guay, 1977).

This test and others like it have grown in practice all over the globe (Ault & John; 2010). Ault and John (2010) compared results in the US with those of other developed countries. Findings indicated that among engineering students results were similar, an average of about 75% on the PSVT (Ault & John; 2010). However, among non-industrialized countries and even some disadvantaged areas in the US, scores were significantly lower which points to differences in culture or race as a possible predictor (Ault & John; 2010). Ault and John (2010) also noted that gender differences were significant among other countries as well. In their study, Ault and John (2010) introduced visualization software and curriculum enhancements to African engineering students in an effort to increase visualization skills. In a short time after implementation, the African students' scores on the PSVT were raised significantly.

Defining why there is a difference in achievement related to gender was beyond the scope of this study. The researcher was more interested in understanding whether a difference actually exists between first graders in a specialty area of mathematics and how delivery methods may play a part in leveling the playing field for all students. Based on his findings, Chatterji (2005) suggests that smaller schools may have better performance from minority and female populations. Because the Western, NC elementary schools fit this category, it was interesting to see that the results of this study did support Chatterji's (2005) previous research. In addition, the results of this study also aligned with the findings from Ault and John (2010) in that enhancements in the form of manipulatives and multimedia in the instructional delivery can help close the gap in visual inadequacies among students.

Geometric Concept Domains

Geometric concept domains are conceptions of geometric principles and the way individuals store, process, and interpret geometric objects (Gorska & Sorby, 2008). Visualization skills are generally observed and measured by how an individual perceives an object in a rotated form, how an individual accurately identifies a shape in its three-dimensional form when presented in its two dimensional form, and how an individual recognizes rotations from various focal points around a three-dimensional object (Guay, 1977). Visualization skills are needed in many areas, but are most obviously sought after in science, technology, engineering, and math (STEM) (Page, Bailey, & Van Delinder, 2009). Studies conducted on gender differences in this field show a difference in job acquisition and retention between women and men; furthermore, minorities are also underrepresented (Page, Bailey, & Van Delinder, 2009).

According to the National Science Foundation (2006), only 21.7% of individuals employed in science and engineering careers were minorities. Although women made up approximately 42% of the entire science and engineering jobs, only 4% were Asian, 3% were Black, 2.5% were Hispanic, and less than 1% were American Indian/Alaskan Native. There is not complete agreement on why boys outperform girls in STEM related subjects while in school; but this seems to be a predictor of job placement later (Kovas, Haworth, Petrill, & Plomin, 2007). Research specifically on minority achievement in STEM related subjects has its boundaries (LaRocque, 2008), but how instruction influences student achievement based on gender and race was addressed in this study.

Understanding how children develop geometric concept domains may be as simple as observing them while they are at play. Some researchers argue that boys develop more adept geometric concept domains because of the nature of the toys they play with even before they attend any type of organized schooling (Casey, et. al., 2008). Others contend that early interactions may be partially responsible for spatial development, but intrinsic reasons may best describe why differences show up between genders (Levine, Huttenlocher, Taylor, & Langrock, 1999). Perhaps a better question to ask is how can deliberate instruction provide meaningful progress in individuals who may have a disadvantage in geometric concept domains at an early age? Development of a baseline process can help students in both short-term and long-term achievement. Students who gain confidence in their learning abilities early on are more likely to be successful in high school and college which will open more doors for career choices later.

Brooks (2009) discussed the relationship between the hands-on drawing process and the development of visualization skills by children. Brooks' (2009) study is directly related to the research of this study in that, as of yet, there is no clear way to provide the support students need to build a strong foundation for visualization skills. Brooks (2009) stated "like any other activity children do encounter problems when drawing and many adults seem to be at a loss as to how to support children's drawing efforts" (p. 323). The findings reported by Brooks (2009) helped to determine the direction and approach for this study. Brooks (2009) developed a model combining thought and drawing. She calls the combination "visual thought" which leads to meaning for the child (Brooks, 2009, p.326). The focus of Brooks' (2009) study was scientific visualization which closely relates to mathematical visualization, a component vital to this study.

Van Garderen (2006) linked the problem based approach in mathematics to the visualization skills necessary in promoting understanding among students. Van Garderen's (2006) study drew conclusions on a strong relationship between the need to develop visualization skills in students in order for them to critically think about mathematical problems, especially word problems. The findings of this study directly link spatial and visual abilities to mathematical performance (Van Garderen, 2006).

Similar to Brooks (2009), Ernst and Clark (2007) discussed the role of visualization in scientific communities. Their study focused on the power of graphics and multimedia in engineering and technology curriculums to help students develop good visualization skills. The software used to develop the two-dimensional and three-dimensional scientific presentation models is similar to the software used in engineering design. The difference is the parametric and associative qualities found in the engineering software which makes the models more precise for manufacturing purposes.

Associativity is a term in modeling that describes the linkage of models, drawings, and assemblies and how they dynamically update all files by only changing one (Lieu & Sorby, 2009).

Guven and Kosa (2008) conducted a pre-experimental study on the effects of three-dimensional software on helping student teachers develop better visualization skills. This study provides evidence to support the relationship of graphical software in the building of visualization skills. The study's findings are directly related to the focal point of this study in looking at what can be done to promote these skills at an earlier age. It also supports the problem statement in the study that teachers may not be conversant enough to provide the quality of instruction the NC mathematical competency calls for. Guven and Kosa (2008) found that parametric modeling software does enhance visualization skills because of its advanced features and graphics.

Casey, et. al. (2008) studied the simple effect of introducing building blocks to help build visualization skills and boost the students' abilities in geometry later. Casey, et. al. (2008) also argues that little importance is placed on geometry in lower grades because of the other objectives teachers have to cover. By implementing an instructional method that may already be present as a dramatic play entity, teachers can incorporate new ideas with minimal overhead (Casey, et. al., 2008). Casey, et. al., (2008) had three groups of students. The control group did not receive the intervention while two experimental groups received a block building intervention. One experimental group also received a storytelling exercise in addition to the block building (Casey, et. al., 2008). Children were given a specific design criteria for a structure in which post-test performance was raised by eight percent with a significant effect for the experimental block building groups, $F(1,91) = 3.54$, $p = .033$. Students with both block building and storytelling scored the highest (Casey, et. al., 2008). Casey, et. al., (2008) also mentioned the variation of social status with the schools in their study.

Research points to enhanced instruction as an effective way to boost geometric concept domains in students regardless of age, race, or socioeconomic status. The results of this study undeniably enforce this method of hands-on learning. The research calls for better implementation of learning tools. Teachers do not have to feel alone in their instructional endeavors. New delivery methods may seem overwhelming, but support can be found nearby. Most school systems are in close proximity to colleges or universities with instructors or support staff who are excited about reaching out to their service areas.

Benefits of Community College and School Partnerships

The type of instruction discussed in this study was made possible by a partnership between a Western NC community college Mechanical Drafting Technology program and Western NC school district. By examining the effectiveness of this partnership, other K-12 partnerships can be considered and encouraged in various service areas across the United States. The schools will benefit because it will allow teachers to be trained on a different approach to teaching mathematical objectives (deCastro & Karp, 2009). Pay-off for colleges may not be as immediate, but partnerships can develop strong relationships with people in the community that could be a source of recruitment later. These future students will have the educational background in mathematics and visualization skill to successfully pursue STEM programs in college. Not only will degree seeking students be readily accepted into the STEM programs, but “researchers have found positive correlations between spatial visualization ability and successful completion of engineering and technology degree requirements" (Ferguson, Ball, McDaniel, & Anderson, 2008, p.2). Students who have exercised visualization competencies over their childhood years will have the knowledge and experience it takes to prosper in a higher education facility.

All colleges and universities can provide support, but the community college seems to be at the forefront for community outreach. Community colleges and school partnerships are not new phenomena; states have been reaping the benefits of these joint efforts for years (Barnett & Hughes, 2009; Marrow & McLaughlin, 1995). In recent times, NC high school students have benefited from opportunities for dual enrollment, Huskins, and Learn and Earn Online programs where students earn college credit and high school credit by completing college courses while simultaneously enrolled in high school (NCDPI, 2008). Other states offer similar programs with high schools students, and some states have mentoring programs at the middle school level (Berkeley & And, 1997; deCastro, & Karp, 2009; Gould, Brimijoin, Alouf, & Mayhew,2010). These interactive programs help schools offer more career and technical courses without incurring the heavy cost of equipment and supplies. Students have the twofold benefit of gaining college credit which also counts toward high school graduation credits (NCDPI, 2008).

Community college systems are generally smaller and play a large role in serving traditionally underserved populations (Provasnik & Planty, 2008). Kelly (2009) reports that disadvantaged students who do not have the support they need at early ages may never reach a college level math course much less graduate with a college degree. Community colleges may be a better alternative for these students because of the services they offer and the size of the institutions. "Community colleges enroll a diverse group of students, with various reasons for going to college, and have larger percentages of nontraditional, low-income, and minority students than four-year colleges and universities" (Provasnik & Planty, 2008, p.24). This service is especially apparent in areas of STEM where schools are not equipped to teach all subjects effectively (Jarvis & Quick, 1995; Lin, & Dwyer, 2010). In light of new legislation by the NC Board of Education (NCBE), the Career and College Promise initiative, as outlined by the NC State Board of Community Colleges (NCSBCC) (2008), is going to make these partnerships more important than ever. The Career and College Promise initiative will allow students to choose a career cluster in high school that aligns with a college program of study (NCSBCC, 2008). Students are encouraged to complete the college program while still in high school or shortly thereafter (NCSBCC, 2008). This initiative is a tremendous opportunity for students, but requires the students to make decisions on career selection as early as middle school; therefore, the partnership in this study is not as implausible on a wide scale as it may seem at first thought. By laying down the foundation for success early, students will be able to make good choices in middle school. Helping teachers and guidance counselors understand the pathway process will enable them to advise students properly to make the most out of their primary and secondary school experience (Barnett & Hughes, 2009; Marrow & McLaughlin, 1995). A cooperative environment is essential in transitioning students to the next level. Educational partnering can be a cooperative movement that serves as a model of innovation. A close network can provide the most meaningful experience for all involved.

According to Van Hiele (1986), students should be at a level three out of the five levels of geometric reasoning by the time they reach seventh grade. Teaching students to be effective learners with good visualization skills is imperative in elementary school. By schools partnering with community college programs at the elementary level, the interaction can have positive paybacks for teachers and students which could lead to a smoother transition later. The researcher intended to develop this type of partnership through this study by incorporating enhanced visualization instruction into elementary classrooms where students were given the opportunity to physically lay their hands on solid geometric models, debate the functional qualities of each shape, and learn from advanced modeling software in the form of multimedia presentations.

Quality partnerships can be a life preserver for teachers, but just as Ault and John (2010) explained, even colleges have seen recent struggles in increasing visualization skills of incoming students. As with other colleges around the country, the Western NC community college in this study cut out manual board drawing from the curriculum in 2005. Geometric constructions are still taught with board drawing tools; however, the time spent on this competency is limited to a couple class meetings. At the same time, NC high schools launched a new drafting blueprint and end of course VOCATS test for all NC high school drafting courses (Branoff, et. al., 2005). The high school curriculum paralleled the college trend and placed heavy emphasis on computer aided drafting with use of two-dimensional and three-dimensional software programs (Branoff, et. al., 2005). These changes in curriculum at the high school and college level are keeping up with new technological advances as required in career and technical courses, but the change also requires students to have the same visualization skills that may have once been enhanced by the lessons taken away. If this is the case, then more and more STEM courses will look to elementary schools to help promote basic skills such as visualization at an earlier age so students will be ready to take on the vast technological tools that have become teaching objectives in high school and college.

Summary

The literature reviewed in this section was comprehensive and explored a broad spectrum of ideas and concepts about aspects of visualization. The inspiration for this study came from an engineering perspective in a global economy. Skills and abilities associated with engineering are problem solving, critical thinking, creativity, and spatial thinking. These characteristics are commonly interchanged with verbiage describing innovation. The desire for every teacher is to inspire students to perform to the best of their abilities. Spatial ability is a skill that is often overlooked, but very important in areas of STEM. "The commonly mentioned salient skill among the various definitions of spatial ability is visualization" (Baki, Kosa, & Guven, 2011, p.292). After exploration of previous studies, there is still much to be examined in the way visualization skills are addressed in the classroom. Most studies reported findings on adolescent or adult participants, but more recent research seems to naturally progress toward younger participants since geometric concepts have started being introduced at these earlier ages. Research on younger participants may be the most challenging because validated instruments for this age group may not be available and creating an experimental environment can and should be restricted in most cases.

By taking the challenges discussed and findings from previous research into consideration, this study was shaped to specifically explore visualization skills of first grade students in NC. Since increasing the impact on the STEM community was a grounded theme for imperial significance, the role that gender and race played in student achievement at the first grade level was also regarded. The effect of the two variables of gender and race on achievement has been an underlying question in STEM research for some time, but a clear answer is yet to be found. Varying ideas still surround the differences in minority and gender representation in STEM education and career fields (Liu & Wilson, 2009; Chatterji, 2005; Neuville & Croizet, 2007).

The multimedia and manipulatives used in this study helped students learn to identify, describe, draw, and build basic geometric figures as prescribed by the NC standard course of study Mathematics Competency Goal Three (NCSCS, 2003). Studies do show that instructional tools and enhancements in manipulative and multimedia form have helped students' growth and achievement in mathematical subjects, but there are still gaps in when and how instructional delivery should take place. In addition, subject matter experts point to lack of content knowledge as an indicator of limitation in student achievement. The literature was clear on the need for further research and the educational community will be enlightened from the findings of this study. Certainly, this study did not fill in the gaps entirely, but findings did establish that gender and race were not deemed a significant factor in student success. As supported by the literature, the instructional delivery method was found to be a significant predictor of post-test outcomes.

CHAPTER 3: METHODOLOGY

The methodology chapter covers the chronological approach it took to conduct the study and provides an overview of the environment and sample. The methodology was carefully planned so the study could be completed during the 2011-2012 school year with data collection at the end of the yearly cycle. All materials used in the study had to be created and distributed before instruction started on the math competency three. Teacher training had to be conducted before that time as well. Pseudonym names of the school district, community college, and elementary schools taking part in the study were used in this chapter and throughout the manuscript. Chapter three introduces the participants, setting, instrumentation, procedures, research design, and data analysis for this quasi-experimental study. Each section is outlined for clear interpretation and reproduction.

Introduction

The purpose of this study was to introduce first grade students to three-dimensional objects and their properties by using different techniques that develop and support the visualization skills needed to master math competency three. Combining the mathematics competency of geometric shapes with the contextual approach to innovation was a new method that could have nurtured both visualization and innovation. The contextual model of innovation was used as a theory basis for developing visualization curriculum materials to encourage growth of ideas in students who were for the first time in their school careers being introduced to three-dimensional objects. Object visualization skills are necessary in technical areas of STEM, and it should be a grounded effort to enhance them at an early age (Kozhevnikov, Motes, & Hegarty, 2007). Under traditional methods of instruction, students are not currently gaining the understanding and seeing the importance of this mathematical competency as it relates to subsequent grades and, perhaps, pre-engineering concepts (Titus & Horsman, 2009; Paar, 2005). This study provided empirical evidence about promoting visualization skills in first grade students and the differences in achievement there might have been between student gender and race.

Research Design

Nine classes in four different elementary schools located in the same district were randomly assigned to treatment and control groups, and data was collected both, before and after, the treatment. This study was thus a quasi-experimental study using the non-randomized subjects, non-equivalent control group design approach (Gall, Gall, & Borg, 2010). This research design was chosen because the participation in research projects policy code for the Western NC school district does not allow for research to disrupt instructional time. A true experimental design would have been the most rigorous research and preferred, but school policy prohibited random assignment. In this case, the strongest design with the least amount of disruptions was the non-randomized subjects, non-equivalent control group design approach (Gall, Gall, & Borg, 2010). While the research was instructional in nature, random assignment of students to groups would call for students to be separated from their normal classroom. This experience could have caused disruption and elevated the occurrence of the Hawthorne effect (Gall, Gall, & Borg, 2010). Furthermore, assigning groups by classroom allowed for the teachers to be trained and deliver the enhanced instruction which lent to personal experience and professional growth for later classes.

The independent variables for this study were the delivery method participants received, the gender of each participant, and the race of each participant. The dependent variable was the end of course assessment scores on the NC standard course of study Mathematics Competency Goal Three measured by the standard course assessment. The covariate was the pre-test scores. The curriculum materials for enhanced visualization instruction were developed by the researcher who is an experienced drafting and teaching professional having taught visualization skills to high school and adult students for 12 years. The curriculum materials aligned with the objectives for NC standard course of study Mathematics Competency Goal Three and were taught by the regular classroom teacher during the study. The four delivery methods were regular instruction, regular instruction enhanced by manipulatives, regular instruction enhanced by multimedia, and regular instruction enhanced by both, manipulatives and multimedia. Regular instruction is defined by the current normal teaching strategy of first grade teachers. Regular instruction with manipulatives is defined by the current normal teaching strategy of first grade teachers with the addition of manipulatives which are three-dimensional solid objects in standard geometric shapes created by a three-dimensional printer and pattern developments used for creating paper models. Regular instruction with multimedia is defined by the current normal teaching strategy of first grade teachers with the addition of multimedia which is a series of videos identifying, describing, drawing, and building basic geometric figures using a parametric solid modeling system. Regular instruction with both, manipulatives and multimedia, is the current normal teaching strategy of first grade teachers with a combination of the two. Gender of each participant is defined as either male or female. Race is defined by the ethnic background the participant self-discloses himself or herself to be considered. Race was identified by teachers through current school records.

The treatment was in the form of enhanced visualization instruction which included the introduction to solid objects through hands-on activities with rapid prototypes and visual stimuli from a three dimensional solid modeling system. Students stayed in their regular classrooms during the instructional period in which the delivery method took place. This intentional strategy was to allow regular first grade teachers to be active players in the instructional activities meant to help them in their teaching of the subject knowledge.

The questions this study attempted to answer were:

1) Did participants' tests scores measured by the standard course assessment significantly differ based on instructional method and gender (male or female)?
2) Did participants' tests scores measured by the standard course assessment significantly differ based on instructional method and race (participants' self-disclosed ethnicity)?

Participants

The participants were drawn from a convenience sample of 164 students from the first grade classrooms of four schools in a Western NC school district. All 164 students with their parents' permission were asked to participate. With only seven students not given parental consent, the volunteer rate was 96%. Overall, there were an even number of boys, $n = 81$, and girls, $n = 76$, participating. The participants were randomly assigned by classroom to either the control or one of the three experimental groups. At least 30 participants per group were required for the non-randomized subjects, non-equivalent control group design approach (Gall, Gall, & Borg, 2010). Approximately 60 to 65 participants per group were suggested for the use of an ANCOVA analysis for medium to large effect size with a statistical power of .80 (Howell, 2011). There were 34 participants in the control group. The remainder of the participants was divided between the three experimental groups: 1) the manipulatives group had 35 participants, 2) the multimedia group had 35 participants, and 3) the both, manipulatives and multimedia, group had 53 participants.

Setting

A Western NC school district is the site where this study was conducted. The Western NC school district is governed by a Board of Education. There are currently eight board members. The administrative structure is similar to others commonly found in the K-12 system. Teachers from each school report to the school principals. The principals report to the Director of Curriculum and Instruction who reports directly to the Superintendent. The Western NC school district has seven schools for students in various grades from pre-kindergarten to twelfth grade. The district has about 2700 students. The NC Department of Public Instruction (NCDPI) requires that students in grades three through twelve undergo testing as a passing requirement to go to the next grade. All schools met or surpassed the state requirements based on data displayed in the last four years (NCDPI, 2008).

There were four elementary schools that took part in the study. All four schools are rurally located public schools in the foothills of Western NC. The population of each school is predominantly white, but there were other nationalities represented too, including African American, Hispanic, and Multiracial. Each school offers a preschool and after school program as an additional service to the community. Each elementary school has had recent (within the last ten years) renovations or additions to its buildings. The square footage for each classroom was appropriate for the number of students. Every classroom was equipped with technological teaching tools such as document cameras, a teacher computer, and other devices. For the most part, there was evidence that each teacher used the tools regularly. There was also evidence of some consumable supplies in each classroom, but none of the classrooms taking part in the study had materials such as those provided by the study.

The central elementary school serves about 450 students. There were three first grade classes with a total of 54 students at the time of data collection. The northern and the southern elementary schools serve about 350 students each with a total of 81 first grade students at the time of data collection. The western elementary school serves about 250 students with two first grade classes totaling 29 students at the time of data collection. There were 157 total participants for this study. The first grade class sizes were small, 14 to 21 students each, which made for appealing sites for the study. The researcher is familiar with the administrators and teachers at the schools. Considering the researcher is originally from the area, assimilation into the school environment was conducted with ease. The study required several visits to the classrooms throughout the year. Students were familiar with the researcher's presence and were not aware of any differences in the instruction. The teachers were helpful and eager to use the instructional materials with their students.

Treatment

The experimental groups received curriculum materials to use as part of their instructional delivery method. The three treatment groups were divided by delivery methods: 1) regular instruction enhanced by manipulatives, 2) regular instruction enhanced by multimedia, and 3) regular instruction enhanced by both, manipulatives and multimedia. Groups using the manipulatives were given enough manipulatives for each student. The manipulatives were solid figures that, to the common person, would look like nothing more than building blocks. Each set of manipulatives had nine solid figures: 1) cube, 2) rectangular prism, 3) pentagonal prism, 4) hexagonal prism, 5) octagonal prism, 6) cone, 7) sphere, 8) square pyramid, and 9) cylinder. Pattern developments of paper manipulatives were also given for each student. The types of solid figures created were deliberate for alignment with the curriculum, and a set with these unique figures could not be commonly found in stores.

Teachers were asked to implement these props as part of their daily lesson plans for competency three. Students were already receiving instructional materials in the form of worksheets from their standard math workbook. Teachers used some slides and visual aids provided by the text publishing company. A few teachers had a building block set they used as a visual to hold up in front of the class. None of these strategies were taken away. Teachers were simply asked to pass out the set of nine solid figures to students as they were instructing them on the properties of the shapes. Students were then able to have a personal hands-on experience with the solid figure. Students were asked to make live comparisons between plane figures and solid figures. Students were also asked to combine the shapes to make a more complex object and determine which solid figures could stack, slide, or roll. Students used the solid figures to conclude how many faces, edges, and vertices were on each. Students were asked to compare the solid figures to everyday items within the classroom to recognize geometric figures in all objects. The pattern developments were cut out by the students and glued together to make their own paper solid figures. The fold and cut lines on the pattern developments were used to label and count the faces, edges, and vertices as well.

The multimedia was developed as a series of videos covering the specific geometry topics for the competency. The videos were packaged on a DVD labeled

Geometric Shape Series and given to teachers in the appropriate groups. The five videos were: 1) Plane Figures, 2) Combining Shapes, 3) Solid Shapes, 4) Find the Shape, and 5) Line of Symmetry. Each video aligned with the state competency. Again, teachers were already using workbooks and other instructional aides to help demonstrate the geometric concepts. The videos served as an enhancement. They started with the basics of plane figures and worked through how a shape went from a two-dimensional figure to a three-dimensional solid object. Teachers were asked to show the videos and use their own worksheets as a supplement to the videos. All the videos combined were about one hour of instructional material. The videos were created using several different software editing packages, but the graphics were created using a parametric solid modeling system. The videos were narrated with proper geometric terminology.

Classrooms using both, manipulatives and multimedia, were able to implement an audio/visual, as well as, a hands-on experience for each student. After all data was collected at the end of the study, each first grade classroom received all the instructional materials created no matter what group they had been assigned to previously. These materials can be used repeatedly with future students. As part of the college and school partnership, teachers were also encouraged to remain in contact with me for further support or updates they would like to share.

Instrumentation

The NC standard assessment for first grade students was used as the instrument for measuring visualization ability for both the pre-test and post-test. The NC standard assessment is used statewide to determine students' growth and achievement according to the NC curriculum competencies. The course assessment for first grade students is deemed valid and reliable according to the NC Department of Public Instruction (NCDPI)

(2010). "NC End Of Grade (EOG) and End of Course (EOC) tests administered operationally produce subscale scores that correlate highly with total scores (r = .70 to .95)" (NCDPI, 2010, p.75). This reliability score reflects the consistency of test outcomes over the last four years (NCDPI, 2010). Questions from the standard assessment are taken from the course blueprint competencies to ensure the validity of each (NCDPI, 2010). The assessment measures on a grading scale of zero to 100. The highest score is 100. There is also a standard pre-test similar in format to the post-test with the same grading scale. In 2008 NC petitioned "input from the Blue Ribbon Commission on Testing and Accountability, the State Board of Education crafted the Framework for Change - twenty-seven recommendations to dramatically change the scope of the Standard Course of Study and assessments and testing" (NCDPI, 2008). On October 22, 2010, the standard tests of NC were approved under Title I of the Elementary and Secondary Education Act of 1965. A copy of this approval letter is found in Appendix A.

Procedures

Permission from the school board in the Western NC school district was sought before proceeding with the study. A letter of request was sent to the Director of Curriculum and Instruction at the Western NC school district's central office (See Appendix B). The letter granting approval from Western NC school district can be found in Appendix C. Before beginning research and collecting data, Liberty University's IRB approval was requested and granted. The letter of IRB approval is found in Appendix D.

In this quasi-experimental study, first grade students were asked to participate in a classroom with enhanced visualization instruction designed to fit the NC standard curriculum of study to increase students' visualization skills thereby increasing their test scores on the standard end of course assessment. This study adhered to guidelines of the National Research Act of 1974. Participants were not physically or mentally harmed in any way. Permission was obtained from parent(s) or legal guardian(s) of each participant. Each parent and student was asked to sign a Parental Consent Form and Participant Ascent Form which can be found in Appendices E and F. The Parental Consent and Participant Ascent Form were sent home with the student. A letter explaining the study accompanied the form (See Appendix G). The students were offered a small incentive in the form of colorful pen, valued at one dollar, if the consent and ascent forms were returned within a week. The students received the incentive whether they participated in the study or not. Participation was completely voluntary. Students who were not given parental consent still received the instruction since it was part of their regular day; however, their pre-test and post-test scores were not reported to me for use in the data analysis.

Meetings with teachers and administrators at the four elementary schools were held to outline their needs and roles for the study. The letter requesting a meeting with each is found in Appendix H. There were nine first grade classrooms taking part in the study. After random assignment, the classrooms were coded as letters of the alphabet, A through I. Group One was the control group and consisted of classrooms A and B. Group One classroom teachers delivered regular instruction without enhancements. Group Two was an experimental group and consisted of classrooms C and D. Group Two classroom teachers delivered regular instruction enhanced by manipulatives. Group Three was an experimental group and consisted of classrooms E and F. Group Three classroom teachers delivered regular instruction enhanced by multimedia. Group Four was an experimental group and consisted of classrooms G, H, and I. Group Four classroom teachers delivered regular instruction enhanced by both, manipulatives and multimedia. A code manual was created as a master key for me to match which classrooms were assigned to each group.

As part of their class assignments, the researcher had students in a DFT 154 Introduction to Solid Modeling course create solid models of all the geometric shapes required to identify and describe based on the first grade curriculum. This aspect of the partnership served as instruction on modeling and prototyping for college students as well as visualization for the elementary students. The researcher allowed for time to create sets of three-dimensional prints of the geometric shapes to use as manipulatives. Although the study only calls for manipulatives for key experimental groups, a set was prototyped for each student in first grade. The schools kept the prototypes for further instructional use when the study was complete. The geometric shapes were modeled using the SolidWorks parametric solid modeling system and printed on a Dimension three-dimensional printer. The pattern developments were also created using specialized drawing software. Pattern developments allowed students to create their own paper models. The researcher also created a series of five multimedia simulation videos outlining the physical properties of the geometric shapes, how the shapes transform from two-dimensional to three-dimensional, and how primitive shapes come together to form complex objects. The multimedia simulation videos aligned with worksheets students normally completed. The worksheets then served as a supplement to the video instruction. Example pictures and screen shots of the materials can be found in Appendix I. A full six weeks was allotted to prepare tools, software, and other instructional materials for the study. The curriculum creation timeline is found in Appendix J.

Training was conducted with first grade teachers of the experimental Groups Two, Three, and Four to instruct them on implementation of curriculum materials. There was no training required for control Group One teachers. The training took place during various teacher workdays when professional development was required by the school system. The study was quasi-experimental because students were not randomly assigned to groups but stayed in their regular classrooms during the instructional period in which the delivery method took place. This approach was required by the school board, but became an intentional strategy to allow the actual first grade teachers to be active players in the activities meant to help them in their teaching of the subject knowledge. The classrooms were randomly assigned to an instructional delivery method using random selection in SPSS. All first grade teachers held a current teaching license by the state of NC. The difference in training for study purposes was that teachers delivering regular instruction were not trained on the use of the study materials, the manipulatives and the multimedia. Teachers delivering regular instruction with manipulatives were only trained on the use of the manipulatives. Teachers delivering regular instruction with multimedia were only trained on the use of the multimedia, and teachers delivering regular instruction with both multimedia and manipulatives were trained on both. Teachers were asked not to discuss instructional methods during the study time to eliminate any effect the enhanced information may have had on teaching strategies and study results. The training schedule is found in Appendix K. During training, teachers were coached to complete the same tasks their students would have done in the enhanced instruction environment. They were introduced to the curriculum materials, and the researcher explained how to incorporate the instructional materials into their regular teaching routine. Teachers were trained on separate days according to classroom assignment.

Pre-tests for math objectives in the first grade had already been administered by the classroom teachers earlier in the school year. Scores for the pre-tests were coded by the classroom teachers for their individual students. A list of scores was reported to me with the students' classroom assignment, gender, and race indicated beside each score. All participant scores were reported anonymously and identified only by classroom assignment. Classroom assignments were only shared with the classroom teacher of which they were given. All classroom assignments are kept in a confidential code manual that is locked in a separate filing cabinet from the data reports. At no time were participant names indicated.

The instruction was carried out during the fourth six weeks grading period at each school site. During the last six weeks grading period, teachers administered the standard post-test by NC testing guidelines. Scores for the post-tests were coded by the elementary teachers' for their individual students. A list of scores from each classroom was reported to me with the student classroom assignment, gender, and race indicated beside each score. An example of reporting procedures can be found in Appendix L.

The Family Educational Rights and Privacy Act of 1974 was also adhered to in this study. The instruction was conducted in the safe environment of their regular classroom. The participants were not embarrassed or singled out. Individual work and test scores were not and will not be made public. The scores were only seen by the school, classroom teacher, and me. The classroom teachers conducted the assessment during the regularly scheduled testing time in the sixth six-weeks of the normal grading period. No deception was required to conduct this study.

Data Analysis

The participant assessment scores were recorded and analyzed. Out of 164 possible participants, there were seven students who were not given parental consent to use their pre-test and post-test scores in the study. Descriptive statistics including the standard deviation, variance, and range are reported. The data was analyzed to see if the population distributions were normal. The first method used was a histogram. In addition, a Kolmogorov-Smirnov and Shapiro-Wilk test was run to compare the distributions to see if they are the same across classrooms (Howell, 2011). It was assessed that the pre-test scores had a linear relationship with the post-test scores and that there was no violation of the regression homogeneity in the population (Stevens, 1996). Levene's Test for Equality of Variance was used to determine if the population distribution had equal variances (Howell, 2011).

When all assumptions were met, a two-way ANCOVA was used for testing hypotheses while controlling for academic differences between groups and establishing whether a significant difference existed among the different sample means based on delivery method and gender. An additional two-way ANCOVA was used for testing hypotheses to control for academic differences between groups and establish whether a significant difference existed among the different sample means based on delivery method and race. The ANCOVA was the analysis method of choice for this study because it was a pre-test, post-test design where the pre-test served as a covariate to control for academic differences between groups making the design stronger (Stevens, 1996). The ANCOVA analysis allows for error variance to be removed from the dependent variable and corrects for initial group differences, thereby, increasing the power of the analysis. In the statistical breakdown, main effects and interaction effects between the independent variables, instructional delivery method, gender, and race were analyzed. An evaluation of the multiple comparisons for delivery method was completed using the Tukey's HSD test (Howell, 2011). The Eta squared statistic as interpreted based on Cohen's *d* (1988) was used to determine the effect size, and power was also reported. A significance level of 95%, $p < .05$, was used for all analyses in the study to determine if the null hypotheses could be rejected.

CHAPTER 4: FINDINGS

Chapter 4 presents the analysis of the factual data found in this study. The purpose of this quasi-experimental study was to test the effect of different instructional delivery methods (regular instruction, regular instruction enhanced with manipulatives, regular instruction enhanced with multimedia, and regular instruction enhanced with both, manipulatives and multimedia) on first grade students' visualization skills as measured by the NC standard course tests and to examine the impact the different instructional methods had on the achievement of participants of different gender and race. This quantitative study was conducted using the non-randomized subjects, non-equivalent control group design approach (Gall, Gall, & Borg, 2010).

There were a total of 157 participants in this study. Participants were divided into four groups by instructional delivery method, the control group, and the three experimental groups. All groups took a standard pre-test. One independent variable was the delivery method participants received which had four levels: 1) the control group received regular instruction, 2) one experimental group received regular instruction with manipulatives added, 3) the second experimental group received regular instruction with multimedia added, and 4) the third group received regular instruction with both, manipulatives and multimedia, added. The dependent variable was the end of course post-test assessment scores. The descriptive statistics for the pre-test and post-test scores are found in Table 1 and Table 2.

Table 1

Descriptive Statistics for Pre-test Scores by Instructional Delivery Method

Instructional Delivery	*n*	Mean	Std. Deviation
Regular	34	43.97	14.42
w/ Manipulatives	35	37.60	15.21
w/ Multimedia	35	40.11	10.89
w/ Both	53	44.60	11.81
Total	157	41.90	13.23

Table 2

Descriptive Statistics for Post-test Scores by Instructional Delivery Method

Instructional Delivery	*n*	Mean	Std. Deviation
Regular	34	73.91	12.79
w/ Manipulatives	35	79.48	13.07
w/ Multimedia	35	82.94	9.18
w/ Both	53	83.71	9.97
Total	157	80.47	11.74

The other two independent variables were the gender of each participant (two levels) and the race of each participant (four levels). There were a total of 81 males and 76 females participating. The four different races reported were Caucasian (*n*=114), African American (*n*=9), Hispanic (*n*=24), and Multiracial (*n*=10).

Table 3

Descriptive Statistics for Pre-test Scores by Gender

Student Gender	*n*	Mean	Std. Deviation
Male	81	41.63	13.32
Female	76	42.20	13.21
Total	157	41.90	13.23

Table 4

Descriptive Statistics for Post-test Scores by Gender

Student Gender	*n*	Mean	Std. Deviation
Male	81	79.42	12.59
Female	76	81.61	10.75
Total	157	80.47	11.74

Table 5

Descriptive Statistics for Pre-test Scores by Race

Student Race	*n*	Mean	Std. Deviation
Caucasian	114	43.44	13.59
African American	9	35.11	15.39
Hispanic	24	37.04	10.18
Multiracial	10	42.20	10.02
Total	157	41.90	13.23

Table 6

Descriptive Statistics for Post-test Scores by Race

Student Race	*n*	Mean	Std. Deviation
Caucasian	114	79.39	12.08
African American	9	79.67	12.12
Hispanic	24	85.46	8.73
Multiracial	10	81.60	12.34
Total	157	80.47	11.74

Question 1:

The first question this study sought to answer was: Did participants' tests scores measured by the standard course assessment significantly differ based on instructional method and gender (male or female)? The first null hypothesis was: There is no significant difference in the means of participants' test scores based on the instructional delivery method (regular instruction, regular instruction with manipulatives, regular instruction with multimedia, and regular instruction with both, manipulatives and multimedia) and gender (male or female) while controlling for academic differences between groups with a standard pre-test.

The two-way ANCOVA was used to examine the independent variables and dependent variable for statistically significant mean differences while controlling for between group differences in academic skill using the pre-test scores (Stevens, 1996). The dependent variable was continuous, the independent variables were discrete, the samples were independently drawn and normally distributed, and the variances were equal (Howell, 2011; Stevens, 1996). The pre-test and post-test scores were first checked for normality by using a histogram. In the pre-test assessment, the scores ranged from a minimum of 4 to a maximum of 73. In the post-test assessment the scores ranged from a minimum of 38 to a maximum of 100. Both the pre-test and post-test scores had a slightly negative skew, but the skewness and Kurtosis were close to one, indicating normality.

Table 7

Comparison of Descriptive Statistics for Pooled Pre-test and Post-test Scores

Assessment	*N*	Mean	Std. Deviation	Skewness	Kurtosis
Pre-test	157	41.90	13.23	-.16	-.26
Post-test	157	80.47	11.74	-.59	.17

In addition, the assumption of normality was evaluated within groups using the Kolmogorov-Smirnov and Shapiro-Wilk tests (Howell, 2011). The tests showed evidence that within two groups, regular instruction and regular instruction with both manipulatives and multimedia, the scores were not normally distributed. The evidence supported normality for the other two groups by a significance greater than alpha which was .05 (Howell, 2011). The Kolmogorov-Smirnov and Shapiro-Wilk tests also indicated normality between groups by gender. When tested using a scatterplot, the pre-test scores covariate did show a linear relationship with the post-test scores dependent variable with the fit lines appearing straight. There was no violation of the regression homogeneity in the population which was tested using the F-test for the assumption that the pre-test scores covariate was unrelated to the instructional delivery method (Stevens, 1996). The F-test results of the interaction between pre-test scores and instructional delivery method were statistically insignificant at alpha level .05.

The assumption of homogeneity of variances was tested and found tenable using the Levene's Test, $F(7, 149) = 1.31$, $p = .25$. The two-way ANCOVA indicated there was not a statistical difference in the mean of scores shown in the tests of between-subject effects. After adjusting for the pre-test, the delivery and gender interaction analysis showed, at $\alpha = .05$, $F(3, 148)= 1.22$, $p =.30$, partial $\eta^2 = .02$, $\delta= .32$. The effect size as interpreted by Cohen (1988) was small, .02, which indicates that only 2% of the variance in post-test scores can be explained by the interaction effect of delivery method and gender. The observed power of .32 indicates a possibility of a Type II error if the null hypothesis was rejected; thus, there was not enough evidence to reject the null hypothesis. Figure one charts the adjusted means of post-test scores based on the interaction of the four levels of instructional delivery and the two levels of student gender.

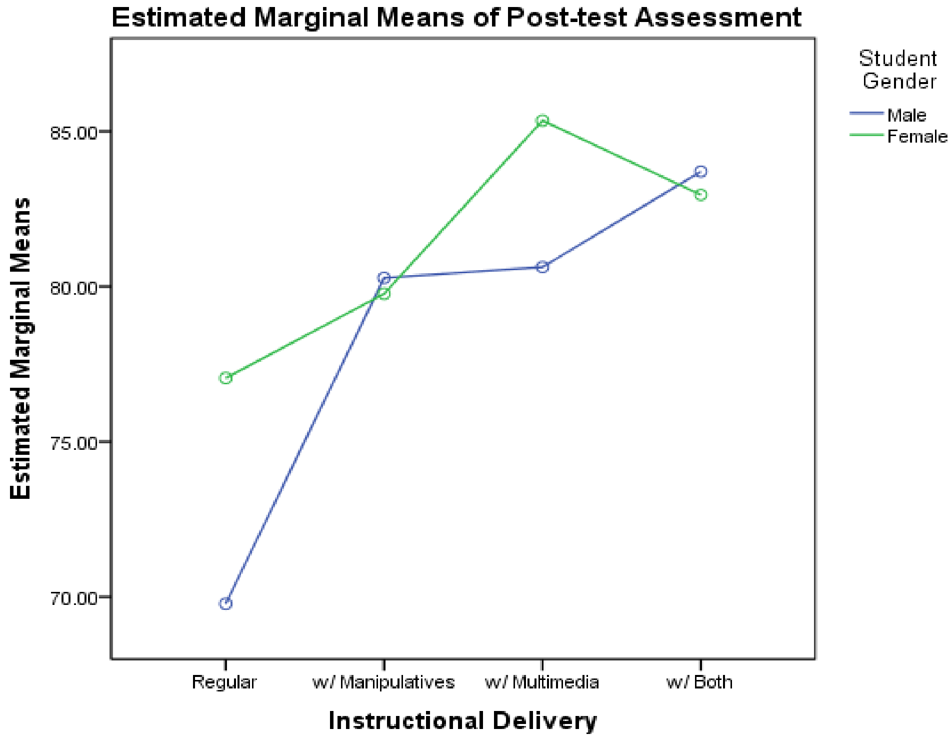

Figure 1. Profile plot for post-test scores based on the four levels of instructional delivery and student gender.

The second null hypothesis was: There is no significant difference in the means of participants' test scores based on instructional delivery method (regular instruction, regular instruction with manipulatives, regular instruction with multimedia, and regular instruction with both, manipulatives and multimedia). Instructional delivery method was found to be a significant factor in determining post-test assessment scores, $F(3, 148)= 6.39$, $p =.00$, $\eta^2 = .12$, $\delta= .97$. The r value for instructional delivery analysis was .67. Findings showed that the effect size was larger; 12% of the variance in post-test scores can be explained by the delivery method variable (Cohen, 1988). Furthermore, the power of the test was .97 which indicates limited error. The second null hypothesis was rejected based on statistical evidence.

The ANCOVA revealed a statistical significance for the main effect of instructional delivery; therefore, an evaluation of the multiple comparisons was completed using a post hoc Tukey's HSD test for within group interactions (Howell, 2011). The adjusted means for each group based on instructional delivery method are shown in Table eight.

Table 8

Descriptive Statistics Comparison of Means and Adjusted Means by Instructional Delivery Method for Post-test

Instructional Delivery	*n*	Mean	Adjusted Mean
Regular	34	73.91	73.42
w/ Manipulatives	35	79.48	80.02
w/ Multimedia	35	82.94	82.99
w/ Both	53	83.71	83.33

Note. The data for adjusted mean was evaluated while controlling for the pre-test covariate.

There was a significant difference, $p < .05$, found between the means of post-test scores between the regular instruction group and each of the three other instructional delivery groups, regular instruction with manipulatives (p =.04), regular instruction with multimedia (p =.00), and regular instruction with both manipulatives and multimedia (p =.00). There were no other significant differences between the three experimental groups. Figure two charts the adjusted means of post-test scores based on the four levels of instructional delivery. By analyzing the adjusted means for each group, there is a notable difference in the means. The experimental group participants who received enhanced instruction averaged 8.69 more points on their assessments than did the control group participant.

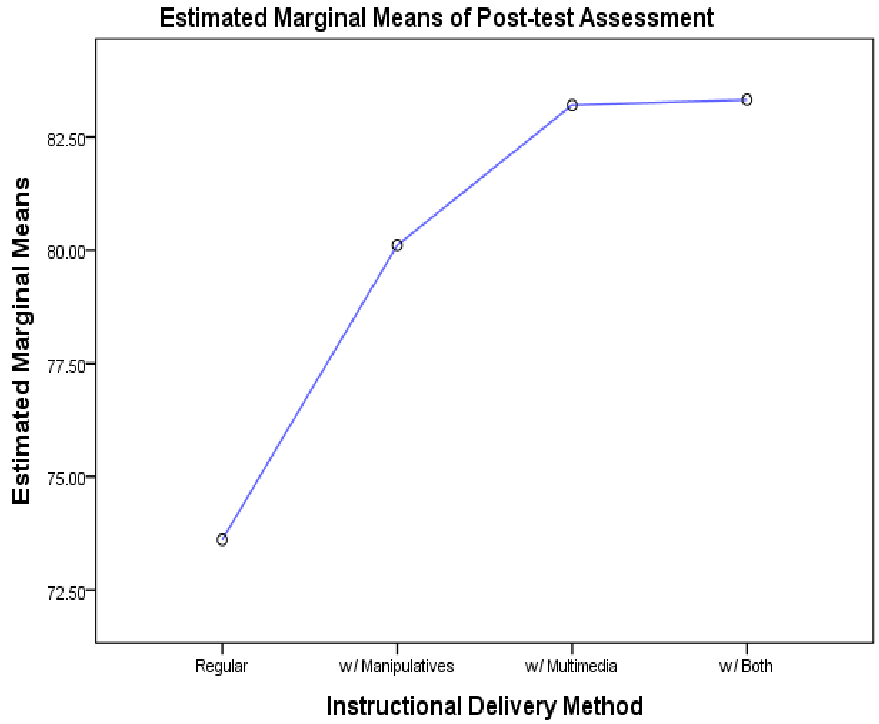

Figure 2. Profile plot for adjusted means of post-test scores based on the four levels of instructional delivery.

The third null hypothesis was: There is no significant difference in the means of participants' test scores based on gender (male or female). Gender was not found to be a significant factor in determining post-test assessment scores, $F(1, 148) = 2.19$, $p = .14$, $\eta^2 = .02$, $\delta = .31$. As with the interaction effect of delivery method and gender, the gender main effect only accounted for 2% of the variance with a low power as well. Therefore, the third null hypothesis could not be rejected. Figure three charts the adjusted means of post-test scores based on the two levels of student gender. As seen in the chart, girls outscored boys by an average of 2.19 points.

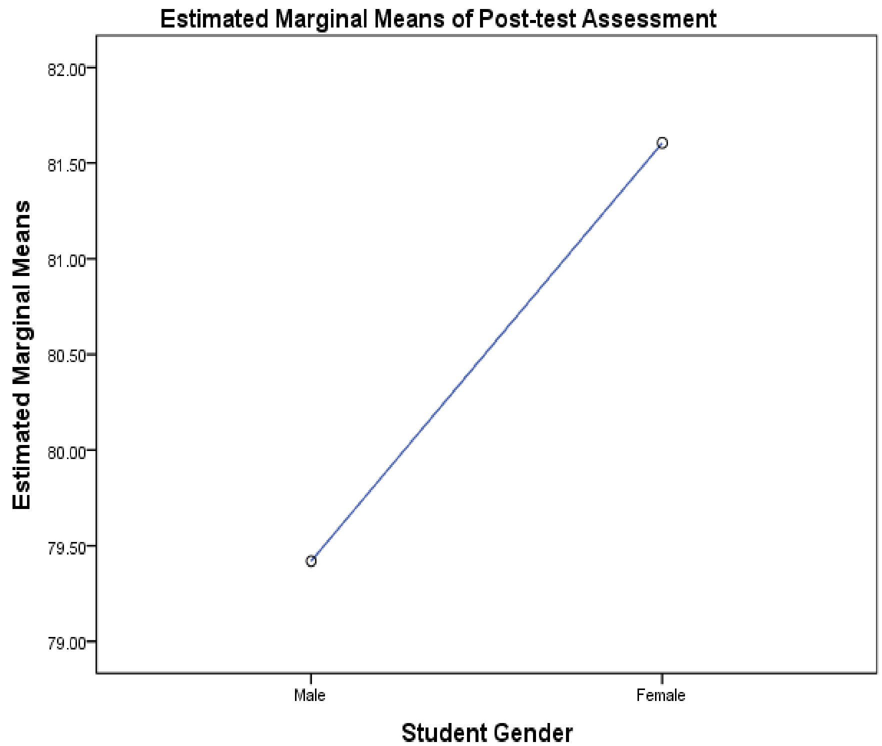

Figure 3. Profile plot for adjusted means of post-test scores based on student gender.

Question 2:

A second two-way ANCOVA was computed to test the fourth null hypothesis of: There is no significant difference in the means of participants' test scores based on the instructional delivery method (regular instruction, regular instruction with manipulatives, regular instruction with multimedia, and regular instruction with both, manipulatives and multimedia) and race (participants' self-disclosed ethnicity) while controlling for academic differences between groups with a standard pre-test.

Since the covariate and dependent variables were the same, assumption testing for the second two-way ANCOVA was the same as the first analysis with the additional tests for the independent variable of race instead of gender. The Kolmogorov-Smirnov and Shapiro-Wilk tests also indicated normality between groups by race. The assumption of homogeneity of variances was tested and found tenable using the Levene's Test, *F*(12,

144) = 1.55, p = .11. The second two-way ANCOVA indicated there was not a statistical difference in the mean of scores shown in the tests of between-subject effects. After adjusting for the pre-test, the delivery method and race interaction analysis showed, at $\alpha = .05$, $F(6, 143) = .96$, $p = .45$, partial $\eta^2 = .04$, $\delta = .37$. The effect size as interpreted by Cohen (1988) was small, .04, which indicates that only 4% of the variance in post-test scores can be explained by the interaction effect of delivery method and gender. The observed power of .37 indicates a low power.

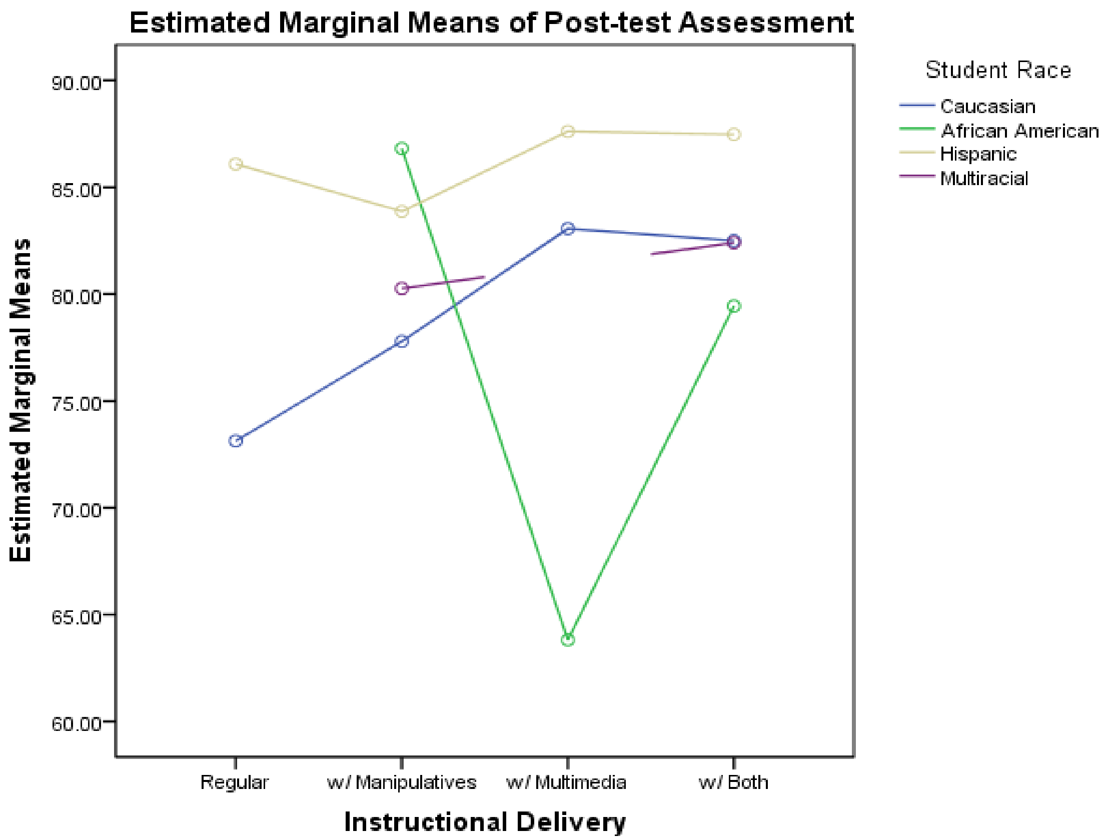

Figure 4. Profile plot for post-test scores based on the four levels of instructional delivery and student race.

There was not enough evidence to reject the null hypothesis. Figure four charts the adjusted means of post-test scores based on the interaction of the four levels of instructional delivery and the four levels of student race. As seen in Figure four, not all races were represented in each of the four instructional delivery method groups.

The fifth null hypothesis was: There is no significant difference in the means of participants' test scores based on instructional delivery method (regular instruction, regular instruction with manipulatives, regular instruction with multimedia, and regular instruction with both, manipulatives and multimedia). This hypothesis is the same as the second null hypothesis and no further tests were needed, F(3, 148)= 6.39, p =.00, η2 = .12, δ= .97. The null hypothesis was rejected.

The sixth null hypothesis was: There is no significant difference in the means of participants' test scores based on race (participants' self-disclosed ethnicity). Race was not found to be a significant factor in determining post-test assessment scores, $F(3, 143)= 2.03$, $p = .11$, $\eta^2 = .04$, $\delta = .51$.

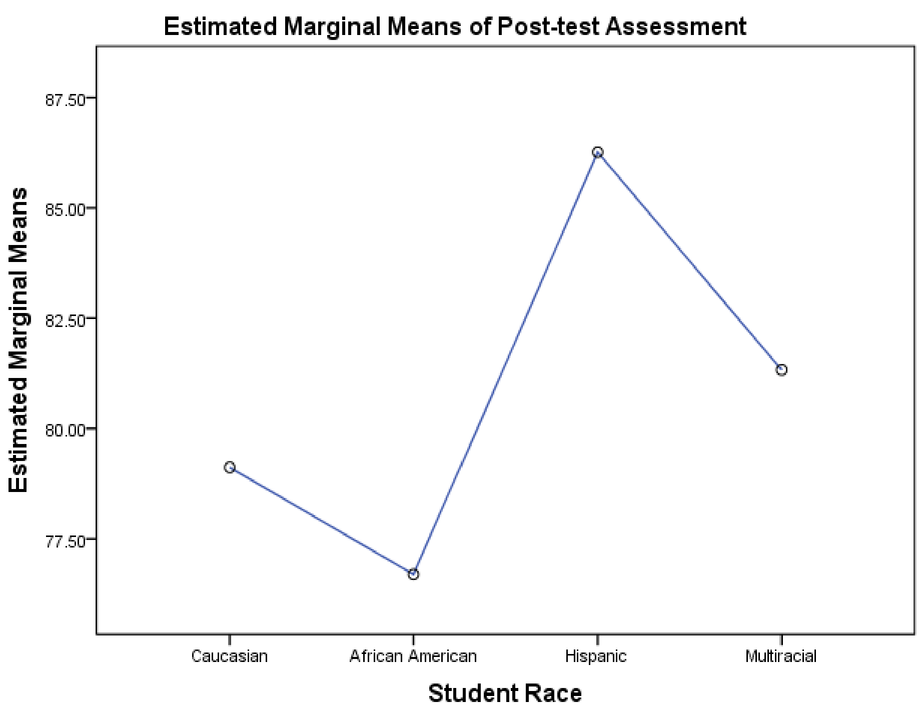

Figure 5. Profile plot for post-test scores based on the four levels of student race.

As with the interaction effect of delivery method and race, the race main effect only accounted for 4% of the variance with a slightly higher power of .51 (Cohen, 1988). Therefore, the sixth null hypothesis could not be rejected. Figure five charts the adjusted means of post-test scores based on the four levels of student race. Further comparison of participant scores by race and gender can be seen in Figure six. Females outscored males in each racial group except for African Americans.

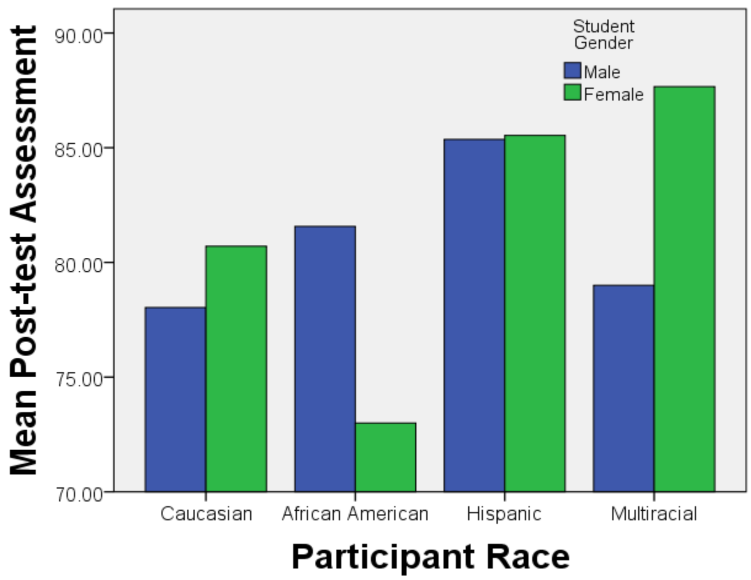

Figure 6. Cluster bar chart with means for each race and gender comparison.

Tables nine and ten list the mean comparisons of pre-test and post-test scores within the instructional delivery groups by race and gender. Table 11 lists the difference of pre-test and post-test means for each group. African American males in the group with manipulatives had the highest growth at a pre-test/post-test mean difference of 60.75. Multiracial females in the group with both had the second highest growth at a pre-test/post-test mean difference of 59.00. Hispanic males showed noticeable differences in both the regular and with both group.

Table 9

Comparison of Means for Pre-test Scores within Groups of Instructional Delivery Method by Race and Gender

	Regular		w/Manipulatives		w/Multimedia		w/ Both	
	Male	Female	Male	Female	Male	Female	Male	Female
Caucasian	43.20	45.61	40.27	37.11	40.60	40.38	52.73	43.39
African American	-	-	22.25	-	-	48.00	46.00	41.00
Hispanic	26.00	-	39.00	35.33	32.00	38.00	33.00	42.80
Multiracial	-	-	38.00	56.00	-	-	39.80	35.00

Table 10

Comparison of Means for Post-test Scores within Groups of Instructional Delivery Method by Race and Gender

	Regular		w/Manipulatives		w/Multimedia		w/ Both	
	Male	Female	Male	Female	Male	Female	Male	Female
Caucasian	68.93	77.56	76.64	77.89	80.47	85.46	85.73	81.83
African American	-	-	83.00	-	-	65.00	79.67	81.00
Hispanic	83.00	-	84.75	80.67	79.00	88.20	87.60	85.80
Multiracial	-	-	78.00	84.50	-	-	79.40	94.00

Table 11

Mean Differences between Pre-test and Post-test scores within Groups of Instructional Delivery Method by Race and Gender

	Regular		w/Manipulatives		w/Multimedia		w/ Both	
	Male	Female	Male	Female	Male	Female	Male	Female
Caucasian	25.73	31.95	36.37	40.78	39.87	45.08	33.00	38.44
African American	-	-	60.75	-	-	17.00	33.67	40.00
Hispanic	57.00	-	45.75	45.34	47.00	50.20	54.60	43.00
Multiracial	-	-	40.00	28.50	-	-	39.60	59.00

CHAPTER 5: DISCUSSION

This chapter includes important insight and value gained from conducting this study. The chapter is comprised of five sections meant to summarize the statistical findings, discuss the outcomes based on current literature, outline the study's limitations, overview the practical implications, and provide recommendations for future research.

Summary of Findings

Participants were divided into four groups by instructional delivery method, the control group received regular instruction, and the three experimental groups received the treatment in the form of different instructional delivery methods. One experimental group received regular instruction with manipulatives added. The second experimental group received regular instruction with multimedia added, and the third group received regular instruction with both, manipulatives and multimedia, added. Instructional delivery was found to be a significant factor in determining post-test assessment scores. Based on the Eta Squared value, 12% of the post-test assessment outcome can be attributed to the instructional delivery method (Cohen, 1988).

Although, gender was not statistically significant in the analysis, the mean of the girls' scores was slightly higher than the boys' scores. In addition, race was not a significant factor in the post-test outcome, but as seen in the results, Hispanic students had the highest mean out of all the other races. Even more surprising based on the majority research is that Caucasian students had the lowest mean out of the four races. African American students scored slightly higher than Caucasians, while Multiracial students scored the second highest overall. When comparing the scores of girls and boys of different races, girls outscored the boys in each racial group except for African Americans. The study showed that non-traditional groups of minorities achieved higher success rates by introducing different instructional enhancements. The means of scores between the three experimental groups were not significant when compared to one another, but all were significant when compared to the control group. This means that instructional enhancements do help students acquire skills better. Even students with relatively low post-test scores compared to overall average means showed growth with the use of instructional enhancements.

In addition to the data analysis, the researcher was interested to know how students verbally described the solid figures. Some examples of student answers from each instructional group were shared. Students in the regular instruction group did use terminology such as plane shape and solid shape to describe differences between a rectangle and a rectangular prism. On the same question, students in the manipulatives group described the differences with more descriptive properties such as the number of corners and faces. The multimedia group used descriptors like prism, number of corners, number of faces, and number of edges. The manipulatives and multimedia group used the same verbiage as the other experimental groups, but they also used terms such as three-dimensional and two-dimensional. When students were able to use the proper terminology, they exhibited a higher order cognitive level, and this behavior revealed that teachers understood and taught the geometric language as well.

Discussion Based on Literature and Theory

Van Hiele (1986) was certainly a leader in early research on geometrical mathematics education. He emphasized instructional methods that would allow for students to advance to higher cognitive levels. His operationally defined levels have been referred to numerous times for over four decades. Wirszup (1976) founded principles in his study from the Van Hiele levels, but used his own modified version. In the 1980s, researchers such as Usiskin (1982) and Fuys, Geddes, and Tischler (1988) initiated their studies with Van Hiele's work. Battista (1990) based his study about spatial visualization and logical reasoning in high school geometry students on the Van Hiele levels. Aslan and Arnas, (2007) and Halat (2006) also researched ways in which students recognize geometrical shapes. More recently, Khairulanuar, Nazre, Jamilah, Sairabanu, and Norasikin (2010) used the Van Hiele theory in their research, and they focused more on three-dimensional objects.

The findings from this study do show that carefully planned instructional strategies can be promising in student outcomes. Using manipulatives and multimedia in the learning environment has an obvious advantage. Olkun and Tuluk (2004) used manipulatives to train pre-service teachers. Boakes (2009) and Brooks (2009) reported on the benefits of providing a hands-on learning experience; this point is particularly true when teaching visualization skills. Ferguson, Ball, McDaniel, and Anderson (2008) reported a larger growth among non-STEM majors when using manipulatives as an instructional enhancement. Other notable researchers had similar findings as well. Since the demand in industry for visualization, problem solving, and innovation is growing, it only makes sense to rise to the challenge. The same solid modeling software that is utilized to train drafters and engineers was used in this study to help enhance instruction. Other researchers are in agreement that we need to pursue partnerships between colleges and schools to make these graphic technologies available to train our teachers and make our students more successful (Guven & Kosa, 2008; Brooks, 2009; Ernst & Clark, 2007; Jarvis & Quick, 1995; Lin, & Dwyer, 2010).

Commonalities between the visualization research studies extend beyond the focus on Van Hiele and geometric concept domains. These studies also concentrated on gender differences in mathematic achievement. There is a trend that can be recognized as the literature is tracked over the years. Earlier studies found a wide gap in the success of students based on gender (Wirszup, 1976; Battista, 1990; Fuys, Geddes, & Tischler, 1988). In addition, earlier studies were conducted with adolescents as participants. Secondary school age students are still sought after as research participants, but in the last eight to ten years, the research showed there to be more of a focus on younger children especially in areas of mathematics and geometry. Moreover, less implication on differences in achievement seem to be based on gender.

In accordance to the findings in this study, there does seem to be a transition period where gender differences are more evident as students age. First grade participants in this study showed no significant difference in achievement based on gender. Although age was not asked of the participants, first grade students are generally seven to eight years old. Khairulanuar, et al. (2010) conducted a study very similar to this one except they studied eight to ten year olds. The sample population was very small, (N=36), but they did incorporate instructional methods with advanced technology and three-dimensional figures. Khairulanuar, et al. (2010) did find a significant difference in achievement based on gender. They found that boys had higher outcomes than girls (Khairulanuar, et al., 2010). This study had a larger sample size (N=157), but girls had slightly higher scores. It is evident that the time period between the first and third grade may be a crucial point in being able to forecast when gender differences become apparent and how students could become academically at-risk.

In direct relation to gender, the gap in racial barriers also seems to be changing (Jordan, Kaplan, Locuniak, & Ramineni, 2007). Some research shows the gap closing, but STEM studies with participant samples from kindergarten to college have maintained significant differences in achievement based on race (Ohland, et al., 2011; Chatterji, 2005; Downer & Pianta, 2006). Ohland, et al., (2011) states "disaggregation by race and gender, is less common as studies focus on narrower groups of disciplines, because the population sizes of some race-gender groups precludes meaningful analysis" (p.100). Chatterji (2005) linked achievement with class size, school size, and the community environment to reasons for low achievements from minority groups. Research on topics of engineering and manufacturing professions delineate just how significant race may be related to success (Page, Bailey, & Van Delinder, 2009; Kelly, 2009). The findings from this study showed that race was not a significant factor in predicting post-test scores, and minority students actually had the highest achievement on the post-test. No matter what the case may be, one common recommendation in the literature is to start recognizing individual classroom or school trends and amending instructional strategies for these students at an early age.

Study Limitations

The sample for this study was chosen as a sample of convenience from local elementary schools from the same district in rural Western, NC. Results of the study may not represent the general population. The schools were relatively small and basically homogenous. Caucasians made up 72.6%, African Americans 5.7%, Hispanic 15.3%, and Multiracial 6.4% of the sample pool. By conducting the study under these finite conditions, there may be some veracity in reflection of the literature. Chatterji (2005) and Ohland, et al., (2011) discuss how narrowing population sampling to particular areas may have an effect on results of gender and racial differences. Another reason gender and racial differences may have been insignificant is due to the age of the participants. Unfortunately, there is no real way to determine if an error may have resulted. Perhaps the most disconcerting element for teachers is that the majority of their students scored the lowest on the post-test.

This study was designed around the NC state curriculum for first grade students. Curriculum varies by state which could pose additional limitations in generalization of results. Because states and even districts within states differ in legislature and budgeting, the findings may not matter if teachers are still unable to replicate the setting environment. Partnerships between academic entities will become more important than ever, but as they develop, there will be more of an alignment with the contextual approach to innovation.

The study was a non-randomized subjects, non-equivalent control group quasi-experimental study. This was the strongest design possible for the nature of the study environment. Overall, the innate threats to this design were limited. Students were not even aware of differences between classrooms. The sample was positive with only seven students out of 164 not given parental permission to participate. Teachers were very helpful and graciously willing to contribute. However, upon reflection, the researcher would have tried to control for differences in teacher experience and/or subject anxiety. There were no teacher related variables in this study.

Study Implications

In the discussion section of this chapter, the direction scholars seem to be taking in regards to studying areas of STEM was mentioned. In many ways, the findings in this study are contradictory to popular research and beliefs that have developed over time. Neither gender nor race was a significant predictor of the post-test scores, but instructional method was key. In closing the gap between minorities in STEM, the focus should be at younger ages. By the time students reach adolescence, the differences are apparent. Instructional methods may not be as important after the fact because students do not have the time to catch up to their peers. Kelly (2009) reports that once students fall behind their chances of enrolling in an advanced math class, such as geometry, beyond their sophomore year in high school drops by half. Furthermore, if students do not have the extra incentive of advanced high school mathematics, they are not likely to gain momentum in areas of STEM in college. The time to act is in the primary grades.

Instructional techniques on how to teach geometrical mathematics education has gained attention, but changes in technology and society demand an updated delivery method. “It is important that children are taught using appropriate and relevant instructional strategies based on their level of geometrical understanding” (Khairulanuar, Nazre, Jamilah, Sairabanu, & Norasikin, 2010, p. 177). Students in the first grade classrooms participating in this study had a chance to develop skills which will lead to more immediate understanding in grades to come. In NC, each subsequent grade curriculum covers geometry topics as part of the standard curriculum. It is imperative that students progress each year with a higher cognitive level of geometrical experience. According to Van Hiele’s (1986) operational levels, students should be at level three before proceeding to middle school. Students must have obtained mastery in visualization, analysis, and ordering of geometric figures and concepts. This study implies that without training teachers and providing ways to enhance instruction, students may not reach these levels. The more immediate implication is that students may not do well in subsequent grades after the first grade, but the long-term ramification may be that students do not get the chance to enter a STEM profession. In that case, the United States may have a hard time being a global competitor in technological areas in the years to come.

Recommendations for Future Research

There are several ways findings from this study could cultivate future research. The most obvious would be to conduct additional experiments by replicating this study on a more widespread basis. With additional findings, the data would be validated to the general population. More insight could be provided on that pivotal moment when gender and minority differences become more pronounced. Another interest stems from studying the same concept in at least one different elementary school grade level. The materials would have to be upgraded, but the same principles would apply. The study could be longitudinal and track students throughout their time in school to see if those who were exposed to technology enhanced instruction at an early age actually assimilated into the STEM college or career pathways with greater ease.

This study did not take into account any teacher variables that may have affected the student outcomes. Elementary teachers have varying backgrounds and experiences. They are not likely to be subject matter experts like their high school and college counterparts; however, there is much to say about character and atmosphere in the classroom. There may be a directly proportional relationship in teaching style or personality to success in some subjects. Most of the literature reviewed in this study focused on quantitative data and content knowledge, but it may benefit the mathematical and technological realm if a qualitative study on the softer skills of teaching were addressed.

The focus of this study centered on development of visualization skills, but the importance of innovation was also brought to light. One of the preliminary ideas for this study was to incorporate a measure for testing innovation in the classroom, but there was not a prevalent instrument validated for this age group. The notion of using the measure of innovation as a dependent variable could blossom into a future related study. The materials could be the same, but the setting would change to permit open ended discussion about the geometric figures. Structured debates would take place to allow students to actively provide arguments on the advantages and disadvantages of each shape. Debates would force students to constructively interact and problem solve together. By promoting community involvement, debate also increases tolerance, respect, and civic engagement (Lundberg, 2010). Badran (2007) calls for this type of engagement to promote creativity and innovation in the classroom. The environment would become learner centered instead of teacher centered.

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APPENDIX A: NC STANDARD TEST ASSESSMENT LETTER

UNITED STATES DEPARTMENT OF EDUCATION

OFFICE OF ELEMENTARY AND SECONDARY EDUCATION

OCT 2 2 2010

THE ASSISTANT SECRETARY

The Honorable June Atkinson
North Carolina Department of Public Instruction
301 North Wilmington Street
Raleigh, North Carolina 27601

Dear Superintendent Atkinson:

I am pleased to approve North Carolina's standards and assessments under Title I of the Elementary and Secondary Education Act of 1965 (ESEA) as amended. This letter applies to changes made in the assessment system after North Carolina's initial approval as documented in the June 2006 letter from Henry Johnson. My decision is based on input from peer reviewers external to the U.S. Department of Education (Department) and Department staff who reviewed and carefully considered the evidence submitted by North Carolina.

North Carolina's standards and assessments in reading/language arts, mathematics and science meet all applicable statutory and regulatory requirements of the ESEA. Accordingly, North Carolina's standards and assessment system warrants Full Approval. Specifically, North Carolina's system includes academic content standards in reading/language arts, mathematics and science as well as end-of-course standards in English I, Algebra I and Biology; student academic achievement standards in reading/language arts, mathematics, science, English I, Algebra I and Biology; alternate academic achievement standards in reading/language arts, mathematics and science for students with the most significant cognitive disabilities; modified academic achievement standards for eligible students with disabilities in reading/language arts and mathematics; general assessments in reading/language arts and mathematics in grades 3 through 8, end-of-course assessments in English I and Algebra I, a writing test (grade 10) and science assessments in grades 5 and 8 and the end-of-course Biology assessment; alternate assessments based on alternate academic achievement standards (the NCEXTEND1) in the corresponding grades in reading/language arts, mathematics and science; and alternate assessments based on modified academic achievement standards (the NCEXTEND2) in reading/language arts and mathematics in grades 3 through 8.

Please be aware that approval of North Carolina's standards and assessment system under the ESEA is not a determination that the system complies with Federal civil rights requirements, including Title VI of the *Civil Rights Act of 1964*, Title IX of the *Education Amendments of 1972*, Section 504 of the *Rehabilitation Act of 1973*, Title II of the *Americans with Disabilities Act*, and requirements under the *Individuals with Disabilities Education Act*. Finally, please remember that, if North Carolina makes significant changes to its standards and assessment system, the State must submit information about those changes to the Department for review and approval.

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OCT 27 2010

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400 MARYLAND AVE., SW, WASHINGTON, DC 20202

The Department of Education's mission is to promote student achievement and preparation for global competitiveness by fostering educational excellence and ensuring equal access.

We have found it a pleasure working with your staff during this review process. Please accept my congratulations for North Carolina's approved standards and assessment system in reading/language arts, mathematics and science under the ESEA. I wish you well in your continued efforts to improve student achievement in North Carolina. If you have any questions, please do not hesitate to contact Sue Rigney (sue.rigney@ed.gov) of my staff.

Sincerely,

Thelma Meléndez de Santa Ana, Ph.D.

cc: Governor Bev Perdue
Lou Fabrizio
Tammy Howard

EVIDENCE REQUIRED FOR PEER REVIEWS OF ASSESSMENT SYSTEMS UNDER TITLE I OF THE ELEMENTARY AND SECONDARY EDUCATION ACT

NORTH CAROLINA
June 2010

United States Department of Education

NCLB Assessment System Review

Peer Reviewer Notes – Revised January 12, 2009
NCLB Assessment System Review

APPENDIX B: LETTER REQUESTING STUDY APPROVAL

Mr. Aaron Greene
Director, Curriculum and Instruction
[redacted]

Hello,

My name is Amber Thompson. I am the Mechanical Drafting Technology instructor and Interim Dean of Applied Sciences and Technology at [redacted] I am pursuing an Educational Doctorate Degree from Liberty University in Educational Leadership. My dissertation is on The Effect of Enhanced Visualization Instruction on First Grade Student's Scores on the NC Standard Course Assessment. I would like to meet with you to discuss using Polk County School's first grade classrooms as a component of my research.

As part of the research requirements, I am conducting a study to evaluate first grade students' visualization skills as they pertain to geometric shapes. The study will attempt to identify how teachers can increase pre-engineering skills by using enhanced instructional strategies when teaching the mathematics competency of defining and analyzing geometric shapes.

Why first grade? Students are introduced to three-dimensional shapes for the first time in their school careers in this grade. For both parties to benefit from this study, I would like to form a partnership with the drafting and design program at the college level and the first grade classrooms. This partnership would include the creation of three-dimensional prototypes of geometric shapes for every student in first grade. I would also develop multimedia presentations to supplement regular instruction. There are other benefits that we can discuss as well.

The data collected in the study will be anonymous throughout the entire study process. If you allow this study to be conducted, [redacted] will receive the added benefits of all instructional materials used in the study free of charge.

Thank you for taking the time to contribute to the research process. I appreciate you in helping provide valuable data that will assist me in completing my research and help [redacted] Schools advance in the areas of technology and math.

Sincerely,

Amber C. Thompson

APPENDIX C: STUDY APPROVAL LETTER

[redacted]

September 26, 2011

To Whom It May Concern:

My name is Aaron Greene and I am currently Director of Curriculum and Instruction for [redacted] I am writing today to address a request by Amber Thompson for permission to research in our district. Please direct any questions or concerns regarding the provision of research permission to Aaron Greene at the phone or address listed.

As the Superintendent's designee for the review of research proposals, I officially grant Amber Thompson permission to work with and access to [redacted] Grade elementary applicable records and assessment information, classrooms, students, and teachers. Amber Thompson's institutionally approved research project, "The Effect of Visualization Workshop on First-grade Student Scores on the Standard Course Assessment," is explicit in the types of access to schools, students, teachers, and associated data needed to complete the project. I am granting permission based on the assumption that the research will follow this outline and the provisions listed therein with regards to schools and students. Furthermore, [redacted] reserves the right to terminate this agreement at any time if it is deemed detrimental to students or school operations. Otherwise, we wish Amber Thompson the best of luck and look forward to the sharing of her results with our district and teachers. Again, please contact Aaron Greene with any questions or concerns.

Respectfully,

Aaron Greene
Director of Curriculum and Instruction

STEARNS EDUCATION CENTER

Post Office Box 638
125 East Mills Street
Columbus, NC 28722
828.894.3051
828.894.8153 FAX

The Board encourages agencies and individuals to conduct research on issues related to student achievement and the effective operation of the school system.

The Superintendent may approve a request for participation in a research project if:

1. the research results ultimately may benefit students of the school system;
2. the project's purpose and methodology are compatible with the goals and objectives of the Board and school system; and
3. the project will not disrupt instructional time.

The Superintendent is encouraged to involve central office administrators, school administrators, teachers and parents in making this assessment. The Superintendent shall report on approved research projects that directly affect student achievement or operations of Polk County Schools at the next regularly-scheduled Board meeting.

A research project involving a survey of students must comply with policy 4720, Surveys of Students.

All research projects must comply with the confidentiality requirements of policy 4700, Student Records, and policy 4705/7825, Confidentiality of Personal Identifying Information.

Legal References: G.S. 115C-47, -230

Cross References: Student Records (policy 4700), Confidentiality of Personal Identifying Information (policy 4705/7825), Surveys of Students (policy 4720)

Adopted: November 15, 2001

Revised: October 10, 2011

APPENDIX D: IRB APPROVAL LETTER

LIBERTY
UNIVERSITY

The Graduate School at Liberty University

February 2, 2012

Amber Thompson
IRB Approval 1254.020212: The Effect of Enhanced Visualization Instruction on First Grade Students' Scores on the North Carolina Standard Course Assessment

Dear Amber,

We are pleased to inform you that your above study has been approved by the Liberty IRB. This approval is extended to you for one year. If data collection proceeds past one year, or if you make changes in the methodology as it pertains to human subjects, you must submit an appropriate update form to the IRB. The forms for these cases were attached to your approval email.

Thank you for your cooperation with the IRB and we wish you well with your research project.

Sincerely,

Fernando Garzon, Psy.D.
IRB Chair, Associate Professor
Center for Counseling & Family Studies

(434) 592-5054

LIBERTY
UNIVERSITY
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APPENDIX E: PARENTAL CONSENT FORM

Liberty University

Research Participant Information and Consent Form

Title of the Study: THE EFFECT OF ENHANCED VISUALIZATION INSTRUCTION ON FIRST GRADE STUDENTS' SCORES ON THE NORTH CAROLINA STANDARD COURSE ASSESSMENT

Principal Investigator: Amber C. Thompson (phone: 828-286-3636 ext. 252) (email: athompson@isothermal.edu)

<u>DESCRIPTION OF THE RESEARCH</u>

Your child is invited to participate in a research study about increasing visualization skills as they pertain to the standard NC curriculum objective of defining, visualizing, and analyzing geometric shapes.

Your child has been asked to participate because he or she is first grade student in a Western NC school district.

The purpose of this study is to introduce first grade students to three dimensional objects and their properties by using different techniques that develop and support the visualization aptitude of each child.

The target population for this study will be all first grade students in a Western NC school district.

This study will take place as part of the regular school day and is intended to provide enhanced instruction for the mathematics goal three standard course of study for first grade students in NC.

<u>WHAT WILL MY CHILD'S PARTICIPATION INVOLVE?</u>

If you agree to let your child participate in this research, your child could be asked to take part in classroom activities meant to enhance visualization skills in first grade students.

<u>ARE THERE ANY RISKS TO ME?</u>

We do not anticipate any risks to your child from participation in this study. No conflict of interest exists in this study.

ARE THERE ANY BENEFITS TO ME?

We do not expect any direct benefits to your child from participation in this study except receiving an intervention that could help increase visualization skills. The school will benefit by receiving instructional materials made to provide hands-on and interactive experiences for the students.

HOW WILL MY CHILD'S CONFIDENTIALITY BE PROTECTED?

This study is anonymous. Neither your child's name nor any other identifiable information about the school will be recorded. Only the researcher, Amber Thompson, and advising professor have access to the requested information. Data will be presented in summary form to the school and parents.

WHOM SHOULD I CONTACT IF I HAVE QUESTIONS?

You may ask any questions about the research at any time. If you have questions about the research after you leave today you should contact the Principal Investigator, Amber C. Thompson at 828-286-3636 ext. 252.

If you are not satisfied with response of the research team, have more questions, or want to talk with someone about your child's rights as a research participant, you should contact the Liberty University IRB office at Fernando Garzon, Chair, 1971 University Blvd, Suite 1582, Lynchburg, VA 24502 or email at fgarzon@liberty.edu.

Your child's participation is completely voluntary. If you decide not to let your child participate or choose to withdraw your child from the study, it will have no effect on any services or treatment your child is currently receiving.

Your signature indicates that you have read this consent form, had an opportunity to ask any questions about your child's participation in this research and voluntarily consent to allow your child to participate. You will receive a copy of this form for your records.

Name of Child (please print): ______________________________

Name of Parent (please print):______________________________

Signature ______________________________ Date____________________

APPENDIX F: PARTICIPANT ASCENT FORM

Liberty University

Research Participant Information and Ascent Form

Title of the Study: THE EFFECT OF ENHANCED VISUALIZATION INSTRUCTION ON FIRST GRADE STUDENTS' SCORES ON THE NORTH CAROLINA STANDARD COURSE ASSESSMENT

Principal Investigator: Amber C. Thompson (phone: 828-286-3636 ext. 252) (email: athompson@isothermal.edu)

DESCRIPTION OF THE RESEARCH

You are invited to participate in a research study about increasing visualization skills as they pertain to the standard NC curriculum objective of defining, visualizing, and analyzing geometric shapes.

You have been asked to participate because you are in the first grade and are a student in a Western NC school district.

The purpose of this study is to introduce you to three dimensional objects and their properties by using different techniques that develop and support your visualization aptitude.

The target population for this study will be all first grade students in aWestern NC school district.

This study will take place as part of the regular school day and is intended to provide enhanced instruction for the mathematics goal three standard course of study for first grade students in NC.

WHAT WILL MY PARTICIPATION INVOLVE?

If you agree to participate in this research, you could be asked to take part in classroom activities meant to enhance visualization skills in first grade students.

ARE THERE ANY RISKS TO ME?

We do not anticipate any risks to you from participation in this study. No conflict of interest exists in this study.

ARE THERE ANY BENEFITS TO ME?

We do not expect any direct benefits to you from participation in this study except receiving an intervention that could help increase visualization skills. The school will benefit by receiving instructional materials made to provide hands-on and interactive experiences for the students.

HOW WILL MY CONFIDENTIALITY BE PROTECTED?

This study is anonymous. Neither your name nor any other identifiable information about the school will be recorded. Only the researcher, Amber Thompson, and advising professor have access to the requested information. Data will be presented in summary form to the school and parents.

WHOM SHOULD I CONTACT IF I HAVE QUESTIONS?

You may ask any questions about the research at any time. If you have questions about the research after you leave today you should contact the Principal Investigator, Amber C. Thompson at 828-286-3636 ext. 252.

If you are not satisfied with response of the research team, have more questions, or want to talk with someone about your child's rights as a research participant, you should contact the Liberty University IRB office at Fernando Garzon, Chair, 1971 University Blvd, Suite 1582, Lynchburg, VA 24502 or email at fgarzon@liberty.edu.

Your participation is completely voluntary. If you decide not to participate or choose to withdraw from the study, it will have no effect on any services or treatment you are currently receiving.

Your signature indicates that you have read this ascent form, had an opportunity to ask any questions about your participation in this research and voluntarily consent to participate. You will receive a copy of this form for your records.

Name (please print): ______________________________

Signature _______________________________ Date____________________

APPENDIX G: EXPLANATION OF STUDY LETTER

First Grade Parents
Western NC school district

Hello

My name is Amber Thompson. I am the Dean of Applied Sciences and Technology and Mechanical Drafting Technology Lead instructor at aWestern NC community college. I am pursuing an Educational Doctorate Degree from Liberty University in Educational Leadership.

As part of my research requirements, I am conducting a study to evaluate first grade students' visualization skills as they pertain to the NC course of study Math Competency Three. The study will attempt to identify how teachers can increase visualization skills by using different instructional strategies.

The students will be offered a small incentive in the form of colorful pen, valued at one dollar, if the attached consent and ascent forms are returned within a week. The students will receive the incentive whether they participate in the study or not just be returning the forms. Participation will be completely voluntary.

I have approval from the school board and have already touched base with the principals at your child's schools. The study will not be time consuming or take away instructional time from your child's class.

The school will benefit by receiving free instructional materials made to provide hands-on and interactive experiences for the students.

Thank you for taking the time to contribute to this study. I appreciate you in helping provide valuable data that will assist me in completing my research and help the Western NC school district advance in the areas of technology and math.

Sincerely,

Amber Thompson

APPENDIX H: LETTER TO FIRST GRADE TEACHERS

First Grade Teachers
[redacted]

Hello

My name is Amber Thompson. I am the Dean of Applied Sciences and Technology and Mechanical Drafting Technology Lead instructor at [redacted] I am pursuing an Educational Doctorate Degree from Liberty University in Educational Leadership.

As part of my research requirements, I am conducting a study to evaluate first grade students' visualization skills as they pertain to the NC course of study Math Competency Three. The study will attempt to identify how teachers can increase visualization skills by using different instructional strategies.

The data collected in the study will be anonymous throughout the entire study process. Your school will receive the added benefits of all instructional materials used in the study free of charge.

I have approval from the school board and have already touched base with the principals at your schools. Your role in the study will not be time consuming or take away instructional time from your class.

At this point, I would like to meet with each teacher individually to discuss:

1. What role your class will be in the study
2. Administration of a simple pre-test before you start on competency three in your classrooms

From information I have gathered in conversation, most of you do not teach competency three until the third or fourth six weeks. I will be sending more information out about this study in the next couple weeks. For now, will you let me know what time is a good time to meet with you to further discuss the two points above?

Thank you for taking the time to contribute to this study. I appreciate you in helping provide valuable data that will assist me in completing my research and help [redacted] advance in the areas of technology and math.

Sincerely,

Amber Thompson

APPENDIX I: EXAMPLES OF INSTRUCTIONAL MATERIALS

Manipulatives

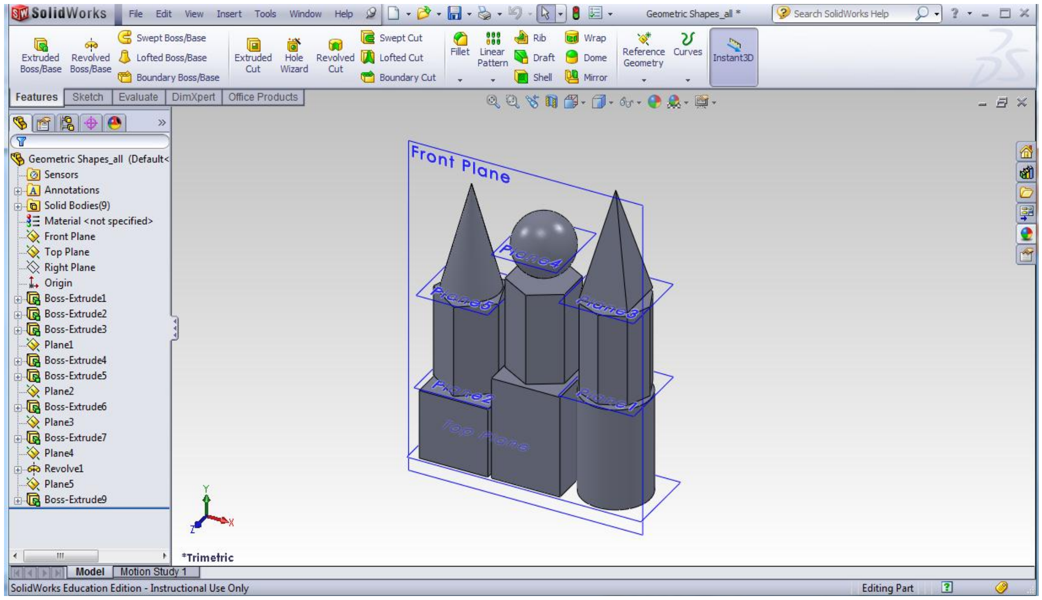


Figure 7. Screen capture of the geometric shapes as they were modeled for three-dimensional printing. By stacking the models, material waste and the number of base plates is reduced.

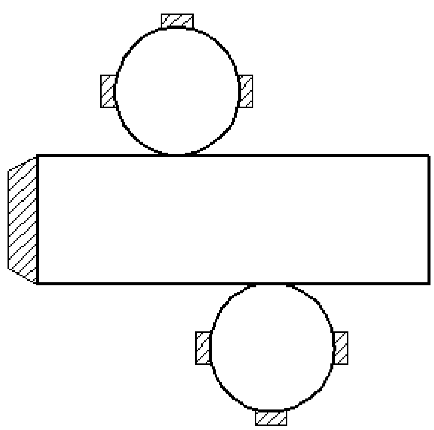
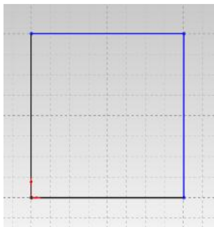
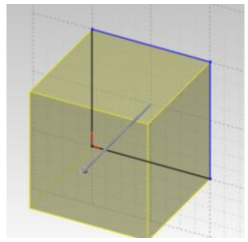
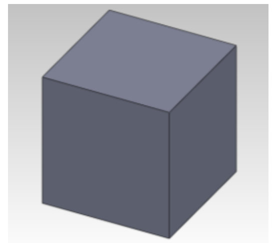
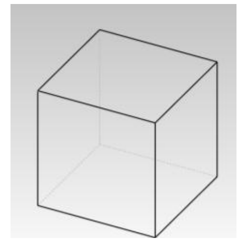
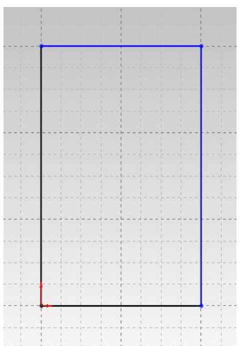
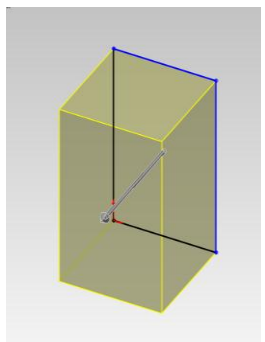
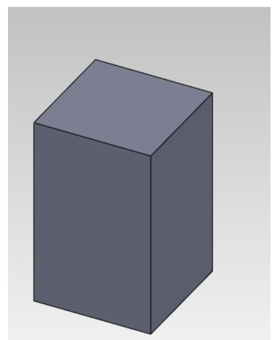
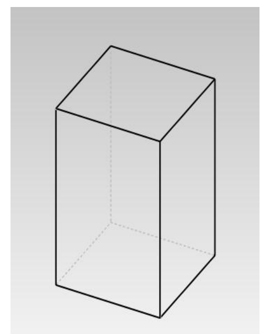
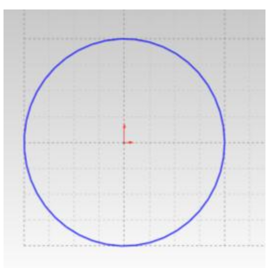
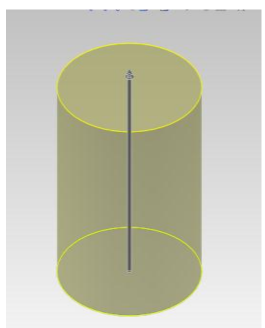
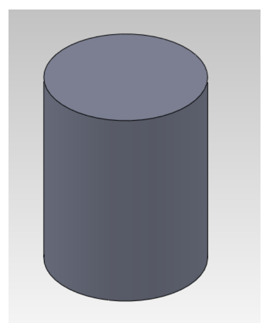
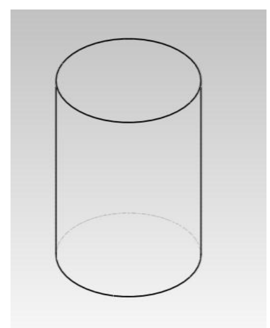
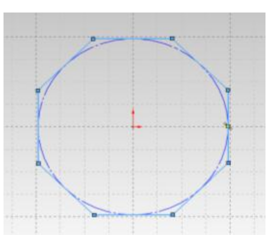
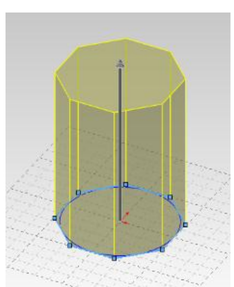
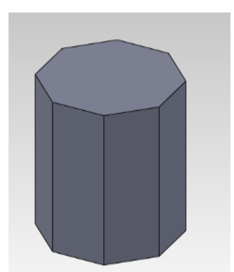
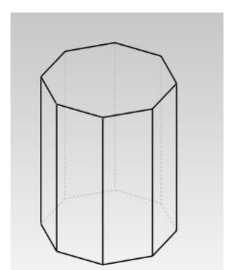


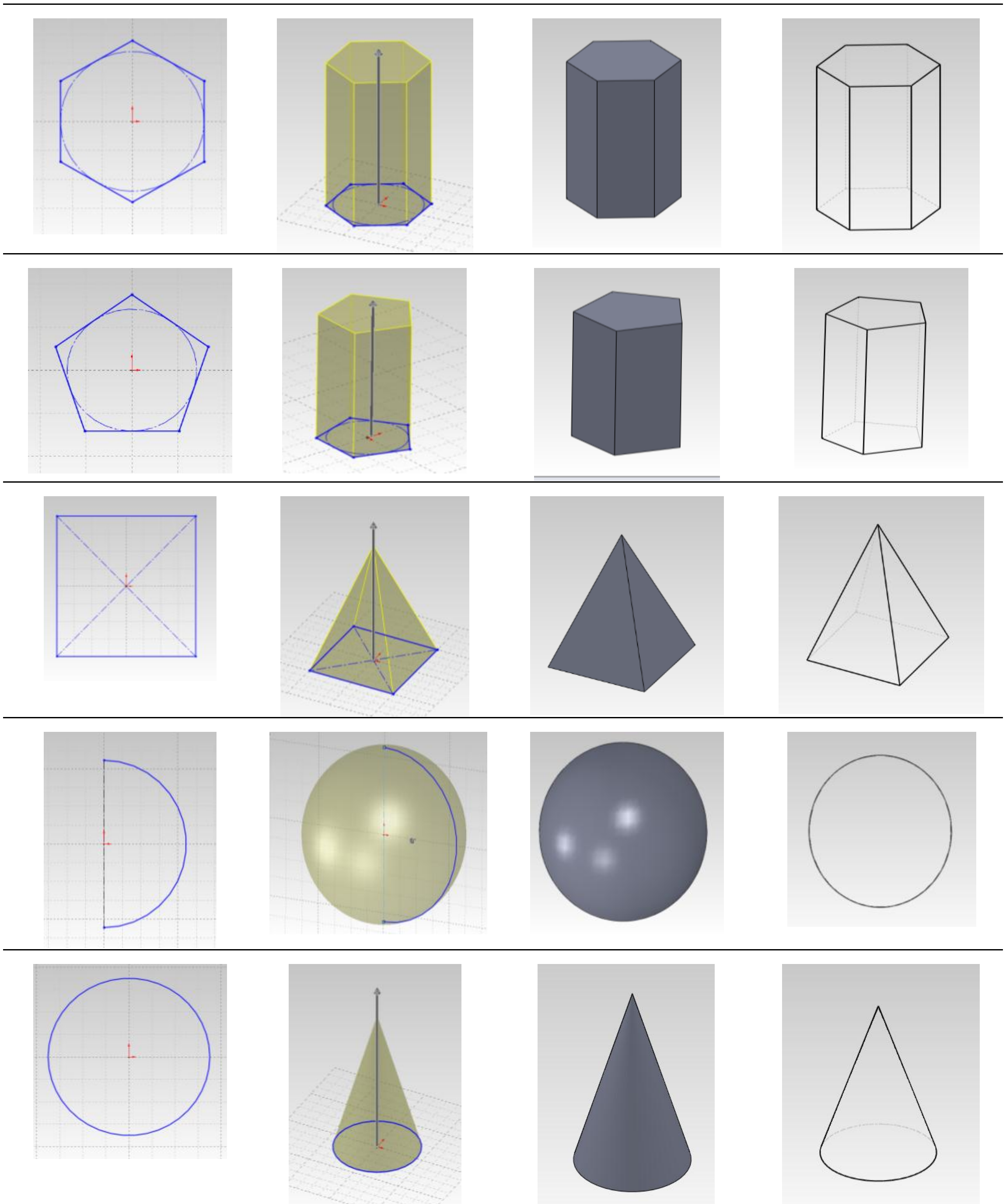
Figure 8. Screen capture of a cylindrical pattern development. Participants in Groups Two and Four will cut out pattern developments for each geometric shape and construct paper models.

Multimedia

Table 12

Multimedia Story Board One

2D Sketches	Extrusion to Add Thickness	3D Geometric Shape	Wireframe for Practice Drawing
			
			
			
			



Note: This table represents the progression of modeling from two-dimensional sketches to three-dimensional geometric shapes. The last example in each row is a picture of a practice drawing. The video will be accompanied by isometric graph paper for guided drawing practice.

APPENDIX J: CURRICULUM CREATION TIME LINE

Table 13

Curriculum Materials Creation Schedule

Materials	Time Needed	Start Time	End Time
Manipulatives			
Three-Dimensional Prints	37 Working Days	Nov. 16, 2011	Jan. 10, 2012
Pattern Developments	4Working Days	Nov. 16, 2011	Nov. 21, 2011
Multimedia			
Story Board Creation	10 Working Days	Nov. 1, 2011	Nov. 30, 2011
Video Creation/Editing	15Working Days	Nov. 30, 2011	Dec. 16, 2011
Supplemental Handouts	5 Working Days	Jan. 4, 2012	Jan. 13, 2012

Note: This table represents the curriculum material creation schedule. The days listed are the estimated number of working days it will take to create instructional materials needed for the enhanced instruction during the study.

APPENDIX K: CLASSROOM TEACHER TRAINING SCHEDULE

Table 14

Classroom Teacher Training Schedule

Group 1	No Enhancements	
Classroom A	No Training Required	
Classroom B	No Training Required	
Group 2	Manipulatives	
Classroom C	March 5, 2012	8:00am to 10:00am
Classroom D	March 5, 2012	11:00am to 1:00pm
Group 3	Multimedia	
Classroom E	February 14, 2012	11:30pm to 1:30pm
Classroom F	February 14, 2012	2:00pm to 4:00pm
Group 4	Manipulatives and Multimedia	
Classroom G	February 24, 2012	7:45am to 10:15am
Classroom H	February 24, 2012	10:30am to 1:00am
Classroom I	February 24, 2012	1:15pm to 3:45pm

Note: This table represents training days for first grade teachers. The training is scheduled on regular workdays during the school calendar year.

APPENDIX L: DATA REPORTING EXAMPLE

Table 15

Example Data Report

Classroom Assignment	Pre-Test Score	Post-Test Score	Race of Participant	Gender of Participant
Classroom A	68	87	Hispanic	Female
Classroom A	45	92	White	Male

Note: This table represents an example of the data classroom teachers will report. All participant scores will be reported anonymously and identified by classroom assignment. Classroom assignments will only be shared with the classroom teacher of which they are given. All assignments will be kept in a confidential code manual that will be locked in a separate filing cabinet as the data reports. At no time will participant names be indicated.