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The Effectiveness of Computer-Aided Instruction on Math Fact Fluency

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Doctoral Study Submitted in Partial Fulfillment

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Abstract

Sixth grade students at a Mid-Atlantic, urban, PreK-8 public school have shown weak mathematical performance. In accordance with the No Child Left Behind (NCLB) Act of 2001, the local district has implemented numerous policy changes to improve performance, but no substantial improvements in test scores have been seen so far. This project study focused on the development of automaticity and fluency of math facts to address this problem. The theoretical framework of the study was based on Haring and Eaton's instructional competency hierarchy framework, which claims that students who master basic mathematics skills are better able to progress to more general and abstract skills. A modified, quasi-experimental, nonequivalent control-group design was used with 2 groups of 20 sixth grade students who were neither randomly selected nor assigned to either group. Data analysis using one-way analysis of variance revealed that computer aided instruction—specifically, Fluency and Automaticity through Systematic Teaching and Technology (FASTT) Math—was more effective than the other classroom's mathematics instruction in developing multiplication fluency. In response, a curriculum policy recommendation was drafted as a project and will be presented to the board of education to conduct additional evaluations of FASTT Math as a supplemental tool in third through eighth grades in the district. This project is expected to contribute to social change by improving mathematics achievement which will create a mathematically literate cadre of students to meet the needs of 21st century employers, thus improving the quality of life in the broader community.

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Dedication

To my wife, Caryl, who is my inspiration and my love. I would not have been able to complete this journey without you.

Acknowledgments

There are many people who have assisted me on this journey through research. First and foremost, my former Committee Chair, Dr. Robert Bernard was always supportive. He continually encouraged me to keep working and would provide plenty "food for thought." A special thank you to Dr. Seymour who became my Committee Chair during the last phase of my journey. An additional thank you to the rest of the committee for their insight and input. I also must acknowledge my school and school district for permitting me to collect data and perform this study.

Table of Contents

List of Tables

List of Figures

Section 1: The Problem

Introduction

Mathematical skills are an essential prerequisite for both school achievement and success in the workplace. Completion of advanced mathematics courses in high school influences college graduation more than any other factor (Adelman & Office of Vocational and Adult Education, 2006). Students who complete mathematics classes beyond Algebra II double their chances of earning a bachelor's degree (Adelman et al., 2006). This is important because nearly two-thirds of the fastest growing jobs in the United States will require a bachelor's degree (Dohm & Shniper, 2007, p. 90). Today, the link between increased education and good jobs is stronger than ever. Over the last 30 years, there has been a marked decline in jobs for high school graduates, whereas the prospect for those possessing postsecondary education and training has increased significantly (Carnevale, Jayasundera, Hanson, & Georgetown University, 2012). These findings clearly indicate that mastering mathematical skills has far-reaching implications for students.

In the last decade, high-stakes testing has been systematically implemented to assess students' skills, often called *achievement* (Au, 2011; Martindale, Pearson, Curda, & Pilcher, 2005). While some scholars have concerns about the increased dependence on high-stakes testing as a means to evaluate schools (Zimmerman & Dibenedetto, 2008), this issue is not a part of this research. High-stakes testing provides the means for government institutions to monitor and evaluate their educational systems (Morris, 2011). The National Assessment of Educational Progress (NAEP) is administered in fourth, eighth, and twelfth grades to measure student performance on a national level. No Child

Left Behind (NCLB) requires each state to administer annual standards-based assessments in math and reading to students from third through eighth grades, and at least once in high school (New Jersey Department of Education, 2009). In addition, local districts implement their own practice testing.

Federal expectations have mandated benchmarks in language arts literacy, mathematics, and science at these grade levels. In response to NCLB, the State of New Jersey implemented the New Jersey Assessment of Skills and Knowledge (NJ ASK) program beginning in 2003. By 2006, full implementation of ASK 3-8 and High School Proficiency Assessment (HSPA) provided New Jersey school districts with the means to monitor academic progress over time (New Jersey Department of Education, 2009).

Since 2006, New Jersey school districts have collected summative annual data in order to comply with NCLB legislation (New Jersey Department of Education, 2009). ASK data determines the success or failure of each school and district. NJ ASK data has provided the vehicle to monitor and evaluate student achievement in ways that were not previously available. Schools now have the wherewithal to make decisions about policy and programs based on their state's standardized test data.

Definition of the Problem

In one urban PreK-8 New Jersey public school, NJ ASK historical data documents what school officials know: Students' mathematics skills are weak (New Jersey Department of Education, 2013). From 2006 through 2011, this school had not achieved adequate yearly progress (AYP) and, based on this lack of progress, was classified as a Category I school (i.e., is in need of improvement) (New Jersey Department of Education, 2013). To determine the level of a school's academic achievement, NCLB created a six-category system, with 1 being the lowest category and 6 the highest. Category One schools "did not achieve AYP and have an achievement gap of more than 25% below the acceptable benchmark for attaining the state standards in either language arts literacy or mathematics" (New Jersey Department of Education, 2010a, para. 1). Lack of progress has been a constant concern of teachers and administrators in this school since NCLB data began being collected in 2006. Furthermore, the school was placed in "year 4 – corrective action" within the NCLB's Title 1 monitoring program in 2011 (L, Hyman, personal communication, March 15, 2011).

During the 2011-2012 school year, the U.S. Department of Education allowed states flexibility about the specific requirements of NCLB in exchange for "rigorous and comprehensive state-developed plans designed to improve educational outcomes for all students, close achievement gaps, increase equity, and improve the quality of instruction" (U.S. Department of Education, 2011, para. 3). The reason cited for this flexibility was the barriers unintentionally created by NCLB that hindered raising student achievement (U.S. Department of Education, 2011). New Jersey was one of the first states to be granted a waiver from some of the requirements of NCLB. In exchange, New Jersey developed a new school accountability system. This system identified the lowest 5% and highest 5% of academically achieving schools, as well as those schools with the largest in-school achievement gaps based on the performance of subgroup populations (New Jersey Department of Education, 2012c). Based on this new accountability system, the school under study does not meet any of the aforementioned criteria as one of the targeted schools, which would remove its label as a school in need of improvement.

However, New Jersey's flexible NCLB waiver included the development of yearly progress targets using 2011 ASK scores as a baseline. Schools are expected to make yearly progress in order to reach the goal of halving the distance between their baseline and 100% proficiency by 2017 (New Jersey Department of Education, 2014). Continual progress will be necessary to ensure that the school under study does not return to failing status.

In accordance with NCLB, the local school district has attempted to address this lack of achievement by implementing numerous changes. In an attempt to improve mathematics test scores, the district aligned the curricula with state and Common Core standards; it implemented curriculum benchmarks and established new math coaching positions (math instructors who assist classroom teachers with implementing mathematics curriculum and instructional practices). Furthermore, teachers whose students had the lowest student test scores were replaced. Despite these initiatives, substantial improvements in test scores did not materialize at the sixth grade level. Therefore, an alternative approach to improve student achievement was warranted during the 2013-2014 academic year.

Rationale

Evidence of the Problem at the Local Level

According to the New Jersey report card, 78.8% of sixth grade students across the state scored either *proficient* or *advanced proficient* in 2012 (New Jersey Department of Education, 2013). Students are placed into one of three categories based on their NJ ASK scores: *partition proficient* (failing, scoring under 200), *proficient* (passing, scoring 200-249), or *advanced proficient* (passing, scoring 250-300). The New Jersey Report Card is an annual public report mandated by New Jersey statute 18A:7E 1-5 that provides pertinent information on school success (New Jersey Department of Education, 2013). At the local district level, the proficient percentage was 66.7, approximately 12 % below the state's average performance. At the level of the school under study, only 53.1 % of sixth grade students performed at *proficient* or *advanced proficient* levels. Figure 1 shows the consistently poor performance of sixth grade students from 2008 through 2012. During this period, less than 60 % of them performed at the *proficient* or *advanced proficient* level.

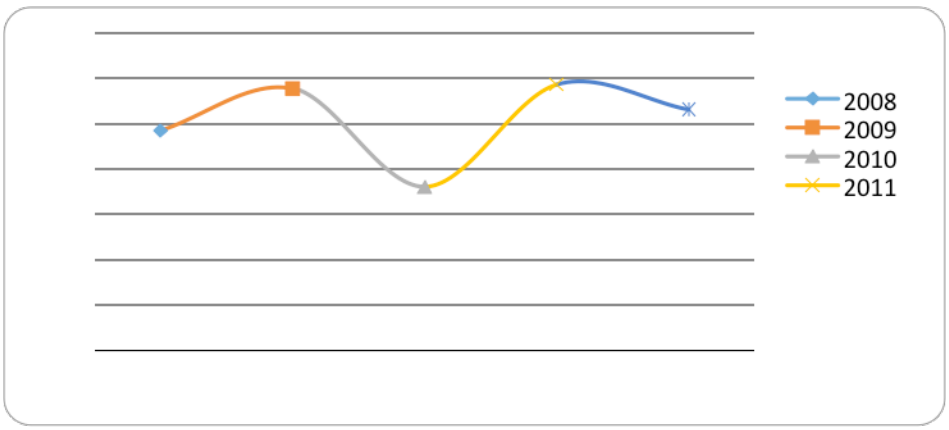

Figure 1. NJ ASK sixth grade proficient percentages, 2008-2012. This figure presents a comparison of the percentage of students classified as *proficient/advanced proficient* from 2008 through 2012. Students who meet the minimum competency requirement are classified as *proficient* (New Jersey Department of Education, 2013).

In addition to NJ ASK data, the local district developed four benchmarks to monitor student progress in mathematics. The quarterly benchmarks corresponded to the first four of New Jersey's core content standards in mathematics: Number and Numerical Operations, Geometry and Measurement, Patterns and Algebra, and Data Analysis & Probability (New Jersey Department of Education, 2010b). The first benchmark's data, from 2013, indicated that over half of the sixth grade students lacked competency in subject matter—consisting of number sense, numerical operations and estimation—as measured by the school's developed measurement tool. When comparing the pretest/posttest benchmark data, student achievement in sixth grade increased approximately 7.5% overall. Although not piloted for reliability or validity, the benchmark proved effective to demonstrate the need for an appropriate intervention.

Socioeconomic status and school funding and teacher quality

Research during the later half of the 20th century has shown a strong correlation between socioeconomic status (SES) and student achievement (New Jersey Department of Education, 2010c). In an attempt to group like schools together for a more accurate and fair comparison, New Jersey developed a system, called District Factor Grouping (DFG), to rank its school districts by SES. DFG classifies each school district on a scale from *A-J*, with *A* being the lowest and *J* the highest on the SES ladder. The higher a school district is on the ladder the higher the SES of the community. Status is determined by using data from several indicators obtained from decennial census data (New Jersey Department of Education, 2010c, para. 4). These indices include "percent of population with no high school diploma, percent with some college, occupation, population density, income, unemployment, and poverty" (New Jersey Department of Education, 2010c). Based on the contributing data, the district under study had a DFG of an *A*. The percent of sixth grade students in DFG *A* who scored *proficient* or *advanced proficient* was 57.9. When compared to similar districts, the school still lagged behind in achievement, with only 53.1 % of sixth grade students scoring *proficient* or *advanced proficient.* Even if low SES has an effect on student achievement, it does not fully explain the gap in student achievement.

It is possible that this gap was due to funding. Financial data suggested that school funding is not a direct factor in poor performance. In 2012, the local district budget spent approximately 35% more per pupil than the state average. For comparison with DFG *A* districts, the local district budget was 20 % larger. Therefore, other factors must be investigated to determine an appropriate course of action.

It is also possible that this gap was due to the lack of high-quality teachers. It is well established that teacher quality affects student outcomes (Goe, Biggers, & Croft, 2012). By providing students with high-quality teachers who implement best practices, higher achievement is obtainable. NCLB mandated that all core academic subject teachers become “highly qualified” during the 2005-2006 school year (U.S. Department of Education, 2006, para. 6). In August 2006, the U.S. Department of Education issued a report stating that New Jersey had an “acceptable plan” (U.S. Department of Education, 2006, para. 11) in place to ensure highly qualified teachers would be instructing students. In order to be deemed highly qualified, a teacher must have a bachelor’s degree, full state certification or licensure, and prove they know the subject. According to a report by the U.S. Department of Education (2006), 100% of the core academic teachers at the school under study highly qualified. Therefore, despite increasing the quality of teaching staff, student academic achievement still lags.

An Alternative Approach

If the explanation is not SES, school funding, or high quality of teachers, then investigating an alternative approach to teaching may provide some answers. Sutton and Krueger (2002) may have an explanation. “Despite significant changes throughout society over the last half century, teaching methods in most mathematics classes have remained virtually unchanged" (Sutton & Krueger, 2002, p. 26). One possible approach was the use of computer-aided instruction (CAI). CAI refers to supplementing or replacing traditional instruction with a software-based program or application. This approach is discussed in the CAI section of the literature review.

Evidence of the Problem from the Professional Literature

Less than adequate mathematics achievement is a problem throughout the United States (Department of Education, 2008). Slavin and Lake (2008) noted that the mathematics scores of fourth and eighth graders steadily improved from 1990 through 2005, but more gains in mathematics achievement are necessary if the United States wants to be competitive globally (R. E. Slavin & Lake, 2008, p. 427). The results from the 2011 Nation's Report Card indicated that only 40% of fourth graders and 35% of eighth graders performed at or above the *proficient* level in mathematics (National Center for Education Statistics, 2011). The National Mathematics Advisory Panel (NMAP) found it "particularly disturbing" that American students are performing at mediocre levels in mathematics compared to their peers internationally (U.S. Department of Education, 2008, p. xii). Furthermore, Juvenon, Le, Kaganoff, Augustine, and Constant (2004) stated that, according to their findings, "U.S. children do not start out behind those of other nations in mathematics and science achievement, but they do lag by the end of the middle school years" (Juvonen et al. , 2004, p. 31).

It is well documented that mathematics achievement in the United States has trailed many of the top-performing countries. According to the report from PISA—the Program for International Student Assessment that administers tests in key subjects to a sample of 15-year-old students in participating countries—the United States ranked well below average (25th) in mathematics (Organisation for Economic Cooperation and Development, 2010). U.S. students appear to be “running in place” (U.S. Department of Education, 2008, p. 9) when compared to other nations. Similarly, U.S. students are also underperforming on state assessments. For example, many New Jersey students are not proficient on the mathematics portion of the NJ ASK. At the local level, a majority of students do not meet AYP in mathematics throughout the middle school grades (New Jersey Department of Education, 2013).

According to the National Mathematics Advisory Panel (2008), students in the United States have a poor understanding of core arithmetical concepts and lack fluency in complex algorithms, which impedes learning higher-level mathematics, such as algebra. In addition, many U.S. students who lack fluency with single-digit addition, subtraction, multiplication, and division of whole numbers may never gain proficiency (NMAP, 2008).

This is disturbing given that in order for students to become successful in mathematics, they must become proficient in factual, procedural, and conceptual knowledge (U.S. Department of Education, 2008). Factual knowledge, also referred to as declarative knowledge, refers to the ability to recall a small set of mathematical facts from long-term memory (i.e. addition, subtraction, multiplication, and division). Procedural knowledge refers to the steps or rules that must be followed to solve a particular problem (e.g., standard algorithms). Lastly, conceptual knowledge refers to understanding meaning, that is, answering the why question in mathematics. The National Mathematics Advisory Panel argued that “these capabilities are mutually supportive, each facilitating learning of the others” (U.S. Department of Education, 2008,

p. 26). If students do not possess the basic foundations of mathematics their ability to perform at the higher levels will be negatively impacted.

In 2009, state leaders launched the Common Core State Standards (CCSS) to ensure that all students graduating high school were adequately prepared for college and career. These standards were informed by the best standards already in existence, experience of educational leaders, and feedback from the public. (National Governors Association Center for Best Practices (NGA Center) and the Council of Chief State School Officers (CCSSO), 2010) Based on these standards for mathematics, by the end of fifth grade, students should have a “solid foundation in whole numbers, addition, subtraction, multiplication, division, fractions and decimals – which help young students build the foundation to successfully apply more demanding math concepts and procedures, and move into applications” (NGA Center & CCSSO, 2010, para. 1). Yet, many students in sixth grade have not achieved factual knowledge. Loveless (2003) found that although students have made progress in mathematics on the NAEP, progress in basic arithmetic has “ground to a halt”(p. 41), indicating a deficiency in either procedural or factual knowledge.

When students posses a foundation in basic math facts, they spend less time working on rudimentary mathematics and more time on higher level thinking. When students gain fluency with their math facts to the point where these facts become automatic, automaticity occurs. Crawford (2003) defined automaticity with math facts as the ability to answer instantly, without having to stop and think about a response (e.g., 5 x 6 = 30). Without such ability, students must compute their response using a variety of counting strategies, likely causing a “high cognitive load as they perform a range of complex tasks" (Woodward, 2006, p. 241). Cummings and Elkins (1999) found that when mathematical errors occurred, they were often due to "errors in calculating" math facts rather than lack of procedural knowledge, thus indicating a lack of factual knowledge (p. 171). Furthermore, "information-processing theory supports the view that gaining automaticity in math facts is fundamental to success in many areas of mathematics" (Woodward, 2006, p. 269). This theory supports the belief that working memory, also referred to as short-term memory, is limited and can perform only a few tasks at one time. Gagné (1983) stated that this limited working memory is where "problem solving occurs" (p. 15). He continued, "The scarce cognitive resource of attention needs to be devoted to the most intricate and complex part of the task" (p. 15). Thus making an argument for the importance of automaticity of math facts.

"A student who is automatic with basic facts will complete problems at a faster rate and therefore is likely to have more opportunities to respond (i.e., practice trials), which can enhance accuracy, fluency, and maintenance" (Poncy, Skinner, & Jaspers, 2007, p. 27). While automaticity pertains to the speed of a skills performance with minimal thinking, fluency pertains to the speed and accuracy of performing a particular skill. For example, to be fluent in multiplying multidigit numbers, one has to know automatically the fact that 7 x 8 = 56. As students learn a new skill, they will become increasingly fluent until automaticity is achieved (Axtell, McCallum, Mee Bell, & Poncy, 2009). Students who attain a level of fluency may possess less math anxiety and therefore be more likely to complete assigned tasks (Poncy, Skinner, & Axtell, 2010). Furthermore, increasing students' accuracy and speed of basic math facts is crucial for developing and mastering more advanced math skills (Poncy, Skinner, & Jaspers, 2007).

With the lack of mathematical achievement in the local school, an appropriate intervention is warranted. In order to reduce the number of underperforming students in mathematics, the Institute of Education Science (IES) produced a practice guide containing evidence-based recommendations of best practices. IES provided 10 recommendations to increase achievement (Gersten et al., 2009, p. 6). Recommendation 6 stated that interventions should devote about 10 minutes in each session to building "fluent retrieval of basic math facts" (Gersten et al., 2009, p. 6) This recommendation is intended to lay the framework for content and daily time consumption.

Numerous studies have demonstrated successful ways to increase math fact fluency (Aleven, Kay, Arroyo, Royer, & Woolf, 2011; Axtell et al., 2009; Baroody, Bajwa, & Eiland, 2009; Crawford, 2003; Poncy et al., 2007; Poncy et al., 2010; Smith, Marchand-Martella, & Martella, 2011; Wong & Evans, 2007; Woodward, 2006). The focus of this study was to determine the effectiveness of computer-aided instruction (CAI) as a means to increase student fluency in basic math facts as compared with traditional instruction.

Definitions

Adequate yearly progress (AYP) is the year-to-year measure used by states to determine if a school, school district, and state are reaching academic standards measured by state assessments in order to comply with the national No Child Left Behind Act (U.S. Department of Education, 2001).

Automaticity refers to the ability to recall facts quickly and with little effort (Poncy et al., 2007).

Computer-aided instruction (CAI) refers to supplementing or replacing traditional instruction with software-based programs (Hyland, Pinto-Zipp, Olson, & Lichtman, 2010).

Conceptual knowledge refers to knowledge of the concepts of a domain and their interrelations (Schneider et al., 2011, p. 1525). For example, understanding that the equal sign represents equality.

Factual knowledge in mathematics refers to "having ready in memory the answer to a relatively small set of problems of addition, subtraction, multiplication, and division" (Willingham, 2010, p. 15). The answer must be well known or memorized where that calculation is not required. For example, 3 x 4 = 12. The product was a known response rather than requiring the use of counting such as 3 plus 3 plus 3 plus 3 equals 12.

FASTT Math – refers to the computerized math facts fluency program -Fluency and Automaticity through Systematic Teaching and Technology (Scholastic, 2014). Based on two decades of research conducted by Dr. Ted Hasselbring, Co-Director of the Learning Technology Center at Vanderbilt University (PR Newswire, 2012).

Fluency refers to fast and accurate response to a particular mathematical question (Haring & Eaton, 1978).

New Jersey Assessment Skills and Knowledge (NJ ASK) is "a criterion-referenced competency test that assesses student knowledge of New Jersey core content standards" (New Jersey Department of Education, 2009). The areas of focus are language arts literacy, mathematics, and science. Scoring classifications of students include *partially proficient* (scores below 200), *proficient* (200-249) and *advanced proficient* (250 – 300) (New Jersey Department of Education, 2012a). Extensive efforts are made to ensure the validity and reliability of this measurement tool (New Jersey Department of Education, 2012b).

New Jersey Report Card is an annual public report mandated by New Jersey statute 18A:7E 1-5 that provides pertinent information regarding school success (New Jersey Department of Education, 2013). The areas discussed within this report include school environment, student information, student testing performance indicators, other performance indicators (e.g., attendance), staff information, and district financial data (New Jersey Department of Education, 2013, sec. Report Card Fields).

Paper pencil instructions (PPI) – refers to paper pencil instruction as opposed to computer-aided instruction (Wong & Evans, 2007).

Procedural knowledge refers to the ability to "execute action sequences to solve problems" (Schneider, Rittle-Johnson, & Star, 2011, p. 1525). For example, the use of counting in the problem 3 x 4 = 12, whereas the answer is not known but can be figured out by following a set of rules or procedures.

Significance

Primarily, this study is significant because it added to the literature pertaining to CAI instruction and math fact fluency. As discussed in the literature review, few studies have been conducted in this area of study over the last decade. In addition, this study was conducted due to a need for student academic improvement in mathematics. According to school district data, there appears to have been no significant improvement in mathematics performance over the last 5 years (New Jersey Department of Education, 2013). Based on school data from 2012, almost 50% of middle school students scored "*partially proficient*," the lowest classification available to label student performance

(New Jersey Department of Education, 2012a). If students are to improve mathematics test scores, a new mathematics instructional approach is necessary. This study was designed to reveal whether FASTT Math can be used to improve student performance over traditional mathematics instruction. The results of this study should prompt discussion with regards to CAI and math instruction, and may provide guidance for future studies and possibly produce a curriculum policy change in mathematics.

Guiding/Research Question

This study was designed to determine if CAI is an effective method to develop math fact fluency as compared to traditional instruction among sixth-grade students. According to the National Council of Teachers of Mathematics (NCTM), the student's ability to proceed to algebra will be determined by mastering the most critical mathematics skills and concepts that are introduced in sixth grade (National Council of Teachers of Mathematics Commission on Standards for School Mathematics, 2008). In other words, sixth grade is an important transitional period, when students move from focusing on factual and procedural knowledge to more conceptual knowledge.

If developing automaticity and fluency is crucial for developing and mastering more advanced math skills, then it would be paramount to determine the most effective way for students to become fluent in math facts. In the school under study and district, numerous strategies are used to address this need. These include paper-and-pencil exercises, flashcards, copy-and-cover techniques, and CAI. While many instructional techniques can be implemented to increase math fact fluency, few studies have tried to learn whether CAI was more or less effective than other approaches. Thus, this study sought to answer the following research question:

Is there a significant difference in math fact fluency among those sixth-grade students who receive didactic mathematics instruction and those sixth-grade students who receive FASTT Math software instruction, as measured by a 2-minute drill performance instrument?

Review of the Literature

This literature review includes an examination and summary of the current literature on computer-aided-instruction and its effectiveness when used to improve math fact fluency. The literature reviewed for this study was collected using a variety of databases and educational publications. The following databases were used: ERIC, Education Research Complete, Education from SAGE, Education Research Starters, and ProQuest Central. The following search terms were used: *automaticity, computer-aided instruction, computer assisted instruction, CAI, computer based instruction, CBI, computer instruction, conceptual knowledge drills, drill and practice, factual knowledge, FASTT Math*, *math facts, math fact fluency,* and *procedural knowledge.*

Theoretical Framework

The theoretical framework for this research must link changes in the curriculum to changes in the performance of the learner. Thus, the theoretical framework for this research is one of necessity: taking a single module of instruction and testing for changes in students' performance. It was the aim of this effort to improve mathematics abilities, as the previous efforts in the subject school over the previous past 5 years have failed to produce a significant positive change in performance as measured by the NJ ASK.

Haring and Eaton (1978) developed an instructional learning hierarchy that provides systematic guidelines for selecting instructional procedures. Influenced by the works of Piaget (1950), Bloom (1971), and Gagne (1970), this theory suggests that students move through stages of development as they learn (Haring & Eaton, 1978). Applied to mathematics instruction, this model predicts that those students who master basic mathematics skills are better able to progress to more general and abstract skills (Axtell et al., 2009). Based on this theory, in order to become proficient in complex skills, students must first master basic mathematical skills.

Haring and Eaton's hierarchy has four distinct phases in which skills begin slow and inaccurate, then accuracy increases but task completing remains slow. Once speed and accuracy are maintained, learning can be applied to responding to new stimuli and to solving problems (Burns, Codding, Boice, & Lukito, 2010). Theses four levels of performance include acquisition, fluency building (proficiency), generalization, and application or adaption (Haring & Eaton, 1978).

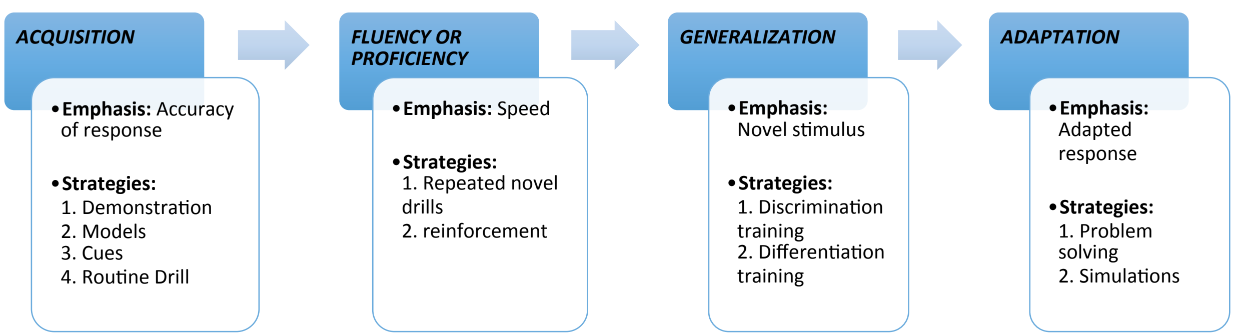

Figure 2. Flowchart depicting the four phases of Haring and Eaton's Learning Hierarchy (1978).

Acquisition is the first step in learning a new skill. "Demonstration of initial performance is but the first of a series of learning stages" (Haring & Eaton, 1978, p. 25).

Teaching accuracy is the focus at this phase. According to Burns et al., students require modeling, guided practice, and frequent feedback in order to obtain acquisition and accuracy (2010). Since developing the ability to respond accurately is the first step to mastery, procedures developed and implemented at this stage can affect subsequent stages of development. Once acquisition is obtained, students can progress to developing fluency.

Fluency is developed when student responses become quick, accurate, and automatic (Haring & Eaton, 1978). During this phase, “students can accurately complete a skill but need additional practice to become more proficient” (Burns et al., 2010, p. 71). Instructional strategies at this level may include incremental rehearsal of math facts, use of manipulative, and modeling using cover, copy, compare and other practice approaches based on the principle of “learning by doing” (Haring & Eaton, 1978, p. 27).

At the generalization stage, students should be able to apply basic mathematics operations to a variety of situations. Building on the first two stages, at this point students should possess a mastery of basic mathematics facts and mathematical operations. Haring and Eaton (1978) suggest that tasks must move beyond drill of basic facts and to practice skills in a variety of scenarios, varying in duration and intensity.

Adaptation (or application) is the final stage of this instructional hierarchy. Adaption occurs when skills are “usable in modified form in response to new problems or in new situation” (Haring & Eaton, 1978, p. 31). Optimal development will occur when practice is provided repeatedly using a variety of different situations. At these higher stages, programs may include “discrimination and differentiation training, problem solving and simulations” (Haring & Eaton, 1978, p. 34).

When this framework is applied to mathematics, Haring and Eaton suggest that students who acquire and maintain basic math facts are better suited to progress to more conceptual abstract skills, such as word problems and problem solving (Axtell et al., 2009). In order to become proficient in these higher order-thinking tasks, students must first become fluent in basic math facts. This study will determine if FASTT Math is more effective than traditional instruction in reinforcing the acquisition and maintenance of automatic recall of basic math facts.

Computer Aided Instruction

A premier authority on teaching math in the United States, The National Council of Teachers of Mathematics (NCTM) wrote that "Technology is an essential tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology" (National Council of Teachers of Mathematics, 2008, p. 1). That premise is the foundation of this research effort. Born out of the works of Skinner in the 1960s with his teaching machines, educators have long attempted to develop ways for technology to deliver effective individualized instruction. In years past that may have meant using a machine and punch cards, while today one might use an Internet-based application; but the goal remains the same. Cates supported CAI as an effective and efficient teaching method stating: "computer-assisted instruction emphasizes the importance of the completion of numerous antecedent-behavior-consequence learning trials" (Cates, 2005, p. 638). The purpose of this review of literature is to determine the level of effectiveness of CAI, as a model of instruction, as it pertains to sixth-grade mathematics.

The National Mathematics Advisory Panel found "instructional software has generally shown positive effects on students' achievement in mathematics as compared with instruction that does not incorporate such technologies" (Department of Education, 2008, p. 50). The panel recommended that high-quality CAI drill and practice should be implemented with fidelity and was a useful tool for developing automaticity.

CAI Meta-Analysis

Numerous meta analysis studies have been conducted to assess the effectiveness of CAI. Below is a general overview of CAI as stated by (Robert E. Slavin & Lake, 2007, p. 17):

> A longstanding approach to improving the mathematics performance of elementary students is computer-assisted instruction, or CAI. Over the years, CAI strategies have evolved from limited drill-and-practice programs to sophisticated integrated learning systems (ILS), which combine computerized placement and instruction. Typically, CAI materials have been used as supplements to classroom instruction, and are often used only a few times a week. Some of the studies of CAI in math have involved only 30 minutes per week. What CAI primarily adds is the ability to identify children's strengths and weaknesses and then give them self-instructional exercises designed to fill in gaps. In a hierarchical subject like mathematics, especially computations, this may be of particular importance.

Slavin and Lake (2007) evaluated the effectiveness of 38 CAI studies, with 15 of those randomized experimental or randomized quasi-experimental designs. Generally speaking, most of the studies produced positive effects, especially on the measures of mathematics computation. Slavin and Lake (2007) found that those studies that reported their results by subscale usually produced stronger outcomes for the area of computation. Across all studies where an effect size could be determined, the effects were considered meaningful. The average effect size based on the 38 available studies was +0.19.

In a later study, Slavin et al (Slavin, Lake, & Groff, 2009) found similar results when evaluating the effectiveness of CAI in middle and high school mathematics. At the middle and high school level, CAI can be divided into three categories: supplemental, core, and computer-managed systems. Supplemental CAI programs, like those primarily used in elementary classrooms, are used to fill in the gaps. These programs are usually implemented ranging from 30–90 minutes per week. Core CAI programs, generally are considered teacher replacements, provide core instruction, opportunities for practice, assessment, and prescription to meet the learner's needs. The third approach, computer-managed systems, uses the computer to assess students, provide assignments, and give feedback to the teacher on student progress.

Thirty-eight qualifying studies were evaluated within this meta-analysis. While the 2009 study found CAI to produce positive effects on student learning, the median effect size was considerably smaller than that found by Slavin and Lake in the 2007 study. The median effect size was +0.10 as compared to +0.19 at the elementary level. When each category of CAI was evaluated separately, a possible explanation becomes apparent. The effect size of core CAI was +0.09 in 17 studies, supplemental CAI was +0.19 in 18 studies, and computer-managed learning systems was -0.02 in 3 studies. The results of the effect sizes indicate that the use of supplemental CAI was the most effective from elementary through high school.

In a more recent meta-analysis, (Cheung & Slavin, 2011) evaluated a total of 74 qualifying studies with a total sample size of 56,886 K-12 students. Once again, the studies indicated that CAI had a positive, but small effect (+0.16) on mathematics achievement. While elementary studies had a larger effect rate (+0.17) than secondary studies (+0.14), the findings were not statistically different.

Li and Ma (2010) found, in a meta analysis of 46 primary studies involving 36,793 learners, that the use of computer instruction had "overall positive effects" on mathematics achievement (p. 232). On average, there was a moderate but significantly positive effect on mathematics achievement +0.71. The findings suggest that CAI was more effective when used with special needs students and when a constructivist approach to teaching was practiced. In addition, Li and Ma supports Slavin et al., 2007, 2009, 2011 assertion that CAI is more effective in elementary mathematic classrooms. Liao, Chang, and Chen (2007), came to the same conclusion, based on a meta-analysis conducted in Taiwan involving over 5000 participants, stating that CAI has a moderate positive effect on elementary students.

Kroesbergen & Van Luit (2003) conducted a meta-analysis to determine the effectiveness of mathematics intervention with special-needs students. Within this meta-analysis, 12 studies addressed the use of CAI. The findings indicated that CAI was useful to increase student motivation under certain conditions. "However, the computer cannot remediate the basic difficulties that the children encounter. The results of the present study show that in general, traditional interventions with humans as teachers, and not computers, are most effective" (Kroesbergen & Van Luit, 2003, p. 112). These findings contradict those found by Li and Ma (2010), although it is important to note that their focus was only on special education students.

Based on the findings of the meta-analysis studies, implementation for developing basic math facts would most likely produce a positive effect on student achievement. One caveat that needs to be mentioned is regardless of when the meta-analysis was published, most of the studies were conducted during the 1980s and 1990s. Searches of various databases have turned up few recent studies focusing on CAI and math fact acquisition and fluency. In the paragraphs below, I will discuss the most recent individual studies that focused on implementing CAI to improve basic math fact achievement.

Tienken and Wilson (2007) investigated the effectiveness of drill and practice CAI that focused on a variety of skills including computation, and combined active learning follow-up exercises on a sample of seventh grade students. The researchers randomly assigned four teachers to experimental (n = 2) and control (n = 2) groups with the total students (n = 267) split between the experimental group of 126 students and the control group with 141 students. A quasi-experimental design was implemented because the students comprised intact groups.

Tienken and Wilson's findings were analyzed using a two-way ANCOVA, controlling for pretest differences and socio-economic status (SES). The CTB/McGraw Hill TerraNova instrument was used to generate the data for analysis, and the findings suggested a positive, although slight, effect size (+ 0.12) on achievement.

The following year, Tienken & Maher (2008) conducted a similar study with eighth grade students. All of the elements of this study mirrored the study from the previous year. In a stark reversal from the previous study, the findings suggest that CAI did not have a positive influence on student achievement. In fact, the control group produced an effect size (+ 0.36).

Wong and Evans (2007) investigated the effectiveness of paper pencil instruction (PPI) and/or CAI as strategies to increase multiplication fact recall in fifth grade students. For the CAI treatment (n = 37), students used the program, “Back to Basics Multiplication” for 15 minutes per session, totaling 11 sessions. Students receiving CAI treatment were given instant feedback as to whether responses were correct or incorrect. The PPI treatment (n = 27), students completed teacher-generated worksheets containing 80 problems during each 15 minute session, also totaling 11 sessions. After each session, worksheets were graded for accuracy and returned to the students before the next session.

The results of one-minute pretest/posttest and maintenance drills were used to measure recall of basic math multiplication facts. The researchers compared the number of correct responses from each drill. The results suggest that systematic practice of multiplication facts was an effective method for improving multiplication fluency. Meaning, both interventions proved successful to increase multiplication recall, although PPI was more effective than CAI. While PPI was shown to be more effective, the researchers cautioned that the pretest/posttest were written in the same format as the PPI worksheets that may have affected performance levels.

Graham, Bellert, Thomas, and Pegg (2007) investigated the effectiveness of the CAI program QuickSmart, “a responsive small group intervention that aims to develop fluent (Quick) and efficient (Smart) strategy use” (L. Graham et al., 2007, p. 410). The researchers wanted to determine if QuickSmart improved fluency, and if so, influenced development of complex skills, such as problem solving, as reflected on students’ performance on standardized achievement tests.

Three schools and forty-two students were involved in the mathematics portion of the study. Participants were selected for treatment based on their statewide school results. Instead of a control group, the researchers used a comparison group of five high-achieving students and five average-achieving students, totaling ten students. Interventions lasted approximately three 30 minutes lessons a week for 26 weeks.

Data was collected based on the pretest/posttest consisting of the standardized Progressive Achievement Tests (PAT) to measure comprehension and the Cognitive Aptitude Assessment (CAAS) to measure speed. The findings indicated that the gap between lower achieving students and their average/high student counterparts was narrowed significantly. Fluency was increased from an average of 3.5 to 2.2 seconds. In addition, accuracy increased from an average of 76% to 89% for correct multiplication facts at the end of the study. The results suggest that when CAI emphasizes practice and structure, improved student achievement is possible. Kopcha and Sullivan (2008) found that low-level learners performed at a higher level when they were provided with a highly structured program-controlled intervention.

Cates (2005) compared the use of peer tutoring and CAI to determine which strategy was the most effective intervention to promote fluency of math addition facts. CAI was implemented in three-minute segments where students interacted with digital flashcards. All responses would result with a “ding”, but the flashcard would remain until a correct answer was provided. Afterwards, the student recorded the number of correct responses. Similarly, the peer tutor group would respond to flashcards for three minutes. Rather than hearing a ding, correct responses would receive verbal praise, while incorrect responses would be ignored. When the correct response was provided, the tutor would change the flashcard until the time was exhausted.

This study consisted of four participants split into an older (ages 10-11) and a younger (age 8) group. Each participant was exposed to both types of treatments. Using a BCBC research design, where “B” represented peer tutoring and “C” represented CAI, the researcher found that the older students demonstrated higher levels of accuracy using the CAI, while the younger students demonstrated higher accuracy using the tutor intervention. The findings supported other research citing CAI an effective instructional strategy. In addition, it suggested that a student’s current stage of learning may be important when selecting an appropriate strategy or intervention (Cates, 2005). While other studies evaluating the effectiveness of CAI were available (Barrow, Markman, Rouse, & Federal Reserve Bank of Chicago, 2007; Campuzano, Dynarski, Agodini, Rall, & Institute of Education Sciences (ED), 2009; Gatti & Petrochenkov, 2010; Resendez & Strobel, 2009; Wijekumar et al., 2009), the focus of those investigations did not pertain to math fact acquisition, fluency, or basic computation.

Summary

The current literature on the effectiveness of CAI to improve mathematics achievement is mixed. Most of the studies found that CAI had a positive effect on student learning (L. Graham et al., 2007; Tienken & Wilson, 2007), although CAI proved less effective than other interventions (Cates, 2005; Wong & Evans, 2007), while in others it resulted in no improvement at all (Tienken & Maher, 2008). Based on the size of these studies it is difficult to generalize the finding to other educational settings, although the study designs may inform other research that may support their findings. Based on the findings of the meta-analysis studies, CAI has been found to show a positive effect on student mathematical achievement. The results have shown that CAI proves to be most effective when it incorporates drill and practice, and when it is used at the elementary level.

Implications

This topic and grade level was selected because of the high degree of attention our school received over the last 5 years pertaining to mathematics performance among our sixth grade students by the New Jersey Department of Education. As discussed in the literature review, sixth grade is an important transition period in mathematical instruction, where the focus of learning begins to shift to higher-level conceptual skills. If students do not have a solid foundation of their math facts by this time, their future mathematical achievement may be negatively impacted. Use of CAI for improving math fact fluency is supported by literature and is a component of the researched district's mathematics curriculum. FASTT Math is one of the software applications that the district purchased to be used as a supplement to increase student achievement in mathematics for third through eighth grades. Teachers have been free to use this program as they deem appropriate. Based on usage reports, FASTT Math has been used inconsistently throughout the district. It has primarily been implemented in the intermediate grades, and usage at the middle school level is almost nonexistent. This study provides data obtained through the analysis of 2-minute drill pretest/posttest scores to determine if consistent use of FASTT Math at the sixth grade level produced increased achievement in math fact fluency. If in fact FASTT Math produces increased math fact fluency, district benchmark data can be analyzed to determine if increased math fact fluency had an impact on student benchmark performance. Furthermore, if this research indicates a positive change in student mathematics, then as a possible project, a policy recommendation in the form of a white paper recommending a school wide module could be designed and implemented to change the stagnant mathematics performance as measured by the NJ ASK.

Summary

One urban PreK-8 New Jersey public school has shown weak mathematical performance at the sixth grade level. In accordance with NCLB, the local school district has attempted to address this lack of achievement by implementing numerous changes. Despite these initiatives, no substantial improvements in test scores have materialized at the sixth grade level.

If students do not possess the basic foundations of mathematics, how will they be able to perform at the higher levels? Based on the Common Core state standards for mathematics, by the end of fifth grade, students should have a solid foundation in math facts and be able to apply them to more demanding math concepts. Yet, many students in sixth grade have not achieved mastery of math factual knowledge. With sixth grade being an important transitional period moving to more advanced conceptual mathematics, it is vital that fluency is mastered before moving to seventh grade.

Some literature suggests that implementation of CAI has a positive effect on student math fact fluency, when compared to traditional instruction, while other studies did not show this effect. Most of the studies found that CAI was most effective when used at the elementary level and outcomes are usually stronger for computation than for concepts or problem solving.

This study focused on the development of automaticity and fluency of math facts. When the ability to respond automatically is obtained, cognitive resources can be applied to more complex tasks (Axtell et al., 2009). This study revealed whether CAI—

specifically, FASTT Math—was more effective than traditional teaching of mathematics to increase student math fact fluency. This study compared the results of 2-minute drills to determine which school-approved approach is more effective. Given the need to increase student fluency in basic math facts, determining which strategy works best is imperative. The findings from this study provided the basis for the development of a white paper discussing the implementation of FASTT Math, as well as an invitation for more discussion about the use of CAI in the classroom.

The following section will describe the research design and methodology used to evaluate the effectiveness of FASTT Math software application as an instructional supplement implemented in a sixth grade mathematics class.

Section 2: The Methodology

Introduction

This study was designed to determine if CAI is an effective method to develop math fact fluency as compared to traditional instruction. The CAI used for this study was FASTT Math, a district purchased program that is part of the mathematics curriculum at the school under study. The study was carried out at the sixth grade level.

This section includes the research design, setting and sample, instruments, data collection process, procedures, and data analysis.

Research Design

To determine if FASTT Math had a positive impact on math fact fluency at the sixth grade level in the study school, research was necessary. To address the problem, I chose a group comparison that would analyze trends or the relationships among the variables. According to Creswell (2012), when researching a problem to explain relationships among variables, a quantitative approach is best. A modified, quasi-experimental, nonequivalent, control-group design was used since participants were not randomly selected nor assigned to the treatment or control group (Gall et al., 2010). Random assignment was not feasible nor ethical because classes were already formed. The quasi-experimental design was used to minimize the disruption in student learning. Figure 3 describes the pretest/posttest quasi-experimental research design whereas O_1 and O_2 represent the experimental group, O_3 and O_4 represent the control group, and X represents the FASTT Math treatment. According to Creswell (2012), quasi-experimental design is frequently used in educational research.

	Pretest Knowledge	Treatment	Posttest Knowledge
Experimental Group	O_1	X	O_2
Control Group	O_3		O_4

Figure 3. Modified quasi-experimental nonequivalent control-group pretest-posttest design, where: $O_{1,}$ O_3 = the observation of mathematics achievement pretest, $O_{2,}$ O_4 = the observation of mathematics achievement posttest. X= FASTT Math.

This study focused on the development of math fact fluency in two groups, an experimental and a control group. During a 3-week period, both groups used the last 10 minutes of a daily 90-minute mathematics class for developing math fact fluency. The experimental group received computer-aided instruction through the use of FASTT Math, while the control group received traditional instruction, consisting of flashcards, paper-and-pencil and oral practice. At the conclusion of the study, the control group received FASTT Math treatment for the same period of time as the experimental group.

The CAI consisted of the use of FASTT Math (Tom Snyder Productions, 2005), developed by Dr. Hasselbring. FASTT Math offers 44 levels of skill testing in multiplication. In this study, students completed a diagnostic test to identify their current level of multiplication skill; lessons were delivered based on that initial diagnostic result. Each CAI practice session provided immediate feedback: It showed their errors and offered additional practice. When students mastered their current level, the program automatically advanced them to the next level. Students received rewards, such as certificates and name placement on FASTT Math leader boards when they exceed prior results. The CAI software also provided reports on student progress.

Setting and Sample

Participants composed of students from a New Jersey PreK-8 elementary school with a total enrollment of approximately 600 students evenly distributed throughout each grade at the time of the study. The student population was classified as economically disadvantaged, as 93% of the students received free or reduced lunch. The ethnic background of the school consisted of 78% African-American, 20% Hispanic, 1% European American and 1% Asian. Of this population, 92% of the students were native English speakers and the remaining students were English language learners who possessed understanding of the language, using English as their primary language while in school (New Jersey Department of Education, 2013). In addition, the mobility rate at this school was approximately 20% (The National Center for Education Statistics, 2011).

In sixth grade, there were 61 total students enrolled into four classes: one special education self-contained class, one mixed regular education classroom with inclusion students, and two fully regular education classes. For the purpose of this study, the two fully regular education classrooms were used. Since classes were already formed prior to conducting this study, convenience sampling (Gall et al., 2010) was used. The participants consisted of 40 regular education sixth grade students divided between two classes of 20 students each.

Based on the power analysis formula, a minimum of 65 participants would be necessary for each group in order to ensure sufficient power (Lipsey, as cited in Creswell, 2012, p. 611). Unfortunately, based on sixth grade's student numbers, I was unable to obtain this number of participants. The total number of participants was 40. Therefore, the sample size rendered for this study was underpowered in detecting group difference. While the results may be underpowered to support statistical significance, they may provide practical significance.

Given my role as my school's technology coordinator, I did not instruct any of the participants in this study. A state-certified mathematics teacher, who is a colleague and not my subordinate, taught both classes. This teacher has taught mathematics at the middle school level for the last 5 years and is familiar with the FASTT Math application. She agreed to participate in this study freely and understands my role is not to collect data about her instruction but to analyze the data that results from pretests/posttest. This teacher administered the 2-minute drills (pretests/posttest), as well as the CAI and traditional instruction as part of her routine mathematics class. My role was only to collect and report the data.

Instrumentation and Materials

The number of multiplication items answered correctly during multiple 2-minute drills was used to measure basic multiplication fact recall. The multiplication pretests contain 80 random multiplication problems chosen from 0 to 12 times tables. The tests were generated using Worksheet Works (2012), a program available from the Internet, which is commonly used by the school's classroom teachers. The posttest was developed using the same worksheet generator and copies of both the pretests and posttest can be found in Appendix C and D respectively. The total number of correct responses on each of the 2-minute drills provided the student's score, with 80 being the highest score possible. Higher scores indicated an increased level of mastery and fluency in multiplication. The results from the pretest and posttest were analyzed for performance change. The performance change for the experimental group (O_2-O_1) and control group

(O_4-O_3) were compared to determine if differences existed. The raw data and results are provided in the form of charts and graphs located in the data collection and analysis section of this study.

2-minute drills have often been used by educators to determine mastery and fluency of math skills, and are commonly used in my school. Historically, timed tests have been a standard measure of student ability in my school, usually derived from worksheets found on the Internet, drill pages located in the back of math textbooks, or other resources. Furthermore, based on conversations I have had with my school's math teachers, timed tests were considered a reliable measure to determine the level of math fact fluency.

The use of multiple assessments can be used to develop an equivalent-form of reliability, or consistency across different forms (Lodico, Spaulding, & Voegtle, 2010). To determine reliability, I analyzed the results of two pretest drills provided by Worksheet Works. While the content of both pretests were consistent, the question bank was populated with different items. As part of routine formative math review, students completed a 2-minute drill pretest using the first worksheet in one instance and completed the second pretest a few days later. The results of both pretests were analyzed to determine the similarity between student responses. To determine the level of reliability of the 2-minute drills, a reliability analysis in the form of Cronbach's alpha, was performed. A test indicating reliability close to 1.0 would support use of 2-minute drills as a reliable instrument to determine math fact fluency. With regards to this study, the items on the 2-minute drill had very little variation due to the limited scope of the skill being assessed.

To further strengthen the reliability of the instrument, the results of each of the two pretests were averaged to produce a pretest automaticity score. Given that the items on the pretests varied to a limited degree—for example 8 x 9 may appear on one pretest, while 3 x 4 may appear on the other—two pretests provided a more reliable automaticity score than one pretest alone. Both pretests were administered during the week prior to beginning any treatments.

According to Lodico, et al. (2010), content validity is composed of sampling validity and item validity. To ensure validity, I approached four certified math teachers in my school, and asked them to review the multiplication 2-minute drills to determine if they were representative of the content that students in sixth grade would encounter. In addition to confirming that the content was valid, those teachers inspected each item and determined that the items did indeed represent the skill that was being assessed. There was a consensus among the math teachers in the school that sixth grade students encounter multiplication items like these in mathematics class, and that these items accurately measured the skill of multiplication.

Data Collection and Analysis

The primary purpose of this study was to determine if the use of CAI, specifically FASTT Math, would show greater rates of growth for students mastering their basic math facts than traditional instruction alone. This section describes the results pertaining to whether the group receiving FASTT Math demonstrated larger rates of growth on the 2-minute drill than the group receiving traditional instruction.

In analyzing the data, it was first necessary to determine the homogeneity of the treatment and control groups towards mathematics achievement, as they existed prior to the commencement of instruction. Simply put, I needed to know how similar the groups were prior to conducting this study. A Levene test using the student's automaticity baseline score was used to determine homogeneity. The Levene test is an inferential statistic that assesses the equality of variances or differences for a variable calculated for two of more groups. Student baseline scores were determined by averaging the results of the student's two pretest scores. Two pretests were given to strengthen the reliability of the use of the 2-minute drill and to provide a mean average of student performance. As anticipated student performance on both pretests was consistent with little variation. The Levene test, as reported in Table 1, indicated significance at .283 for the pretest average, which is above the accepted .05 level for significance, meaning that any differences between the two groups were minimal. In this case, both groups performed very similarly on their pretests and additional adjustments for preexisting differences were not necessary. Therefore, the pretest data analysis revealed there was no significant difference between the mathematics knowledge of the two groups, indicating that both groups should be considered homogenous.

Table 1

Levene Test of Homogeneity of Variances

	Levene statistic	*df1*	*df2*	*Sig.*
Pretest Average	1.185	1	38	.283
Posttest	.090	1	38	.766
Posttest – Pretest Difference	5.477	1	38	.025

A Levene Statistic test was conducted on the pretests to determine the homogeneity of the two groups, concluding that both groups were similar.

During the next three weeks, the treatment group received FASTT Math multiplication practice during the last 10 minutes of math class, while the control group continued to receive traditionally based multiplication practice during the last 10 minutes of math class. The time allotted for instruction for the treatment and the control groups were identical and a posttest was administered at the end of three weeks to produce comparison quantitative data.

The results were analyzed using SPSS for Macintosh, and by using several statistical measures it was determined there was a significant change in performance of both groups when comparing the results from the pretests/posttest, as well as a posttest difference between the treatment and control groups. As seen in Figure 4, box plots illustrate that the posttest indicated that both groups obtained increased math fact fluency during the study, as the FASTT Math group increased by an average of 10 additional correct items on the 2-minute drill posttest, and the traditional instruction group increased by an average of 4 additional correct items on the 2-minute drill posttest.

This difference was determined to be statistically significant when evaluated using one-way analysis of variance (ANOVA). Analysis of variance is used in comparative studies when differences in outcomes are being measured.

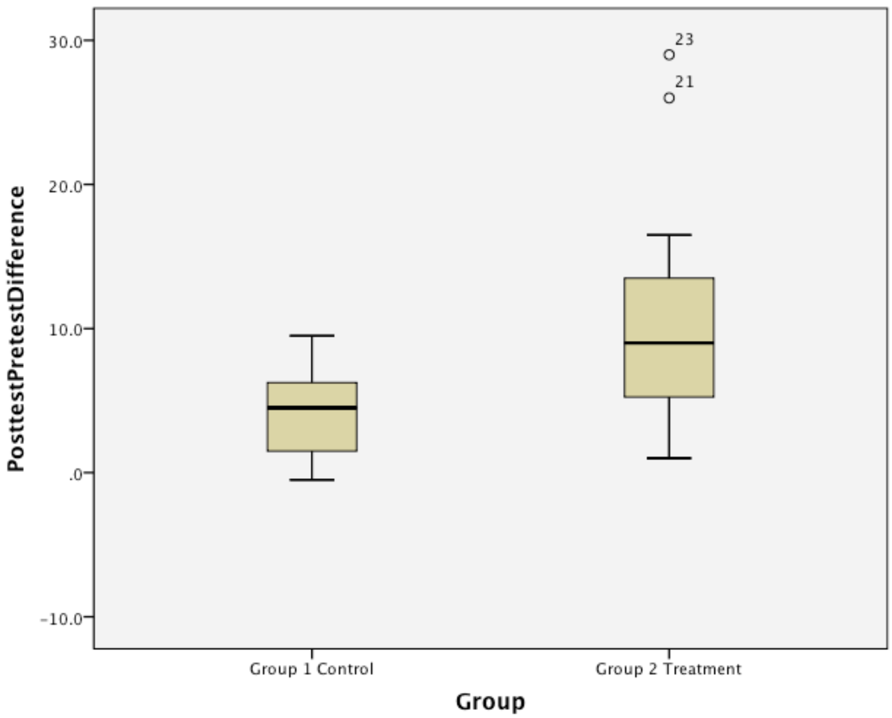

Figure 4. Box plots for 2-minute drill growth scores (posttest-pretest average).

The number of correct items completed during the pretests were used to determine each student's automaticity baseline score. I was looking for a positive posttest minus pretest difference to determine if there was an increase in student's automaticity after treatment. Using information from the SPSS analysis output, the descriptive statistics from both pretests, the average pretest baseline score, and posttest are reported in Table 2.

Table 2 illustrates both groups consisted of 20 students each (N), all of whom completed two pretests, consisting of pretest 1 and pretest 2. The results of both pretests were used to determine the pretest average or baseline score, these were than compared to the posttest scores, resulting with the posttest-pretest difference. In addition, the table displays the minimum and maximum scores for each group, as well as the mean average and standard deviation.

Table 2

Descriptive Statistics

		N	Count	Min	Max	M	SD
Group 1	Pretest 1	20	20	28	71	49	12.9
Control	Pretest 2	20	20	29	72	50	13.4
	Pretest Average	20		28.5	71.5	49.5	13
	Posttest	20	20	34	72	53.6	11.8
	Posttest – Pretest Difference	20	20	-0.5	9.5	4.1	3
Group 2	Pretest 1	20	20	28	70	55.1	11.7
Treatment	Pretest 2	20	20	30	70	56.5	10.8
	Pretest Average	20		29	70	55.8	11
	Posttest	20	20	37	80	66.4	11.4
	Posttest – Pretest Difference	20	20	1	29	10.6	7.1
Group 1&2	Pretest 1	40	40	28	71	52	12.6
Totals	Pretest 2	40	40	29	72	53.2	12.4
	Pretest Average	40		28.5	71.5	52.6	12.3
	Posttest	40	40	34	80	60	13.2
	Posttest – Pretest Difference	40	40	-0.5	29	7.3	6.3

Descriptive statistics describe the number of participants who completed the 2-minute drills, minimum and maximum score of each group, the mean average, as well as the standard deviation.

In addition, the results of Cronbach's alpha indicated that the use of 2-minute drills are a reliable measure for determining student math fact fluency. Cronbach's alpha measures the level of internal reliability of the measurement instrument, such as a 2-minute drill and the closer the Cronbach's alpha is to a score of 1.0 indicates a higher level of reliability. It is important that the instrument used to measure student performance is reliable or the results would be meaningless, and Cronbach's alpha for Pretest 1 and Pretest 2 both measured a reliability statistic of .918, while Cronbach's Alpha for the posttest was .941. This statistic indicates a very high level of reliability. These results can be viewed in Table 3.

Table 3

Cronbach's Alpha Reliability Statistics

			N	%
Cases	Valid		40	100
	Excluded[a]		0	0
	Total		40	100
Reliability Statistics Pretest 1				
Cronbach's Alpha		N of Items		
0.918		80		
Reliability Statistics Pretest 2				
Cronbach's Alpha		N of Items		
0.918		80		
Reliability Statistics Posttest				
Cronbach's Alpha		N of Items		
0.941		80		

Cronbach's alpha reliability statistics determines the internal reliability of an measurement instrument. This table depicts the Cronbach's Alpha for Pretest 1 & 2 and the posttest.

Research Question and Hypotheses

The purpose of this study was to examine whether the group using computer aided instruction would show greater rates of growth on the 2-minute drill than the group receiving traditional instruction. There is only one research question and corresponding hypothesis being explored in this study. The results of the question and hypothesis are presented below.

1. Was there a significant difference in math fact fluency among those sixth grade students who receive didactic mathematics instruction and those sixth grade students who receive FASTT Math software instruction, as measured by a 2-minute drill performance instrument that is supported by the school curriculum?

   H_0: Implementation of FASTT Math will not be significantly associated with a positive change in the automaticity rate in basic multiplication facts for sixth grade students.

   H_1: Implementation of FASTT Math will be significantly associated with a positive change in the automaticity rate in basic multiplication facts for sixth grade students.

   Independent variable: use of FASTT Math

   Dependent variable: change in mean difference between students' pretest and posttest scores

The hypothesis in this study compared the 2-minute drill scores of two groups of sixth grade students, one group received FASTT Math CAI instruction, and the other received traditional instruction. The goal was to determine if the use of FASTT Math would produce a larger change in mean difference between students' pretest and posttest scores. The hypothesis was tested with an ANOVA using SPSS software. The summary of the results of the ANOVA analysis appears in Table 4. Primarily, the posttest-pretest difference between groups (or classrooms) had a mean square of 419.256, which was significant at the .0001 level. This is a clear difference as most ANOVA are considered significant at the .05 or .01 level.

Table 4

One-Way ANOVA

		Sum of Sq.	*df*	Mean Sq.	*F*	Sig.
Pretest Average	Between Groups	400.056	1	400.056	2.769	0.104
	Within Groups	5490.188	38	144.479		
	Total	5890.244	39			
Posttest	Between Groups	1638.4	1	1638.4	12.156	0.001
	Within Groups	5121.5	38	134.776		
	Total	6759.9	39			
Posttest - Pretest Difference	Between Groups	419.256	1	419.256	14.143	0.001
	Within Groups	1126.438	38	29.643		
	Total	1545.694	39			

One-way ANOVA compared the effect of math fact fluency between the control and experimental group to determine the level of significance.

A one-way ANOVA was conducted to compare the effect of math fact fluency instruction on student performance on a 2-minute drill comparing FASTT Math instruction and traditional instruction conditions. There was a significant effect on the automaticity scores on the posttest at the $p < .05$ level for the FASTT Math condition [$F (1, 38) = 14.143$, $p = 0.001$]. The results in Table 4 indicate that the null hypothesis was rejected at $p < .001$. The mean scores on the posttest indicated an increase in performance for both groups. On average, student gain for the control group was 4.1 more correct responses and 10.5 additional correct responses for the treatment group. Students who received FASTT Math instruction showed a significantly greater growth from the pretests to posttest than the control group who received traditional instruction. This means that the students who used FASTT Math showed more growth in mastering math facts than the other students.

Assumptions, Limitations, Scope, and Delimitations

This study assessed the use of FASTT Math to increase basic math fact fluency. The strengths of this study included the use of one specific, easy-to-use software application, as well as, focusing only on one skill, and being implemented at one grade level. The narrow focus enabled the findings to have a more direct correlation with the treatment.

There were numerous variables that influenced the results of research. These include research assumptions, limitations, scope, and delimitations.

For assumptions, I assumed that the students performed as well as they could completing the 2-minute drills. I assumed that the 2-minute drills were administered properly and that the time limits for the drills were adhered to. I assumed that every effort would be made to ensure that the data collected was as valid and reliable as possible. In addition, I assumed that those involved in the study—teachers, students and administrators—would cooperate throughout the entire process. Finally, I assumed that the students would be able to access and operate the FASTT Math program. Based on my observations, interactions with students and cooperating teacher, and careful data gathering process, it appears that these goals were met.

This research contained numerous limitations. The first limitation was the measurement instrument. Because no published instrument was available, the instrument was produced using an online drill bank that is supported by the school curriculum. The use of a quasi-experimental research design made it impossible to establish a causality, only allowing a correlation to be determined. In addition, due to the small sample size (40 student participants), the findings had limited generalizability, therefore limiting its external validity. The small scale of this research suggests that the findings may be indicative of only this school's population rather than a representative sample of the country. Other limitations included time and resources. I was limited to one school, within one district, located in New Jersey.

This study included a few delimitations that may have influenced this study. According to Hancock & Algozzine (2006), delimitations pertain to a study's boundaries that define the limits of the study. The first delimitation was that the study only included regular education students from two sixth grade mathematics classes. Another delimitation was the length of the study as well as the study's research design. It is possible that a longer study, or a study that included a larger participant pool from a variety of grade levels, or a study conducted with a different research design may have produced different results.

Protecting Participants

Protecting the rights of participants was of the highest priority. Because the data produced was part of routine assessment required by the district curriculum, parent consent was not necessary. Prior to collecting data, the project study was reviewed and approved by Walden University's Institutional Review Board (IRB), indicated by the approval number: 12-09-13-0064332. In addition, the site school's principal signed a letter of cooperation and data sharing agreement.

For the purpose of this study, participant's names were changed to protect their anonymity. This was achieved by keying student names with identification numbers that were only known to me. All data from the 2-minute drills is stored digitally on a USB drive in a locked filing cabinet until 2019, when it will be erased.

Conclusion

The purpose of this study was to determine if CAI is an effective method to develop math fact fluency as compared to traditional instruction. The quasi-experimental study included 40 sixth grade students and one teacher over a 3-week period. Instruction focused on math fact fluency, specifically multiplication fluency. Results of this study indicated a statistically significant improvement for those students who used FASTT Math instruction over traditional instruction. The students who practiced math facts using FASTT Math demonstrated a higher level of math fact fluency on a 2-minute posttest drill than students using traditional methods. While the results of this study are promising, more research is necessary to determine the level of impact increasing math fact fluency will have on standardized tests, such as the NJ ASK. Hopefully the results from this study will provide some insight to improving student achievement in mathematics and promote further research into the effectiveness of CAI.

The following section, Section 3, will include details about the project, a white paper, which was used to present the research results to my district's superintendent. This white paper outlined the initial problem at the local and larger levels. It explained the results of this study, and the possible role of FASTT Math throughout the school's district.

Section 3: The Project

Introduction

This study was designed to determine if CAI is an effective method to develop math fact fluency as compared to traditional instruction. This section includes the project's goals, rationale, a literature review, project implementation and evaluation overview, and implications for social change. The policy recommendation presented in the form of a white paper,—the project component of this study (Appendix A)—will inform all district stakeholders of the findings of this study and provide curriculum policy recommendations for the use of FASTT Math in their schools.

Description and Goals

Based on the evidence of my study, the project consists of a mathematics curriculum policy recommendation presented in the form of a white paper. The policy recommendation will be presented to the local school district's superintendent and board of education once my doctoral study has been accepted and approved by Walden University. The goal of the white paper is to discuss the success of FASTT Math instruction, communicate the study's findings and conclusions, as well as provide recommendations for changes in mathematics curriculum policy, to policy makers. The white paper includes an introduction, a description of the problem, the study's findings, policy recommendations, conclusions, and references. The white paper provides recommendations in an attempt to alleviate the district's ongoing math performance issue.

Rationale

Walden University accepts four genres for project development. These include an evaluation report, a curriculum plan, a professional development plan, or policy recommendation with detail. The genre selected for this project was a policy recommendation with detail, delivered in the form of a white paper. The following information provides the rationale for this decision. When considering the genre choices, I needed to review parameters and results of my study, and determine the outcome I was looking for, which is to increase student achievement through the use of the program FASTT Math. FASTT Math is a program that was already purchased and sanctioned for use by the local school district, but does not have a mandate for use.

Based on usage reports, FASTT Math did not have enough usage to conduct a program evaluation; thus that type of study was not pursued. Consequently, an evaluation report would not be an appropriate genre of choice for a project. In addition, since FASTT Math is partially integrated into the existing local school district's mathematics' curriculum and supports the common core state standards, developing a curriculum plan would not be the appropriate genre. With regards to FASTT Math implementation, there is a limited professional development component. The professional development pertains primarily to student management and analyzing student reports, making an elaborate professional development plan unnecessary. What is needed is further evidence at additional grades for the district to justify a mandate for FASTT Math implementation.

I chose to use the white paper format to lay out the research base supporting FASTT Math theoretically, in practice, and within the school's sixth grade. This research base and study findings were used to suggest a policy recommendation for the mathematics curriculum that would mandate the use of the program. Details are carefully listed in the white paper regarding fact fluency, increasing student math achievement, reducing current achievement gaps, and promoting a positive attitude towards mathematics. As an accessible, short, document the white paper is intended to educate teachers in the district as well as administration, the school board, and any interested parents. Importantly, the white paper also presents the findings of this study to inform policy makers of the statistically significant relationship between the use of FASTT Math and student math fact fluency. While the size and scope of the current study is limited, with my assistance studies could be performed in classrooms across the district to assess the helpfulness of FASTT Math at different grade levels given that the range is third through eighth grade. Although the white paper itself is not a solution to the problem, it may provide vital information and recommendations to enable teachers and policy makers to make decisions based on data.

Review of the Literature

This literature review focuses on development of a mathematics curriculum policy recommendation in the form of a white paper that presents the finding of my study, as well as recommendations for increasing math fact fluency through the use of FASTT Math. Several online searches were conducted to produce literature pertaining to FASTT Math implementation and white paper development. Online databases included ERIC, Education Research Complete, Education from SAGE, Education Research Starters, and ProQuest Central. Search terms included *automaticity, CAI, computer aided instruction, computer assisted instruction, data teams, education policy, FASTT Math, math facts, math fact fluency, policy, professional development, response to intervention, and white* *paper*. Many of the results pertaining to math fact fluency and CAI duplicated the searches from section 1, and searches for white paper did not produce many results. Since a comprehensive database search for peer-reviewed studies for white paper yielded only a few sources, a saturation of literature was obtained through the use of Google Scholar and Google web searches.

Policy

Anderson (2014) defines policy as “a purposive course of action or inaction followed by an actor or set of actors in dealing with a problem or matter of concern” (p7). Kraft and Furlong (2012) describe public policy as the choices that government officials make to deal with public problems. These policies are enacted with specific goals and intentions, such as solving a problem or enhancing the quality of life (Wilson, 2016). Policies are designed and implemented by government officials at the federal, state, and local levels, as well as by other organizational entities.

Education Policy

Education policy is a form of public policy that impacts education that is implemented at the federal, state, and local levels. The state governments take on the central role in education policy in America today. According to Lawton (2012), “They are primarily responsible for designing, funding, and regulating public school systems” (p. 455). Although, in recent years the federal government has increased its influence on education policy, for example through the enactment of Race to the Top (RTTT) grant initiative (McGuinn, 2014). At the local level, school boards of education enact education policy. According to the Washington State School Directors' Association (2011), school boards develop policies to enable the functioning of the school district with the primary goal of improving student achievement outcomes. My presentation to the local school district's superintendent and school board of education is a request to change current education policy to assist with this goal.

Policy Recommendation

In order to enact change in current mathematics curriculum policy, a mathematics curriculum policy recommendation will be made to the local school district's superintendent and board of education. According to Doyle (2013), a policy recommendation is "simply written policy advice prepared for some group that has the authority to make decisions, whether that is a cabinet, council, committee or other body" (para. 1). In education, policy makers may be "in state or federal governments or leaders in schools, such as superintendents, principals, curriculum directors or teachers" (Creswell, 2012, p. 271). Policy recommendations are the primary instrument used to initiate change of existing policy, or to develop new policy. The policy recommendation, developed as the project component of this project study, will be delivered in the form of a white paper.

White Paper

Historically, the term white paper referred to official government reports produced in the United Kingdom early in the twentieth century (G. Graham, 2013; Stelzner, 2010). Graham (2013) noted, white papers were short reports or position papers named for the color of their white covers, distinguishing them from the much longer reports with blue covers. These papers provided legislators with background information prior to voting on a particular issue (Kantor, 2010). These papers provided a format for timely information assembly, dissemination, and absorption. Graham (2013) and Stelzner

(2010) claimed that the term originated from the Churchill Paper, also known as the British White Paper of 1922. While white papers continue to be used in government, different forms of white papers have “become prevalent in high-tech industries in recent years” (Willerton, 2012). Primarily, white papers have become commonplace in government as well as business.

Defining the term white paper has some challenges as this term has evolved over time. Historically, white papers refer to government reports on any given topic. While this may be true, white papers today consist of much more than just government reports. Stelzner (2007) defines a white paper as, “a persuasive document that usually describes problems and how to solve them. The white paper is a crossbreed of a magazine article and a brochure” (p. 2). Graham (2013) adds that white papers use “facts and logic to promote a certain product, service, or solution to a problem (loc. 821 of 9545). Kantor (2010) defines a white paper as “a document between six and twelve pages whose purpose is to educate, inform, and convince a reader through the accurate identification of existing problems and the presentation of beneficial solutions that solve those challenges” (p. 11). Although, there is not one single modern definition for the term white paper, I would conclude that there is a consensus that the goal of a white paper is to educate, inform, and persuade.

Since the advent of the Internet, the uses of white papers have proliferated, and have become a major force in the business world (Canright, 2011). White papers are a powerful marketing tool “used to help decision-makers and influencers justify implementing solutions” (Stelzner 2010, p.2). In business, white papers have been successful because they are considered to be marketing with content (Graham 2013).

They address a known problem and provide a credible solution. They are used to educate readers on a company's value as it pertained to a particular product or service. Because these documents are primarily intended to educate, they quickly become viral and spread across an organization (Stelzner, 2007). White papers have become part of the professional literature that is not published through traditional channels. According to Haapaniemi (2010), "white paper's growing appeal stems from its ability to tell an in-depth story and demonstrate a company's thought leadership in addressing business problems"(p. 6). White papers provide credible solution to a problem in a concise, easy to read format that places value on the reader's time (Graham, 2013; Kantor, 2010; Stelzner, 2007). In addition, white papers are very versatile and are easily disseminated through the internet (Clift, 1999).

FASTT Math & Math Fact Fluency

As discussed in section 1, the problem my study addressed was the lack of student achievement in sixth grade mathematics. As our students underperformed on state assessments, I began to ask my school's math teachers the question why? What skills were the students lacking that hindered their ability to succeed on our standardized tests? While I received many responses, one answer was abundantly clear. Our students lacked fluency of basic math facts. Therefore, I began to research theories pertaining to math facts to determine if there could be a connection. After some considerable research, I realized that theories pertaining to hierarchy of learning and working memory supported such a connection. Students who acquired and maintained basic math facts are better suited to progress to more conceptual abstract skills, such as word problems and problem solving (Axtell et al., 2009). In order for students to become proficient in these higher order-thinking tasks, they must first become fluent in basic math facts. Therefore, I was determined to find an effective way to increase student math fact fluency, which led me to FASTT Math.

Studying the impact of FASTT Math was pursued for many reasons. FASTT Math is a computer application purchased by my district and is used in my school. Therefore, it was district approved and one of the instructional tools available for use. FASTT Math is based on an extensive body of empirical and theoretical research that incorporates the use of technology. I also wanted to learn if CAI would have a positive affect on student achievement. Lastly, with a limited budget, was the district expenditure for FASTT Math worth the cost?

At the core of FASTT Math, students develop math fact fluency. According to the National Mathematics Advisory Panel (2008), a computational fluency foundation can be obtained only after students can quickly and accurately recall basic math facts and become familiar with number operations. With this foundation, computational fluency is achieved through meaningful practice that involves developing and strengthening relationships of number combinations (Hasselbring, Lott, & Sydney, 2006). If students do not develop math fact fluency, this will have a negative impact on their future development (Hasselbring et al., 2006) as well as development of higher-order math skills (Loveless 2003).

FASTT Math targets instruction and practice to build declarative knowledge, also referred to as factual knowledge, a fact that is known, such as 7 x 3 = 21. This is important because students who struggle with developing mathematical ideas need instruction that aids them in strengthening their understanding of fundamental mathematical ideas (Burns, 2007). Developing automatic reasoning strategies should be the primary focus of basic math facts practice and not isolated facts drills, which are ineffective and may hinder purposeful practice (Baroody, 2009, Hasselbring et al., 2006). For this reason, FASTT Math adds new facts only after the student is consistently able to retrieve the answer to the fact. Students can draw on their previous knowledge to assist with answering new math facts. Thereby developing fluency only after acquisition has been maintained. In addition, only a small set of new facts are added to studied facts in any given session.

FASTT Math links numbers to optimize memory. The development of math fact fluency provides the foundation for higher-order computation and estimation. Automaticity demonstrates the transfer of basic math facts knowledge from working to long-term memory, thus providing working memory with the capacity to process more advanced mathematics (Baroody, 2009). FASTT Math requires that students type each newly introduced fact such as 7 x 3 = 21, rather than simply typing the answer 21. By doing so a connection is made between the entire problem to promote retention to long-term memory.

Lastly, FASTT Math utilizes technology to improve students' learning. Many computer programs that support number development have the ability to provide immediate feedback to users. This has allowed students to work on their weaknesses in number combinations at their own pace (Van de Walle et al., 2010). NMAP (2008) recommended the use of CAI to assist children in the development of fact fluency and automaticity. In addition, the use of gaming environment allows students multiple opportunities to think strategically and gain additional practice with their learned facts.

Furthermore, when students participate in one of the games, such as becoming a soccer goalie blocking shots with every correct response, they are actively engaged in the process. At the end of each game, students are provided with their scores, which can be compared with their personal best or with the score of their friends. In this way, the game provides some friendly competition that appears to motivate students to give their best effort.

The results of my study determined that the use of FASTT Math had a significantly positive effect on student math fact fluency when compared to traditional instruction. These results, as well as the information from this literature review will be found in the white paper.

Recommendations

The results of my study indicated that FASTT Math was more effective than traditional instruction to develop math fact fluency with sixth grade students and the section above discussed the research foundation of FASTT Math. Below I discuss the recommendations that are found in the white paper and the literature supporting them.

1. Initiate a larger district-wide study to provide further evidence at additional grade levels for the district to justify a mandate for FASTT Math implementation. If supported by the findings, incorporate the use FASTT Math in all third through eighth grades as part of the regular mathematics classes to teach new skills as well as reinforce skills previously taught, by designating FASTT Math as a center for 10-minutes during math class at least three times per week.
2. Provide professional development (PD) for teachers in order to manage student enrollment, monitor student progress, and use data to drive instruction.

3. Expand current data teams in each school to review FASTT Math reports from each student and compare this information with other types of data in order to create a student profile. By tracking data from multiple sources, we will be able to determine the success of implementing FASTT Math and its impact on future student achievement.

The first recommendation suggests conducting further research in order to justify incorporating the use of FASTT Math in all third through eighth grades as part of the regular mathematics classes. Next, the teacher would designate FASTT Math as a center for 10-minutes during math class at least three times per week to teach new skills as well as reinforce skills previously taught. NMAP (2008) warned that most curricula in the United States did not provide sufficient practice of basic math facts to ensure fluency and recommends that high quality CAI drill and practice, implemented with fidelity, be considered as a useful tool in developing students' automaticity, freeing working memory so that attention can be devoted to the more conceptual aspects of complex tasks. By incorporating FASTT Math consistently, student math fact fluency will increase. Furthermore, McCoy, Barnett, & Combs (2013) stated that consistent use of routines can yield organizational and academic benefits for students.

FASTT Math focuses on building math fact fluency of whole numbers using all four mathematical operations. The Common Core State Standards (CCSS) indicates the importance of student fluency with basic math facts. Developing fluency with whole number operations is a critical area of focus in elementary grades, while upper grade level standards build upon this foundation. NMAP (2008) declared that students should have a grasp of basic math fact by the end of fifth or sixth grade.

IES recommends that interventions at all grades should devote about 10-minutes in each class to building fluent retrieval of arithmetic facts. This 10-minute period provides continual practice so students can maintain fluency and proficiency, as well as acquire new facts. Many school districts have started using Response-to-Intervention (RtI) as the way to enhance student learning in general education classes (Zirkel & Thomas, 2010). This approach required the use of several levels of instructional interventions as the way to support struggling learners in regular education classes. The steps involved with RtI include: evaluating each student to determine their instructional needs, followed by high quality interventions, and finally determining an effective way to evaluate student progress (Zirkel & Thomas, 2010). As part of the FASTT Math program, each student completes an initial program evaluation to determine their skill deficiencies and is placed on a learning path individually based on their performance. Teachers can monitor student progress through the use of FASTT Math reports. RtI guidelines suggested that students who demonstrated academic improvements should continue receiving instructional support in regular education classes (Shinn, 2007).

The second recommendation is to provide professional development (PD) for teachers in order to manage student enrollment and progress, as well as how to use data to drive instruction. According to Mizell (2010) ongoing professional development, “creates a culture of learning throughout the school and supports educators’ efforts to engage students in learning” (p. 18). Mizell continued, professional development provides the means for teachers to learn about how their students learn, and how the teacher’s instruction can increase student learning. According to Schechter (2012), to continue to be up to date with educational reforms, teachers must be provided ways to develop and increase their knowledge and abilities. School leadership must present purposeful effort to improve and nurture existing teacher knowledge by creating an environment that encourages teamwork and collaboration among colleagues (Lipshitz, Friedman, & Popper, 2007). Recent literature has provided evidence that collaboration among teacher colleagues as well as professional development activities have improved classroom instruction and increased student achievement (Gallimore, Ermeling, Saunders, & Goldenberg, 2009; Schechter, 2012).

The third recommendation suggests expanding data teams in each school to review FASTT Math reports from each student and compare this information with other types of data. By tracking student data from multiple sources, we will be able to determine the success of implementing FASTT Math and its impact on future learning. According to Allison et al. (2010), Teacher Data Teams are designed to improve teaching, learning, and leadership through combining professional collaboration and decision making based on student data. They help efficiently and accurately choose interventions and program initiatives, and then follow up to determine if they are working (Gray & Harrington, 2011). Data teams are embedded in research and are designed for results.

In order to implement the use of a data team, a six-step process needs to be followed. This process consists of: (1) collection and charting of data, (2) analyzing and prioritizing needs, (3) establishing Specific, Measurable, Attainable, Realistic, and Timely (SMART) goals, (4) selecting instructional strategies, (5) determine results indicators, and (6) monitoring and evaluating results (Allison, et al., 2010, Perry, 2011). Collecting and charting data focuses on collecting formative data and developing a plan to improve student learning. The second step is to analyze and prioritize the needs of the school. Data teams will determine the areas of greatest need of the learners. Once the needs assessment is complete, SMART goals are developed. These goals should be short-term by nature and reviewed and evaluated regularly. The fourth step focuses on determining which research-based instructional practices to implement. Then, data teams monitor and evaluate their progress. By incorporating regular evaluation and reflection periods, programs can be modified to meet the need of the school community (Allison, et al., 2010, Perry, 2011).

In the case of FASTT Math, the data teams would be provided with step one of collecting and chartering data including current student standardized tests scores, the findings of this research, and the findings of the potential larger study. Step two would be prioritizing needs and while this is predetermined as math fact fluency, each classroom will target different skills needing development. This will be evident in step three with the establishment of SMART goals that can be set for a classroom and even for a student within the FASTT Math software. The crucial role that the Data Teams would be asked to do are steps five and six; data teams would set result indicators and then monitor to see if they are being met.

The overarching goal of a mathematics curriculum policy recommendation is to provide, in a white paper, advice to policy makers so that they can make informed decisions regarding policy. Thus this genre is ideal to discuss the problem of student achievement and present the findings of my study to a wide variety of consumers. The white paper offers specific recommendations that could result in new administrative practices and the development of curriculum changes related to math fact fluency and the use of CAI, specifically the implementation of FASTT Math. In addition, this white paper includes research and theories related to acquiring and retaining math fact fluency and its impact on student achievement as well as mathematics' instruction.

In conclusion, this literature review included a brief discussion of policy, education policy, policy recommendation, the historical origins of the white paper and benefits of white papers as an information-sharing format. This literature review also presents the foundations of FASTT Math and policy recommendations for implementation. As administrators and school board members must often read immense amounts of materials prior to reaching a decision (Graham, 2012), the white paper provides an easy to read, time saving format which offers an overview of math fact fluency data related to student performance, and recommendations for improvement.

Implementation

The proposal phase of implementation of the project, which is the policy recommendation in the form of a white paper, will not require many resources beyond the development of the white paper and the time required to disseminate and discuss its merit. The white paper will be saved as a PDF file that will be uploaded to my school's electronic repository for staff members to have easy access if desired. The file will be emailed to my school's administrative team, the district's supervisor of mathematics, as well as the district's superintendent. In addition, a paper copy of the white paper will be delivered to the superintendent with a sincere written request that she would take time out of her busy schedule to discuss it with me. Eventually, I hope to present the policy recommendations to the local board of education. Further implementation would depend on the outcomes determined by the district's superintendent. Permitting a positive meeting with the superintendent, I would like to follow-up with the math supervisor and the district math coaches. In addition, once my recommended larger follow-up study is completed I will add them to the white paper and redistribute it., I will submit the findings of this study, and hopefully the larger study, to present at local education conferences where I will share the white paper. I will also submit the finding, and possibly the white paper, for publication in a regional educational journal. According to Simpson, Yarris, and Carek (2013) scholarship is not attained unless the research advances knowledge in the field of study and is made public and accessible. The white paper will provide a description of the problem that was studied, the findings of the study, as well as its recommendations and implications. This white paper format has digestible research nuggets, local context and findings, with recommendations will be an excellent vehicle for driving the heart of this research home to our schools, parents, and students.

The focal points are the three policy changes with regards to FASTT Math and the mathematics' curriculum. The first recommendation is to gather further evidence to support mandating the district incorporation of FASTT Math into all third through eighth grade mathematics' classes. The second recommendation provides professional development to ensure proper implementation of FASTT Math. Lastly, the third recommendation expands the use of data teams to track student data in order to collect the necessary data to justify mandating FASTT Math. It is my belief that all three of the recommendations taken as a whole are needed to ensure the effectiveness of implementing FASTT Math. If the local school board adopts the three recommendations, actual implementation would take a collaborative effort involving administration, coaches, teachers, and students.

Potential Resources and Existing Supports

In order to develop the policy recommendations in the form of a white paper, research was required. I needed to review literature pertaining to policy recommendations, white papers, the foundations of FASTT Math, and support for recommendations that may lead to curricular policy changes intended to increase student achievement. To complete this task, I relied primarily on the use of the Walden University Library for peer reviewed journals and leads to other literature. In addition, support from the University in the form of my doctoral committee and IRB (12-09-13-0064332) assisted me with this process. Other resources that contributed to this white paper included the data collected through this study as well as the findings it produced. I also relied on literature to assist with the development of the white paper as it pertains to the presentation of the subject matter.

The mathematics curriculum policy recommendations within the white paper are all supported by the literature, but would my recommendations work in my district or at my school? For this reason, I approached a few of my school's math teachers for their input. I proposed each of my recommendations to them and asked for their feedback. Most of the feedback was supportive, indicating that all of the recommendations were welcomed, but some concerns were raised. These concerns will be discussed as a potential barrier.

Technology Supports. The ease of implementation of FASTT Math will support adopting the first recommendation to further study and integrate FASTT Math into all third through eighth grade mathematics classes. FASTT Math was previously purchased by the local school district and can be accessed by all district computers through the district's intranet. Every classroom is equipped with seven computers, which all have access to FASTT Math. Logistically, this makes the possibility for implementation fairly easy. Another support for this recommendation is that FASTT Math supports the current mathematics curriculum and policy pertaining to the use of stations and centers. Teachers are required to differentiate instruction by creating flexible groupings. By implementing the use of FASTT Math in small groups, teachers are provided with an individualized self-paced center that differentiates instruction. Lastly, given the fact that FASTT Math is easy to use, not requiring regular teacher input or student instruction, teachers will be more likely to support its use.

Personnel Supports. Math coaches and technology coordinators will be available to assist teachers with FASTT Math implementation. Staff members in both of these positions have received training for proper implementation of FASTT Math and currently have access to monitor student usage and student progress.

Teachers, math coaches, technology coordinators, and administrators can access and monitor student usage and progress. Providing easy access to reports enables staff members to stay informed on a continual basis. With this said, it is important that someone is responsible to monitor usage and progress to ensure fidelity and to determine the effectiveness of this initiative. In my district this would primarily be the responsibility of the math coaches. Our math coaches monitor all mathematics curriculum and programs that are math related. Math coaches have weekly contact with every mathematics teacher. During their visit they discuss the successes and issues from the previous week as well as plan for the week ahead. The math coaches would ensure that FASTT Math was implemented as directed and provide teachers with data to inform their instruction. The technology coordinators will ensure that each student and math teacher has access to FASTT Math and that the application works properly. This addition of responsibility is already within the scope of the responsibilities of the math coaches and the technology coordinators, therefore resulting in no additional cost to the school district.

Professional Development Supports. Support for adopting the second recommendation to provide professional development for proper FASTT Math implementation can be found in district's belief in providing staff with ongoing professional development. Each year, there are four full days of in-service training provided on a variety of topics, as well as twenty-four, one hour meetings that can be used for professional development. Therefore, there is an infrastructure already developed that could be used for providing training. In addition, training necessary for managing FAST Math is minimal and will not require more than an initial overview session, and follow-up training on an as needed basis. Lastly, teachers would be more inclined to implement FASTT Math's use if professional development was provided.

Professional development for implementing FASTT math will be provided through the use of face-to-face initial training and access to resources located on the school district's webpage. These resources will include short training videos, the FASTT Math manual, a link to the product's resource website, my FASTT Math white paper, and a dedicated discussion board where dialogue can occur. The district's mathematics supervisor will oversee this initiative. A 1-hour face-to-face training will be provided in each school during one of the scheduled professional development meetings and will be facilitated by the math coaches and technology coordinators.

I will present the initial training first to the math supervisor, math coaches, and technology coordinators using a PowerPoint. This is so that they may be able to help with professional development delivery. I will provide an overview of FASTT Math and include a hands-on component including both playing the game as a child, and of setting up a class as a teacher to use FASTT Math. Given that providing professional development is one aspect of the job description of the math coaches and the technology coordinators, and that the meeting is part of the contractual workday, there is no compensation provided for the facilitators or staff members receiving training.

To further assist the professional development coaches and coordinators I will make scheduled visits to the math teachers in different buildings to see them use FASTT Math on their own computers. I will ask them to show me (and other teachers there) how they "do" FASTT Math when they go in to monitor it. When they show me, I can ask them to show me how to use key features they did not use in their demonstration. If they don't know how, I can show them and let them try. In this way, each teacher will have me come, check on their ability, and help them to expand their ability. While somewhat time intensive, this is likely the single most effective practice for increasing the fidelity of the experiment and of the teacher's long-term use of the FASTT program.

I will encourage teachers to email me directly so that I can help them with issues ASAP. I will also post these questions and answers to a discussion board that any teacher can access at any time. The discussion board will be hosted on the district's webpage.

This will be initiated and maintained during my workday, therefore resulting in no additional cost for the school district.

Data Collection Support. Support for the third recommendation to expand current data teams may come from an existing need to monitor student progress and to use data to drive instruction. The recommendation suggests expanding current data teams to monitor the success of FASTT Math once the program is implemented. Given that the data teams are already established and that the math coaches are participants, including FASTT Math data would not too difficult. The math coach would be responsible for aggregating the FASTT Math data and presenting it to the team.

The standardized NJ ASK tests are also a way to track student's mathematical ability due to FASTT Math. Teachers and administrators alike want to find ways to improve student achievement, and data analysis is the only way to determine which programs actually work. In addition, FASTT Math data can be analyzed to determine if a correlation exists between FASTT Math and the NJ ASK. Furthermore, this data would provide another resource to for multiple measures to be used to determine student growth. By incorporating more data into the analysis, a more accurate depiction of student achievement will emerge. This informs administration where additional support is needed so more efficient staffing decisions can be made. Lastly, as we incorporate more data analysis, additional staff must become involved in the process, resulting in a larger conversation about the relationship between data and instruction.

Potential Barriers

The initial potential barrier I foresee with the implementation of the mathematics curriculum policy recommendations would be the lack of acceptance by the superintendent. Will the superintendent accept the research findings as valid and reliable? This is why I will propose to collect additional data from other grades with significant numbers to increase the validity and reliability of the findings. Given that FASTT Math is a district initiative and part of our curricular offerings, the findings would support a program already in place. But, producing a white paper displaying data that demonstrates student success and policy recommendations is only the first step to implementing a change in policy and practice. Additional research would let teachers witness FASTT Math in action.

Beyond policy, teachers will need to exhibit buy-in in order for the recommendations to have lasting effects. Teachers at the classroom level must see the importance of the combined findings and adjust their practices accordingly. Hopefully, given that the findings of this study were produced locally, my colleagues may deem them as relevant, and reproducible. In addition, teachers will need to find the recommendations viable. When I discussed the recommendations with a few of the school's math teachers, I received mostly supportive responses but some concerns arose.

The primary concern was the time that would be allocated to implement FAST Math. Teachers were concerned that FASTT Math would take too much of their already limited instructional time for mathematics. Time is the one resource that will always be scarce, and this appears to be true as we move forward. I believe that limited instructional time would be the biggest hurdle facing implementing FASTT Math on a regular basis.

Another concern was the added need to manage student usage, essentially developing a FASTT Math routine in class. While suggestions can be made to assist teachers with developing a working routine, may times successful implementation results from trial and error. This is another instance where the weekly visit from a math coach is essential. During a visit, teachers can share any concerns or questions they have regarding FASTT Math with their math coach. At this time, the math coach can offer suggestions, provide a model based on another teacher's practice, or direct the teacher to the districts webpage that hosts our message board community. Teachers will need to be encouraged to incorporate FASTT Math in their classrooms through the use of email and face-to-face conversation by the school administrative team and math coaches.

Potential barriers with regards to professional development and expansion of a data team would be increased workload for math coaches and technology coordinators. While I would not expect the need to hire additional staff to provide professional development or conduct data collection and analysis, increased workload would be required to complete both tasks. For example, within my school, I would offer to facilitate the professional development for FAST Math, but would anyone offer to facilitate elsewhere? There may be resistance from colleagues who are requested to perform this task. The same issues would impact the data team as well. While providing professional development and participation on the data teams is a requirement for both of these positions, is does not mean that those participants would be happy performing those tasks. In addition, with all of the initiatives competing for professional development hours, limited professional development "slots" may be a barrier.

Proposal for Implementation and Timetable

Send White Paper PDF to District Administration	October 2014
Request Meeting with Superintendent	
Meet with Math Coaches and Technology Coordinators	October 2014
Email request for volunteer teachers to evaluate FASTT Math	November 2014
Professional Development with Math Coaches and Technology Coordinators	November 2014
Individual Check In with Teacher by Mr. Bochniak	December 2014
Begin Implementation of FASTT Math, pretests in treatment and control	January 2015
Collect Posttest data, Teachers continue FASTT Math, control can start	February 2015
Analysis added White Paper report,	March 2015
E-mail pdf to superintendent and then to all district faculty and staff.	

Figure 5. Timetable for additional data collection and analyses

Professional Development Orientation:	April 2015
All teachers by technology coordinators & math coaches	
All teachers use FASTT Math as a trial run	May-June 2015
Summer Vacation	
Professional Development Small Group and Individual Visits	September 2015
Hands-on: demonstration teacher's own current use of FASTT Math	
PD leaders: Additional options shared, errors remediated.	
All third through eighth grade classes use FASTT Math,	September 2015
Data teams collecting and reviewing data	Oct-Dec 2015
WEEKLY – grade level coaching reviews data with team	
MONTHLY –math coach pull data from FASST and analyze	
Report of FASTT Student Progress across district	January 2016
Monitor FASTT with Administration of Standardized Tests	Spring 2016

Figure 6. Timetable for monitoring FASST Math implementation

Once my doctoral study is approved, I will upload a copy of the white paper to my school's electronic repository and send PDF versions to my school's administrative team and to the superintendent. At that time, I will send a paper copy of the white paper to the superintendent with a request for a meeting. Further implementation of the policy recommendation will depend on the outcome of the meeting with the superintendent. Use of FASTT Math data collection could start this school year if the superintendent approves some form of the plan. It would require permission to collect additional data with volunteer teachers and approved help from the math coaches and technology coordinators. I believe that teachers will want to be part of this larger study because we are always searching for more effective ways to increase student performance. In addition, since the FASTT Math program, and not the teacher will be the focus of the study, more teachers may feel comfortable taking part. Given that FASTT Math is already a district resource, reminding staff that it is available and providing some promotion for use by our math coaches, technology coordinators, and administrators, would most likely increase FASTT Math usage prior to professional development.

Meetings between the math coaches and technology coordinators would be held to ascertain their support for the implementation of FASTT Math. Once these faculty and the other administration had approved moving forward, the superintendent would hopefully approve the additional data collection and analysis with volunteer teachers. Email requests for volunteers would be sent and responses evaluated. The goal would be to have at least ten treatment teachers, ideally from a range of grade levels. The additional requirement for a volunteer is to have same grade teachers in control classrooms from which to collect pre and post data control data. Once the list of volunteers was intact, we would conduct the professional development

Once approved, the orientation professional development could be implemented within 30 days. It would require that the math coaches and technology coordinators meet to finalize the presentation for initial orientation. During this meeting I would present a FASTT Math overview PowerPoint to the math coaches and technology coordinators and request any feedback for any revisions for the final version that would be presented to the math teachers.

Once completed, the PowerPoint would be emailed to each presenter and the math supervisor would assign the dates for initial training for each school. Prior to initial training, I would launch our district's FASTT Math webpage that hosts our FASTT Math instructional videos, FASTT Math manual, FASTT Math white paper, link to FASTT Math webpage with additional resources, and discussion board. Therefore, when initial training was provided, teachers would have additional resources available to review. Furthermore, math teachers would have math coaches and technology coordinators in their building for additional support.

Once professional development is conducted, the volunteer groups will begin collecting data. First, the control and treatment groups will complete two pretests utilizing the same 2-minute drills from this study to determine a baseline. The expanded study's cohort treatment group will spend the following six-weeks collecting FAST Math data. At the conclusion of this period, both control and treatment groups will complete a posttest. Data will be analyzed to determine the effectiveness of FASTT Math when compared to traditional instruction. Data analysis will be comparable to this current study, but would compare results from a variety of grade levels and on a larger scale. Hopefully, the results from this proposed larger study will increase the generalizability of the findings and make it more likely for the superintendent to mandate the use of FASTT Math in all third through eighth grade mathematics classes.

Assuming student performance gains, a revised white paper will be written and presented to the superintendent. Similarly to the initial policy recommendation, this revised report will provide updated results and timeline. If approved, full-scale professional development can be provided by April, and FASTT Math for all third through eighth grade mathematics classes can begin. During the remaining school year, teachers will be encouraged to use FASTT Math on a consistent basis, tracking student progress, and providing feedback to the math coaches about any concerns or issues that they have. As we move into the 2015-2016 school year, teachers will be provided with additional professional development to ensure proper use.

Beginning in October 2015, district-wide data reports can begin to be conducted providing data that would provide a student's base line score and progress monitoring. Math coaches will provide feedback during their weekly visits to teachers and monthly reports to administration. Once data is collected it can be provided to the data team for further analysis. Follow-up on the discussion regarding underperforming students can be shared with the teacher.

Roles and Responsibilities of Student and Others

It will be my responsibility to make the white paper easily available as well as champion my recommendations. This will be accomplished by uploading a PDF version of the white paper to my school's electronic repository and emailing copies to my school's administrative team and to the district's superintendent. I will need to schedule an appointment with the superintendent to present the highlights of the white paper to ensure this subject receives adequate attention.

As the resident expert on conducting analysis of the use of the FASTT Math program, it will be my responsibility to accurately and responsibly communicate the findings of the additional data collection and analyses. It will also be my responsibility to provide adequate training and assistance to the math coaches and technology coordinators.

The roles and responsibilities of implementing the policy changes would be far and wide. All students in all third through eighth grades would have the responsibility to practice FASTT Math on a regular if not daily basis. Teachers would have the role to manage student accounts and monitor students progress. Math coaches would be required to monitor student usage and to review FASTT Math reports. The math coaches and technology coordinators would be required to provide professional development for teachers. Lastly, the math coaches and technology coordinators would be required to participate on the data team to analyze the data to determine the impact FASTT Math has on student achievement.

Project Evaluation

The policy recommendation in the form of a white paper presents the research, findings, conclusions and recommendations from my study on the effect of CAI on math fact fluency. In addition, the policy recommendations support the continued use and further implementation of the FASTT Math application. The white paper provides explicit information to the superintendent pertaining to FASTT Math and its effect on student achievement. The overall goal is to implement recommendations that will increase student achievement in mathematics based on the study's findings; these recommendations have been authored with the help of math teachers in my school.

The white paper presents the theoretical framework and related theories that discuss the relationship between math fact fluency and higher-level achievement. It also presents support for the use of CAI as an efficient and effective delivery method for improving math fact fluency and some strategies that could enhance math classes via CAI, and thus address student deficiencies in automaticity. The goal of including research in the white paper is to educate stakeholders about the topic of math fact fluency and CAI.

Personally, I would consider the policy recommendation a success if FASTT Math begins to play a more integral role in elementary and middle school math classrooms, but a more thorough evaluation is required. The evaluation of this project can be measured using two different data sources. First, an initial assessment is completed the first time a student uses FASTT Math. This initial assessment will be compared with another assessment completed later in the school year. Ideally this pre and post assessment will correspond with the beginning and ending of an academic school year. The second data source would be student NJ ASK math scores. This is where the data team will be extremely valuable. Student NJ ASK scores in conjunction with FAST Math scores will be analyzed to determine if a correlation exists, and to determine the impact of FASTT Math.

Implications Including Social Change

This research and the resulting policy recommendations in the form of a white paper presents a mathematics curriculum policy recommendation that may provide a path to increased student achievement in mathematics, and concomitant success in other areas, for, as discussed in the introduction, mathematical skills are a prerequisite for school achievement and success in the workplace. Research has shown that completion of advanced mathematics courses in high school influences college graduation rates more than any other factor. In turn, students who graduate college are more likely to find a job and will be able to compete at a higher level than those who do not. Therefore, increasing student performance in mathematics is directly connected to success after schooling.

Local Community

The policy recommendation will result in social change at the local level by providing an opportunity for greater student success in mathematics. Students will be able to attain fluency of math facts earlier, which will enable them to focus on more advanced skills. Higher achievement by students may increase student self-esteem and encourage teachers to hold high standards for all students. As student success becomes more widespread, teachers can have confidence that their students have a solid foundation in mathematics. In addition, teachers may be motivated to look for other strategies to improve student learning in other areas. As I have seen many times throughout my career, success is contagious, and has a tremendous impact on morale. Nothing is more detrimental to the psyche of a teacher than working hard everyday with your students, resulting with only very limited success. By increasing student learning in this global way, teacher's self-esteem will be positively affected. This potential shift in beliefs and attitude may help the larger community as students experience greater success. When students perform at higher levels, the relationship between the school and the larger community improves. Parents have greater confidence in the ability of the school to prepare their children and businesses are more likely to employ applicants who were high performers in school.

Far-Reaching

The research and policy recommendation will add to the literature that supports the incorporation of CAI in the classroom. It may spark interest in the use of FASTT Math or other CAI by teachers or administrators in other districts. It may promote additional research that builds upon my current study. Ultimately, the goal of the policy recommendation and resulting white paper is to continue the conversation about increasing student achievement in mathematics.

Conclusion

In this paper, Section 3 outlined the goals, rationale, implementation, and evaluation of the mathematics curriculum policy recommendation presented in the form of a white paper project. The aim of policy recommendation was to change existing mathematics policy that has purchased computer-aided instruction (CAI) in the form of software called FASTT Math, but does not encourage its use. The thought was to promote change by educating and influencing policy makers about the research on math fact fluency as an integral part of mathematical development. That CAI (Cates, 2005; L. Graham et al., 2007; Tienken & Wilson, 2007; Wong & Evans, 2007) has been shown to be an effective way to develop this fluency. In fact, based on the results of this study, adding a FASTT Math session was more effective in developing math fact fluency with sixth-grade students than traditional instruction alone. Current literature included research and theories that guided the development of the policy recommendation related to math fact fluency and CAI. The final part of this section discussed potential implementation of the white paper (Appendix A) and its ability to impact social change. In Section 4, I will reflect on the project, my conclusions, and discuss future research.

Section 4: Reflections and Conclusions

Introduction

The primary purpose of this study was to determine if the use of CAI, specifically FASTT Math, would show greater rates of growth for students mastering their basic math facts than traditional instruction alone. In this section, I will present my reflections and conclusions on this quantitative, quasi-experimental study on math fact fluency. In addition, I will address the strengths and limitations of the proposed mathematics curriculum policy recommendation based on the findings of the study. This section also includes reflections on my role as a scholar, suggestions for further research, and the implications for social change.

Project Strengths

The study and project are relevant because poor mathematics performance has implications that go well beyond schooling. As discussed in section 1, mathematics performance in high school is the leading indicator for college graduation (Adelman & Office of Vocational and Adult Education, 2006), which has a direct correlation with career prospects (Dohm & Shniper, 2007). Therefore, making strides to increase student mathematics performance is of paramount importance (NMAP, 2008).

The strength of the study was that it studied one particular skill, at one grade level, in one school. A narrow scope made it possible to isolate math fact fluency, in this case multiplication, and determine if the treatment was effective. This limited the number of factors—for example, different SES levels would make it hard to compare math fluency overall.

Based on the four genres available for project development, a policy recommendation was best suited for my needs. This study's policy recommendations had the following four strengths:

1. The policy recommendation provided evidence that the currently owned FASTT math software could produce significant gains for sixth grade students compared to the students in the control sixth grade class.
2. The policy recommendation presents research, data, findings, and recommendations that can readily be implemented.
3. The recommendations require no additional costs in equipment or personnel and may provide the means for increased student achievement.
4. The policy recommendation may serve as an example for further research and data collection within the school and district.

Recommendations for Remediation of Limitations

The study's main limitation was the sample size: 20 students in a control group and 20 students in a treatment group. While the limited focus of the study was a strength, the limited sample size and length of study were limitations. I would recommend collecting additional data to support a mandate so that the district would be able to collect and analyze data from over 2,000 students, students who would be tracked from year to year.

The primary limitation of the policy recommendation was my inability to predict if the recommendations will be implemented. While I will attempt to meet with the district's superintendent and discuss and promote the changes to policy, I am unable to foretell the outcome of that meeting to determine if the superintendent is not convinced or does not want to pursue this endeavor.

There is the possibility that a few teachers might be willing to collect some additional data to further the movement. I may not be able to do the additional work necessary to ensure that FASTT Math usage is mandated, although it does not mean that it cannot be implemented to some level of capacity. FASTT Math is a district purchased and approved application for use in all third through eighth grade mathematics classrooms. Therefore, teachers can still be encouraged to implement its use even if it is not mandated. I would email my pdf white paper with an email encouraging use of the FASTT Math, offering to come meet with them one-to-one or in small groups if they wanted me to demonstrate it's use. This is often a person's primary hurdle for trying something new, the need for someone to show him or her first. They need a teacher!

As discussed in Section 3, Walden University accepts four genres for project development that include an evaluation report, a curriculum plan, a professional development plan, or policy recommendation with detail. An alternative approach to address the problem of inadequate FASTT Math usage could simply focus on professional development. If teachers are convinced that this application increases student math fact fluency more effectively than traditional instruction they may implement FASTT Math with fidelity without a policy mandate. By ensuring appropriate professional development and continual support, this route could prove successful.

Scholarship

Traditionally, academic scholarship has been defined as the discovery of new knowledge acquired through the process of research (Simpson, Meurer, & Braza, 2012).

If this is so, then my doctoral journey at Walden University has been an exercise in scholarship. This journey has been a challenging, yet rewarding experience. During this time, I have had to work incessantly on improving my writing. I had to spend many hours working on repeated rewrites of my proposal and final paper with the assistance of my committee and Walden's Writing Center. As time went on, fewer changes were required and my paper began to take shape. While I still need to work on my craft, some growth has developed.

Another area I have seen growth is my ability to read, interpret and conduct research. Prior to entering this program, I would accept many things on face value. If I read a strategy in a teaching guide I would accept it as a best practice. Now, I question most things I read and seek to find resources to either support or disprove any claims. I rely less on feelings, or what others are practicing, but look for empirical evidence to ascertain why I do what I do, as an educator. Furthermore, during this program I have learned how to effectively read peer-reviewed journal articles and actually understand their findings. This skill has proven vital throughout this research process and will prove indispensable to me in the future.

In addition to learning how to consume and produce research, I have learned how to put this research into action. Through the development of the policy recommendation, I am attempting to affect change to increase student mathematics performance, which may have far reaching implications for those students after schooling. If this policy recommendation is adopted, I might be partially responsible for improving more lives district wide than I ever could in a single classroom or school in an entire career.

Project Development and Evaluation

Project development and evaluation took a lot of time and consideration. First, I needed to focus on a topic that would be deemed acceptable by Walden University. The process started with a few very broad ideas, but began to become more manageable after discussing many ideas with colleagues and with my committee chair. Finally, I settled on the effectiveness of CAI on math fact fluency. After completing some initial research, I was convinced that this very narrow area of mathematical skill had an exponential impact on student achievement. This led me to pursue this topic further and conduct this study.

Once the study was completed and the data was analyzed, I needed to determine the best way to convey the findings so that my study could do more than simply earn me a degree. What type of project could take the recommendations of the study and cause action? After some research, I concluded that developing a policy recommendation would be that project. My project went through multiple rewrites and revisions until I was satisfied with the final product. The final evaluation will occur after the superintendent determines if and when she approves the recommendations suggested. Once implemented, data tracking will occur. Initial student usage will provide a baseline for student performance. As participation continues, student usage and progress will be monitored. At the end of the academic year, student performance can be compared with their baseline data to determine the level of growth. This will be the primary evaluation tool used to determine FASTT Math's effectiveness. In addition, this data can be compared with state testing results to determine if a relationship exists.

Leadership and Change

In the early days of my career as a teacher, I just wanted to close my door and wished that I were left alone to teach my students on the island I created for myself. It took many years and some maturation to realize that this isolationist thinking was counterproductive to the greater good. Therefore, I began to visit other classrooms, observing different teachers with different teaching styles, and we began an exchange of thoughts and ideas. At this point in my career, I began to feel revitalized with the desire to improve my craft. I wanted to be part of the larger school community and volunteered on a variety of school committees. Although I was interested, and though I had some valuable insight to offer, I was clearly not yet prepared to take a leadership role within my school. This realization sparked my interest to further my education and eventually influenced me to enroll into Walden University's doctoral program.

During my time at Walden, I have gained considerable knowledge pertaining to various topics within the field of education, which has increased my ability to contribute at the local level. For example, while completing research for my study, I learned about the "math wars" that occurred during the 1990's. Before I began my research I was unaware that there were competing trends in math education at that time. I have learned that the field of education is constantly changing and there are always competing theories, pedagogies, and practices that influence the how's and what's that are taught. While this is good, it is imperative that there are stakeholders within each school and school district who are current on these topics to ensure that best practices are adopted. I now believe that I am worthy to be one of those stakeholders in my school, and possibly school district.

With the development of the policy recommendation, I had an opportunity to be a change agent. My efforts could result with the routine integration of a math program that will have a positive impact on student achievement. My goal was to provide actionable recommendations to my district's superintendent that could be implemented quickly and without any additional financial obligations.

Analysis of Self as Scholar

When I began my doctoral journey, I was not confident in my ability to interpret or conduct research. But over the last few years I have read critically over 200 articles in peer-reviewed journals as well as several books in the field of education. As a scholar, I have learned how to critically analyze these articles and other texts in order to develop the foundation for my study. Each piece of new knowledge influenced the body of knowledge that existed before and either solidified or altered my belief held at that time. One thing that this program has taught me is that the journey to become a scholar is never ending. As we read, write, and converse with others in the field, we continue to learn. To become a scholar is to be a lifelong learner.

Analysis of Self as Practitioner

It is my belief that all teachers are practitioners in the field of education. But, most teachers do not have the opportunity to share their expertise outside their classrooms. In my current position, as my school's technology coordinator, I have the unique opportunity to work with students and staff in a variety of situations. I provide professional development to staff in some instances, work on cross-curricular projects with teachers and their students, and in some instances work with students independently. Within this role, I am able to observe teacher practice throughout my school. In addition, I am able to provide advice to teachers in a variety of settings. In this way, I am able to assist teachers and encourage a collaborative school environment.

With regards to research, I am a practitioner through this undertaking. By conducting a research study and policy recommendation discussing the effectiveness of CAI on math fact fluency, I am adding to the body of research literature. I am confident that this will not be my last research venture . Actually, my study begs for additional research that I hope is pursued, whether or not the policy recommendation is adopted.

Analysis of Self as Project Developer

The project was the result of a process that began with a proposal for research. The proposal was built around a problem, which created the foundation for my research. First, I needed to determine if my problem was actually a real problem. Then I needed to develop my theoretical framework that shaped the parameters of my research. More research was necessary in order to craft the methodology and once satisfying IRB requirements, data collection occurred. At completion, data analysis ensued with the goal of providing valid and reliable results with the utmost of integrity.

One of the major challenges developing the project was to present the findings in a way that could be easily understood by someone who was unfamiliar with research. This was very time consuming and took a lot of effort. In the end, developing the policy recommendation was fulfilling because it gave me the opportunity to offer policy changes that may contribute toward social change in my school district. Ultimately, these recommendations if implemented can have a positive effect on students' mathematics achievement.

The Project's Potential Impact on Social Change

This project contributed to the body of literature surrounding the effectiveness of CAI on increasing math fact fluency. As mathematics achievement continues to be a concern at the local and national level, schools will need continual guidance to find solutions that not only mitigate this problem but also can do so in a timely and practical manner. This study served as a means to this end. Not only does this project produce findings that support increased student achievement, but also provides mathematics curriculum policy recommendations that can be easily implemented and are aligned with the current district's curriculum. In addition, this project served as an example of the type of research that can be conducted within one school at the local level that can promote change throughout the entire school district. As student mathematical achievement improves, greater opportunities for these students will emerge.

Implications, Applications, and Directions for Future Research

The purpose of my study was to determine the effectiveness of CAI on math fact fluency. More specifically, would CAI be more or less effective than traditional instruction to increase student math fact fluency. The findings of my study concluded that students who worked with FASTT Math demonstrated statistically significant better results than those students who received traditional instruction. These findings provided needed insight as my district looks for ways to increase student achievement in mathematics.

Results of my study and recommendations presented in the policy recommendation will provide the superintendent with needed research and data to assist with making decisions pertaining to the direction the district will take with regards to curriculum implementation. It is my hope that I will be able to meet with the superintendent in order to discuss the contents of the policy recommendation and assist with putting the recommendations into action.

Recommendations for future research would be to recreate my study on a larger scale, and then a much larger scale. As part of the recommendations from the white paper, I suggested that FASTT Math be incorporated routinely into mathematics class for all classrooms grades third through eighth district-wide. Primarily, I recommend using FASTT Math as a center or station, for ten minutes a day for at least three days a week. Student usage and performance would be tracked and analyzed to determine the effectiveness of the program. In contrast to the small size of my initial study, a future study could include approximately 2000 students. This would increase the generalizability of the findings significantly. In addition, this data could be compared to NJ ASK data to analyze the level of student growth on our standardized tests.

Conclusion

Section 4 focused on the reflection of the project and its development. Within this section I have discussed the projects strengths, limitations, and recommendations for remediation of the limitations. The implications of this project may provide the foundation for lasting results that will increase student achievement in mathematics. This section also included my reflections on my own thoughts about scholarship, project development, evaluation, leadership, change, self as a scholar, practitioner, and implications that may affect social change.

Finally, this section enabled me to reflect on my doctoral journey. During this period I have grown as researcher and writer and have expanded my view of what it means to be a scholar practitioner. This journey has provided me with the opportunity to gain valuable insight into how students learn and produce findings from research that can have a direct impact on student success. By completing this project I have become an agent of change at my school and local community. As I continue to learn and grow, I hope to continue working for the common good.

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Appendix A: Project

Increase Math Fact Fluency with FASTT Math

A White Paper

By Joseph Bochniak

Introduction

This white paper provides an overview of research related to math fact fluency and the implementation of computer-aided instruction (CAI). This white paper will also provide recommendations to increase student achievement in mathematics through the use of the application FASTT (Fluency and Automaticity through Systematic Teaching and Technology) Math.

Mathematical skills are an essential prerequisite for school achievement and success in the workplace. Completion of advanced mathematics courses in high school influences college graduation greater than any other factor (Adelman & Office of Vocational and Adult Education, 2006). Students who complete mathematics classes beyond Algebra II double their chances of earning a bachelor's degree (Adelman et al., 2006). This is important because nearly two-thirds of the fastest growing jobs in the United States will require a bachelor's degree (Dohm & Shniper, 2007). Today, the link between increased education and good jobs is stronger than ever. Over the last thirty years, there has been a marked decline in jobs for high school graduates whereas the prospect for those possessing postsecondary education and training has increased significantly (Carnevale, Jayasundera, Hanson, & Georgetown University, 2012). These findings clearly indicate that mastering mathematical skills have far reaching implications for students beyond schooling.

> Completion of advanced mathematics courses in high school influences college graduation greater than any other factor.
> (Adelman & Office of Vocational and Adult Education (ED), 2006)

Yet, students at the XYZ School are underperforming in mathematics, especially in the middle school grades beginning with grade six. This is due to a poor foundation in basic mathematics that hinders student progression to higher-level mathematics. This is significant because, according to the National Council of Teachers of Mathematics (NCTM), student's ability to proceed to algebra will be determined by mastering the most critical mathematics skills and concepts that are introduced in grade six (National Council of Teachers of Mathematics Commission on Standards for School Mathematics, 2008). In other words, sixth grade is an important transitional period moving from focusing on factual and procedural knowledge to more conceptual knowledge. If sixth-grade students do not possess mastery and fluency of their basic math facts, advancement to higher-level mathematics will be negatively impacted.

> If sixth-grade students do not possess mastery and fluency of their basic math facts, advancement to higher-level mathematics will be negatively impacted.

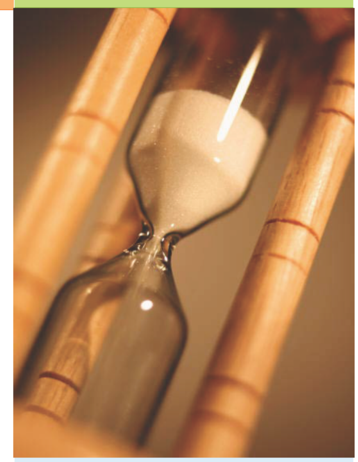
Why Does Math fact fluency Matter?

According to the National Mathematics Advisory Panel (2008), students in the United States possess a poor understanding of core arithmetical concepts and lack fluency of complex algorithms, which impedes learning of higher-level mathematics such as algebra. In addition, studies indicate that many U.S. students who lack fluency with single-digit addition, subtraction, multiplication, and division of whole numbers may never gain proficiency.

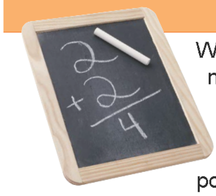
> Students who lack fluency with single-digit addition, subtraction, multiplication, and division of whole numbers may never gain proficiency.

This is disturbing given that in order for students to become successful in mathematics; they must become proficient in factual, procedural, and conceptual knowledge (U.S. Department of Education, 2008). Factual knowledge pertains to the ability to recall a small set of mathematical facts from long term memory (i.e. addition, subtraction, multiplication, and division). Procedural knowledge pertains to the steps or rules that must be followed to solve a particular problem (e.g., standard algorithms). Lastly, conceptual knowledge concerns itself with understanding of meaning, answering the question "Why?" in mathematics. The panel argues, "these capabilities are mutually supportive, each facilitating learning of the others" (U.S. Department of Education, 2008, p. 26). If students do not possess the basic foundations of mathematics, how will they be able to perform at the higher levels?

Based on the Common Core state standards for mathematics, by the end of fifth grade, students should have a "solid foundation in whole numbers, addition, subtraction, multiplication, division, fractions and decimals – which help young students build the foundation to successfully apply more demanding math concepts and procedures, and move into applications" (National Governors Association Center for Best Practices (NGA Center) and the Council of Chief State School Officers (CCSSO), 2010, para. 1). Yet, many students in sixth grade have not achieved factual knowledge. Loveless (2003) found that although students have made progress in mathematics on the NAEP, progress in basic arithmetic has "ground to a halt"(p. 41), indicating a deficiency in either procedural or factual knowledge.



What does the research say about math fact fluency?



When students posses a foundation in basic math facts, they spend less time working on rudimentary mathematics and more time on higher level thinking. When students gain fluency with their math facts to the point where these facts become automatic, automaticity occurs. Crawford (2003) defined automaticity with math facts as the ability to answer instantly, without having to stop and think about a response (e.g., 5 x 6 = 30). Without such ability, students must compute their response using a variety of counting strategies, likely causing a "high cognitive load as they perform a range of complex tasks" (Woodward, 2006, p. 241). Furthermore, "information-processing theory supports the view that gaining automaticity in math facts is fundamental to success in many areas of mathematics" (Woodward, 2006, p. 269). This theory supports the belief that working memory, also referred to as short-term memory, is limited and can perform only a few tasks at one time. Gagné (1983) stated that this limited working memory is where "problem solving occurs" (p. 15). He continued, "The scarce cognitive resource of attention needs to be devoted to the most intricate and complex part of the task" (p. 15). Thus making an argument for the importance of automaticity of math facts.

"A student who is automatic with basic facts will complete problems at a faster rate and therefore is likely to have more opportunities to respond (i.e., practice trials), which can enhance accuracy, fluency, and maintenance" (Poncy, Skinner, & Jaspers, 2007, p. 27). While automaticity pertains to the speed of a skills performance with minimal thinking, fluency pertains to the speed and accuracy of performing a particular skill. For example, to be fluent in multiplying multi–digit numbers, one has to know automatically the fact that 7 x 8 = 56. As students learn a new skill, they will become increasingly fluent until automaticity is achieved (Axtell, McCallum, Mee Bell, & Poncy, 2009). Students who attain a level of fluency may possess less math anxiety and therefore be more likely to complete assigned tasks (Poncy, Skinner, & Axtell, 2010). Furthermore, evidence suggests that increasing students' accuracy and speed of basic math facts is crucial for developing and mastering more advanced math skills (Poncy, Skinner, & Jaspers, 2007).

> Evidence suggests that increasing students' accuracy and speed of basic math facts is crucial for developing and mastering more advanced math skills (Poncy, Skinner, & Jaspers, 2007).

What does the research say about computer-aided instruction (CAI)?

The position of The National Council of Teachers of Mathematics (NCTM) is that "Technology is an essential tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology" (National Council of Teachers of Mathematics, 2008, p. 1). Born out of the works of Skinner in the 1960's with his teaching machines, educators have long attempted to develop ways for technology to deliver effective individualized instruction. In years past that may have meant using a machine and punch cards, while today one might use a web-based application that is streamed to a computer through the Internet. But the goal remains the same. Cates (2005) stated "computer-assisted instruction emphasizes the importance of the completion of numerous antecedent-behavior-consequence learning trials" (p. 638), supporting the belief that CAI is an effective and efficient teaching method.

"Technology is an essential tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology" (National Council of Teachers of Mathematics, 2008, p. 1).

The National Mathematics Advisory Panel (NMAP) found "instructional software has generally shown positive effects on students' achievement in mathematics as compared with instruction that does not incorporate such technologies" (Department of Education, 2008, p. 50). It is recommended that high-quality CAI drill and practice should be implemented with fidelity and was a useful tool for developing automaticity.

Based on the findings of the meta-analysis studies, CAI has been found to show a positive effect on student mathematical achievement. The results have shown that the use of CAI is most effective when used at the elementary level and incorporated practice.

Foundations of FASTT Math

According to NMAP (2008), a computational fluency foundation can be obtained only after students can quickly and accurately recall basic math facts and become familiar with number operations. With this foundation, computational fluency is achieved through meaningful practice that involves developing and strengthening relationships of number combinations (Hasselbring, Lott, & Sydney, 2006). If students do not develop math fact fluency, this will have a negative impact on their future development (Hasselbring et al., 2006) as well as development of higher-order math skills (Loveless 2003).

FASTT Math targets instruction and practice to build declarative or factual knowledge. This is important because students who struggle with developing mathematical ideas need instruction that aids them in strengthening their understanding of fundamental mathematical ideas (Burns, 2007). Developing automatic reasoning strategies should be the primary focus of basic math facts practice and not isolated facts drills, which are ineffective and may hinder purposeful practice (Baroody, 2009, Hasselbring et al., 2006). For this reason, FASTT Math adds new facts only after the student is consistently able to retrieve the answer to the fact. In addition, only a small set of new facts are added to studied facts in any given session.

FASTT Math links numbers to optimize memory. The development of math fact fluency provides the foundation for higher-order computation and estimation. Automaticity demonstrates the transfer of basic math facts knowledge from working to long-term memory, thus providing the foundation for more advanced computation and estimation abilities (Baroody, 2009). FASTT Math requires that students type each newly introduced fact such as 7 x 3 = 21, rather than simply typing the answer 21. By doing this, a connection is made between the entire problem to promote retention to long-term memory.

Many computer programs that support number development have the ability to provide immediate feedback to users. This has allowed students to work on their weaknesses in number combinations at their own pace (Van de Walle et al., 2010). The NMAP (2008) have recommended the use of CAI to assist children in the development of fact fluency and automaticity. In addition, the use of gaming environment allows students multiple opportunities to think strategically and gain additional practice with their learned facts.

Why FASTT Math?

- Easy to Implement
- Aligned to the Common Core State Standards
- Built on “Best Practices”
- Already a District Resource
- Integrates Technology
- Proven Results

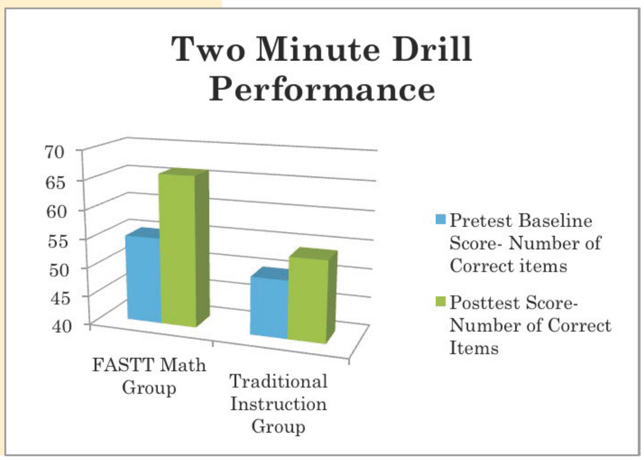
Research Study

A research study was completed during the 2013-2014 school year, at XYZ School to determine if FASTT Math was more effective than traditional instruction to increase student math fact fluency. The research focused on two instructional groups of sixth grade students. The control group received traditional based mathematics instruction, while the treatment group used FASTT Math application for mathematics. The purpose of this study was to determine if CAI is an effective method to develop math fact fluency as compared to traditional instruction. The quasi-experimental study included 40 sixth grade students and one teacher over a three-week period. Instruction focused on math fact fluency, specifically multiplication fluency.

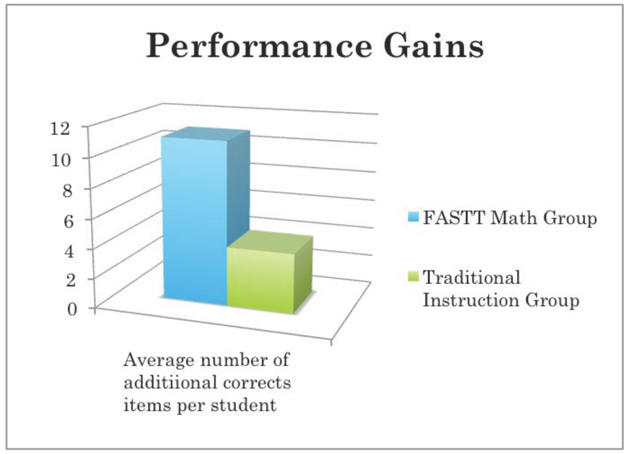
	Pretest Knowledge	Treatment	Posttest Knowledge
Experimental Group	O_1	X	O_2
Control Group	O_3		O_4

Modified Quasi-Experimental Nonequivalent Control-Group Pretest-Posttest Design. Where: O_1, O_3 = the observation of mathematics achievement pretest, O_2, O_4 = the observation of mathematics achievement posttest. X= is FASTT Math

The number of multiplication items answered correctly during multiple two-minute drills was used to measure basic multiplication fact recall. The multiplication pretests contain 80 random multiplication problems chosen from 0 to 12 multiplication tables. The tests were generated using WorksheetWorks (2012), a program available from the Internet, which is commonly used by the school's classroom teachers. The posttest was developed using the same worksheet generator. The total number of correct responses on each of the two-minute drills provided the student's score, with 80 being the highest score possible. Higher scores indicate an increased level of mastery and fluency in multiplication. The results from the pretest and posttest were analyzed for performance change. The performance change for the experimental group (O_2-O_1) and control group (O_4-O_3) were compared to determine if differences exist. The raw data and results are provided here in the form of charts and graphs.

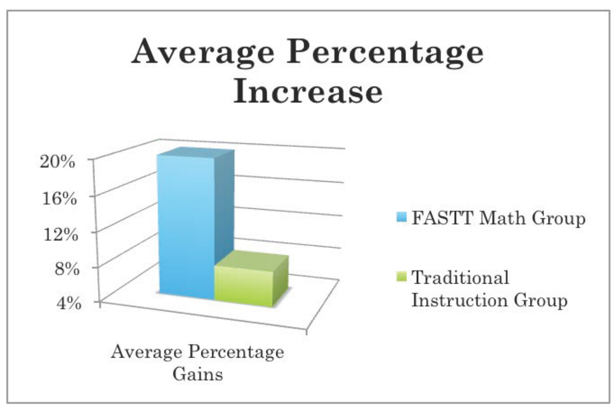


Research Findings



The results were analyzed determining that there was a significant change in performance when comparing the results from the pre/post tests, as well as the difference between the treatment and control groups. As indicated by the Two Minute Drill Performance chart on the previous page, both groups obtained increased math fact fluency during the study. As indicated on the Performance Gains Chart, the FASTT Math group increased by an approximate average of 11 additional correct items on the two-minute drill posttest and the traditional instruction group increased by an average of 4 additional correct items on the two-minute drill posttest. This difference was determined to be statistically significant when evaluated using analysis of variance (ANOVA).

Results of this study indicated a significant statistical improvement for those students who used FASTT Math instruction over traditional instruction. The students who practiced math facts using FASTT Math demonstrated a higher level of math fact fluency on a two-minute drill than students using traditional methods. As noted by the Average Percentage Increase Chart, students who used FASTT Math averaged a 20% increase on the two-minute drill over their pretest scores. Hopefully, the results from this study will provide some insight to improving student achievement in mathematics, as well as, promote further research into the effectiveness of CAI.



Current Policy

FASTT Math was purchased and sanctioned for use by the school district for third through eighth grades, but does not have a mandate for use. Based on usage reports, FASTT Math is used by few students and is not used with fidelity. Since the findings of this report indicated that implementing FASTT Math is an effective method to increase student mathematics achievement, a change in current policy is requested. Below you will find my proposed changes.

Policy Recommendations

Recommendation 1:

Initiate a larger district-wide study to provide further evidence at additional grade levels for the district to justify a mandate for FASTT Math implementation. If supported by the findings, incorporate the use of FASTT Math in all third through eighth grade mathematics classes to teach new skills as well as reinforce skills previously taught, by designating FASTT Math as a center for 10-minutes during mathematics class at least three times per week.

Recommendation 2:

Provide professional development (PD) for teachers in order to manage student enrollment, monitor student progress, and use data to drive instruction.

Recommendation 3:

Expand current data teams in each school to review FASTT Math reports from each student and compare this information with other types of data in order to create a student profile. By tracking data from multiple sources, we will be able to determine the success of implementing FASTT Math and its impact on further student achievement.

Recommendation 1:

The first recommendation suggests conducting further research in order to justify incorporating the use of FASTT Math in all third through eighth grades as part of the regular mathematics classes to teach new skills as well as reinforce skills previously taught by designating FASTT Math as a center for small group instruction for 10-minutes during math class at least three times per week.

NMAP (2008) warned that most curricula in the United States did not provide sufficient practice of basic math facts to ensure fluency and recommends that high quality CAI drill and practice, implemented with fidelity, be considered as a useful tool in developing students' automaticity, freeing working memory so that attention can be devoted to the more conceptual aspects of complex tasks. By incorporating FASTT Math consistently, student math fact fluency will increase. Furthermore, McCoy, Barnett, & Combs (2013) stated that consistent use of routines can yield organizational and academic benefits for students.

FASTT Math focuses on building math fact fluency of whole numbers using all four mathematical operations. The Common Core State Standards (CCSS) indicates the importance of student fluency with basic math facts. Developing fluency with whole number operations is a critical area of focus in elementary grades, while upper grade level standards build upon this foundation. NMAP (2008) declared that students should have a grasp of basic math fact by the end of fifth or sixth grade.

The Institute of Education Science (IES) recommends that interventions at all grades should devote about 10-minutes in each class to building fluent retrieval of arithmetic facts. This 10-minute period provides continual practice so students can maintain fluency and proficiency, as well as acquire new facts. Many school districts have started using Response-to-Intervention (RtI) as the way to enhance student learning in general education classes (Zirkel & Thomas, 2010). This approach required the use of several levels of instructional interventions as the way to support struggling learners in regular education classes. The steps involved with RtI include: evaluating each student to determine their instructional needs, followed by high quality interventions, and finally determining an effective way to evaluate student progress (Zirkel & Thomas, 2010).

As part of the FASTT Math program, each student completes an initial program evaluation to determine their skill deficiencies and is placed on a learning path individually based on their performance. Teachers can monitor student progress through the use of FASTT Math reports. RtI guidelines suggested that students who demonstrated academic improvements should continue receiving instructional support in regular education classes (Shinn, 2007).

Recommendation 2:

The second recommendation is to provide professional development (PD) for teachers in order to manage student enrollment, monitor student progress, use data to drive instruction.

According to Mizell (2010) ongoing professional development, “creates a culture of learning throughout the school and supports educators’ efforts to engage students in learning” (p. 18). Mizell continued, professional development provides the means for teachers to learn about how their students learn, and how the teacher’s instruction can increase student learning. According to Schechter (2012), to continue to be up to date with educational reforms, teachers must be provided ways to develop and increase their knowledge and abilities. School leadership must present purposeful effort to improve and nurture existing teacher knowledge by creating an environment that encourages teamwork and collaboration among colleagues (Lipshitz, Friedman, & Popper, 2007). Recent literature has provided evidence that collaboration among teacher colleagues as well as professional development activities have improved classroom instruction and increased student achievement (Gallimore, Ermeling, Saunders, & Goldenberg, 2009; Schechter, 2012).

Recommendation 3:

The third recommendation suggests expanding data teams in each school to review FASTT Math reports from each student and compare this information with other types of data.

By tracking student data from multiple sources, we will be able to determine the success of implementation of FASTT Math and its impact on future learning. According to Allison et al. (2010), Teacher Data Teams are designed to improve teaching, learning, and leadership through combining professional collaboration and decision making based on student data. They help accurately and efficiently choose interventions and program initiatives and determine if they are working (Gray & Harrington, 2011). Data teams are embedded in research and are designed for results.

In the case of FASTT Math, the crucial role of the Data Teams would be to set result indicators and then monitor to see if they are being met.

FASTT Math Integration Plan

STAGE 1: Prepare for the Larger Study (10/14-12/14)

- Email requests for volunteer teachers to evaluate FASTT Math from a variety of grade levels (3-8) and schools across the school district.
- Provide profesional development (PD) for teachers opting to participate in the larger study. This PD will include a face-to-face orientation presentation as well as a hands-on component to ensure that the teachers are comfortable moving forward
- Continued professional development will be provided on an ongoing basis by the math coaches during their weekly visits, technology coordinators if necessary, and myself as the lead reseacher for this study.

STAGE 2: FASTT Math Study Implementation (1/15-2/15)

- Begin implementation of FASTT Math - pretest for treatment and control group.
- Implement FASTT Math in all designated third through eighth grade classrooms for six weeks vs. traditional instruction in all other classrooms.
- Collect Posttest data.

STAGE 3: Data Analysis (3/15)

- Analyze the findings from the larger study to determine if a FASTT Math mandate is warranted.
- If the data supports the use of FASTT Math, revise this white paper and email a PDF copy to the superintendent, administration and staff.

STAGE 4: Professional Development for all third through eighth grade Math Teachers (4/15)

- Initial professional development will be provided by math coaches and technology coordinators during a school based professional development meeting.
- Follow-up professional development will be provided on an as needed basis during scheduled math coach meetings with teachers.
- Additional resources will be provided through the district's website. Resources will include FASTT Math training videos, FASTT Math manual, FASTT Math white paper,

STAGE 5: FASTT Math Implementation (5/15 - Ongoing)

- Incorporate the use of FASTT Math in all third through eighth grades as part of the regular mathematics classes to teach new skills as well as reinforce skills previously taught, by designating FASTT Math as a center for small group instruction for 10-minutes during math class at least three times per week.

STAGE 6: Monitoring & Evaluation (10/15 – Ongoing)

- Math coaches will monitor student FASTT Math usage and progress.
- Math coaches will initiate and continue weekly dialog with math teachers regarding FASTT Math implementations.
- Math coaches will collect weekly FASTT Math data and share the results with teachers and collect monthy reports for administrators.
- Math coaches will share FASTT Math data with the existing data teams in each school to review FASTT Math reports from each student and compare this information with other types of data in order to create a student profile. By tracking data from multiple sources, we will be able to determine the success of implementing FASTT Math and its impact on further student achievement.

Conclusions

This white paper offered an overview of research related to the topic of math fact fluency and computer-aided instruction, as well as findings from my study evaluating the effectiveness of the program, FASTT Math. Findings from this study indicated that FASTT Math was more effective than traditional instruction to increase student math fact fluency. Research supports the belief that increased math fact fluency will have a direct effect on future mathematics performance.

Based on the findings of my study, this policy recommendation suggests initiating a larger study to provide further evidence at additional grade levels for the district to justify a mandate for FASTT Math implementation. If supported by the findings, the superintendent can mandate incorporating FASTT Math in all third through eigth grades as part of the regular mathematics classes to teach new skills as well as reinforce skills previously taught, by designating FASTT Math as a center. In conjuntion with implementation, professional development designed by the author will be provided by math coaches and technology coordinators. Lastly, school data teams should be expanded with the purpose of collecting and analyzing data to monitor and evaluate FASTT Math's effectiveness.

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Appendix B: Worksheet Works Email

Worksheet Works

Worksheets may be used for educational and non-commercial purposes only.

Email Request:

Time: Sun May 05 16:01:43 CDT 2013

Hello,

I am currently working toward implementing a study to determine the effectiveness of a computer-based program to enhance student math fact fluency, specifically - multiplication. I was planning on using your website's multiplication sheets as a timed assessment to determine a student automaticity base line score (pretest) and then a comparative assessment (posttest). I have used these worksheets in class and personally found them very useful. Based on your copyright information posted on the site, I believe that I am complying with the copyright policy. If this is not the case please let me know.

With regards to my study, would you be able to share some information about your site? Would you be able to share the number of times worksheets have been downloaded from your site or any anecdotal information pertaining to the value teacher's have for your product? In addition, would you have any information pertaining to your works and their reliability to measure accuracy.

Thank you for reading my comments, and providing a very useful product.

Joe Bochniak
jbochniak@acboe.org

Email Response:

john.s.g.churchill@gmail.com
Sunday, May 26, 2013 12:32 PM

Sent to: jbochniak@acboe.org

Hi Joe,
Thanks for the note! I'm glad you're finding the worksheets useful. I have heard of many anecdotes about children who were behind in math suddenly catching up and getting ahead by using our worksheets, but really any would do the job - Kumon included. I've used a variety on my own children. I'm sure there are other cases where they do not work, but people are much less likely to give me any feedback. As to the usage, I can only measure things like the count of worksheets generated, but not actual usage. That number runs to around 50,000 documents across about 15,000 unique users on a busy day, which is predictably highest during school days during U.S. school hours. However that number doesn't say anything about what gets printed and what gets thrown away, and how many prints, if any, are made of any particular document. I do know that schools occasionally print hundreds of copies as take-home work. A directly interactive site such as ixl.com, which can monitor usage down to a per-question basis, probably has some very interesting statistics, including growth of the students. Feel free to let me know if you have any other questions!
Regards,

John

Appendix C: Pretests

Math Facts: Multiplication

Name: ____________________ **Date:** ____________________

10×6	12×10	11×4	6×4	11×6	7×12	7×4	6×2
1×12	7×4	3×7	1×12	4×3	9×3	3×6	5×1
4×1	6×6	12×2	1×3	5×7	9×7	3×5	1×11
1×1	9×9	11×1	3×1	10×4	11×4	8×6	7×9
8×4	10×9	8×9	5×2	3×10	10×2	9×4	6×7
8×10	5×11	12×9	1×4	3×9	6×9	1×2	2×6
4×1	1×4	12×4	7×11	4×9	1×3	5×1	9×2
12×11	9×8	4×11	6×5	8×11	2×8	11×3	10×8
9×3	12×10	1×2	11×7	3×11	5×9	3×1	11×5
8×5	4×6	11×12	7×5	9×11	4×2	8×7	6×1

Math Facts: Multiplication
ANSWER KEY

10 × 6 = 60	12 × 10 = 120	11 × 4 = 44	6 × 4 = 24	11 × 6 = 66	7 × 12 = 84	7 × 4 = 28	6 × 2 = 12
1 × 12 = 12	7 × 4 = 28	3 × 7 = 21	1 × 12 = 12	4 × 3 = 12	9 × 3 = 27	3 × 6 = 18	5 × 1 = 5
4 × 1 = 4	6 × 6 = 36	12 × 2 = 24	1 × 3 = 3	5 × 7 = 35	9 × 7 = 63	3 × 5 = 15	1 × 11 = 11
1 × 1 = 1	9 × 9 = 81	11 × 1 = 11	3 × 1 = 3	10 × 4 = 40	11 × 4 = 44	8 × 6 = 48	7 × 9 = 63
8 × 4 = 32	10 × 9 = 90	8 × 9 = 72	5 × 2 = 10	3 × 10 = 30	10 × 2 = 20	9 × 4 = 36	6 × 7 = 42
8 × 10 = 80	5 × 11 = 55	12 × 9 = 108	1 × 4 = 4	3 × 9 = 27	6 × 9 = 54	1 × 2 = 2	2 × 6 = 12
4 × 1 = 4	1 × 4 = 4	12 × 4 = 48	7 × 11 = 77	4 × 9 = 36	1 × 3 = 3	5 × 1 = 5	9 × 2 = 18
12 × 11 = 132	9 × 8 = 72	4 × 11 = 44	6 × 5 = 30	8 × 11 = 88	2 × 8 = 16	11 × 3 = 33	10 × 8 = 80
9 × 3 = 27	12 × 10 = 120	1 × 2 = 2	11 × 7 = 77	3 × 11 = 33	5 × 9 = 45	3 × 1 = 3	11 × 5 = 55
8 × 5 = 40	4 × 6 = 24	11 × 12 = 132	7 × 5 = 35	9 × 11 = 99	4 × 2 = 8	8 × 7 = 56	6 × 1 = 6

Math Facts: Multiplication

Name: ____________________ Date: ____________________

2 × 11	10 × 1	10 × 3	12 × 7	10 × 6	1 × 10	12 × 6	3 × 1
11 × 4	1 × 6	2 × 4	8 × 10	12 × 11	6 × 8	11 × 3	11 × 1
5 × 6	5 × 9	10 × 8	10 × 5	2 × 3	12 × 3	6 × 3	8 × 12
4 × 3	6 × 2	11 × 8	10 × 2	6 × 12	1 × 12	9 × 6	8 × 4
10 × 9	6 × 9	8 × 10	4 × 5	7 × 6	7 × 3	7 × 11	3 × 9
5 × 3	11 × 6	10 × 3	7 × 2	3 × 3	6 × 4	3 × 4	5 × 3
4 × 2	2 × 7	4 × 7	4 × 7	1 × 4	8 × 3	12 × 9	7 × 6
4 × 1	5 × 1	5 × 6	2 × 5	3 × 8	12 × 4	4 × 11	9 × 3
12 × 7	2 × 12	6 × 8	12 × 5	12 × 9	11 × 12	6 × 9	1 × 12
9 × 8	4 × 10	5 × 7	1 × 3	2 × 9	4 × 8	12 × 6	9 × 1

WorksheetWorks.com

Math Facts: Multiplication
ANSWER KEY

2 × 11 22	10 × 1 10	10 × 3 30	12 × 7 84	10 × 6 60	1 × 10 10	12 × 6 72	3 × 1 3
11 × 4 44	1 × 6 6	2 × 4 8	8 × 10 80	12 × 11 132	6 × 8 48	11 × 3 33	11 × 1 11
5 × 6 30	5 × 9 45	10 × 8 80	10 × 5 50	2 × 3 6	12 × 3 36	6 × 3 18	8 × 12 96
4 × 3 12	6 × 2 12	11 × 8 88	10 × 2 20	6 × 12 72	1 × 12 12	9 × 6 54	8 × 4 32
10 × 9 90	6 × 9 54	8 × 10 80	4 × 5 20	7 × 6 42	7 × 3 21	7 × 11 77	3 × 9 27
5 × 3 15	11 × 6 66	10 × 3 30	7 × 2 14	3 × 3 9	6 × 4 24	3 × 4 12	5 × 3 15
4 × 2 8	2 × 7 14	4 × 7 28	4 × 7 28	1 × 4 4	8 × 3 24	12 × 9 108	7 × 6 42
4 × 1 4	5 × 1 5	5 × 6 30	2 × 5 10	3 × 8 24	12 × 4 48	4 × 11 44	9 × 3 27
12 × 7 84	2 × 12 24	6 × 8 48	12 × 5 60	12 × 9 108	11 × 12 132	6 × 9 54	1 × 12 12
9 × 8 72	4 × 10 40	5 × 7 35	1 × 3 3	2 × 9 18	4 × 8 32	12 × 6 72	9 × 1 9

Appendix D: Posttest

Math Facts: Multiplication

Name: ____________________ Date: ____________________

9 × 7	7 × 9	4 × 1	11 × 3	9 × 4	3 × 2	3 × 1	11 × 8
1 × 9	6 × 5	9 × 8	11 × 6	9 × 1	11 × 12	12 × 7	10 × 11
2 × 11	2 × 1	5 × 8	3 × 12	10 × 6	9 × 2	10 × 2	6 × 7
4 × 6	6 × 4	1 × 1	4 × 4	3 × 12	5 × 4	4 × 12	9 × 11
6 × 2	12 × 8	10 × 6	1 × 4	10 × 9	9 × 2	1 × 8	10 × 11
9 × 12	2 × 11	5 × 6	11 × 3	5 × 11	8 × 7	5 × 10	1 × 5
6 × 12	9 × 6	1 × 2	2 × 8	1 × 6	12 × 9	6 × 3	6 × 10
12 × 4	3 × 8	3 × 5	2 × 8	7 × 12	3 × 4	8 × 12	12 × 10
2 × 5	12 × 6	5 × 3	9 × 5	8 × 10	1 × 2	11 × 10	10 × 3
8 × 5	2 × 6	6 × 9	4 × 11	10 × 7	7 × 8	12 × 11	8 × 6

Math Facts: Multiplication
ANSWER KEY

9 × 7 63	7 × 9 63	4 × 1 4	11 × 3 33	9 × 4 36	3 × 2 6	3 × 1 3	11 × 8 88
1 × 9 9	6 × 5 30	9 × 8 72	11 × 6 66	9 × 1 9	11 × 12 132	12 × 7 84	10 × 11 110
2 × 11 22	2 × 1 2	5 × 8 40	3 × 12 36	10 × 6 60	9 × 2 18	10 × 2 20	6 × 7 42
4 × 6 24	6 × 4 24	1 × 1 1	4 × 4 16	3 × 12 36	5 × 4 20	4 × 12 48	9 × 11 99
6 × 2 12	12 × 8 96	10 × 6 60	1 × 4 4	10 × 9 90	9 × 2 18	1 × 8 8	10 × 11 110
9 × 12 108	2 × 11 22	5 × 6 30	11 × 3 33	5 × 11 55	8 × 7 56	5 × 10 50	1 × 5 5
6 × 12 72	9 × 6 54	1 × 2 2	2 × 8 16	1 × 6 6	12 × 9 108	6 × 3 18	6 × 10 60
12 × 4 48	3 × 8 24	3 × 5 15	2 × 8 16	7 × 12 84	3 × 4 12	8 × 12 96	12 × 10 120
2 × 5 10	12 × 6 72	5 × 3 15	9 × 5 45	8 × 10 80	1 × 2 2	11 × 10 110	10 × 3 30
8 × 5 40	2 × 6 12	6 × 9 54	4 × 11 44	10 × 7 70	7 × 8 56	12 × 11 132	8 × 6 48

Appendix E: Letter of Cooperation

Letter of Cooperation from a Community Research Partner

[redacted]

February 8, 2013

Dear Joseph Bochniak,

Based on my review of your research proposal, I give permission for you to conduct the study entitled, "The Effectiveness of Computer Intervention on Student Math Fact Fluency" within Uptown Complex School. As part of this study, I authorize you to recruit sixth grade students, collect and analyze data, utilize FASTT MATH instructional software, and disseminate the findings. Individuals' participation will be voluntary and at their own discretion.

We understand that our organization's responsibilities include: providing the location, the teaching staff, participation pool, and a flexible instructional schedule for the duration of this study. We reserve the right to withdraw from the study at any time if our circumstances change.

I confirm that I am authorized to approve research in this setting.

I understand that the data collected will remain entirely confidential and may not be provided to anyone outside of the research team without permission from the Walden University IRB.

Sincerely,

Ms. Lakecia Hyman,
Principal
[redacted]

Appendix F: Data Use Agreement

DATA USE AGREEMENT

This Data Use Agreement ("Agreement"), effective as of December 2, 2013 ("Effective Date"), is entered into by and between Joseph Bochniak ("Data Recipient") and Uptown School Complex ("Data Provider"). The purpose of this Agreement is to provide Data Recipient with access to a Limited Data Set ("LDS") for use in research in accord with the HIPAA and FERPA Regulations.

1. Definitions. Unless otherwise specified in this Agreement, all capitalized terms used in this Agreement not otherwise defined have the meaning established for purposes of the "HIPAA Regulations" codified at Title 45 parts 160 through 164 of the United States Code of Federal Regulations, as amended from time to time.

2. Preparation of the LDS. Data Provider shall prepare and furnish to Data Recipient a LDS in accord with any applicable HIPAA or FERPA Regulations

3. Data Fields in the LDS. No direct identifiers such as names may be included in the Limited Data Set (LDS). In preparing the LDS, Data Provider shall include the **data fields specified as follows**, which are the minimum necessary to accomplish the research (list all data to be provided): pretest and posttest results of two-minute drills.

4. Responsibilities of Data Recipient. Data Recipient agrees to:

    a. Use or disclose the LDS only as permitted by this Agreement or as required by law;

    b. Use appropriate safeguards to prevent use or disclosure of the LDS other than as permitted by this Agreement or required by law;

    c. Report to Data Provider any use or disclosure of the LDS of which it becomes aware that is not permitted by this Agreement or required by law;

    d. Require any of its subcontractors or agents that receive or have access to the LDS to agree to the same restrictions and conditions on the use and/or disclosure of the LDS that apply to Data Recipient under this Agreement; and

    e. Not use the information in the LDS to identify or contact the individuals who are data subjects.

5. Permitted Uses and Disclosures of the LDS. Data Recipient may use and/or disclose the LDS for its Research activities only.

6. Term and Termination.

   a. Term. The term of this Agreement shall commence as of the Effective Date and shall continue for so long as Data Recipient retains the LDS, unless sooner terminated as set forth in this Agreement.

   b. Termination by Data Recipient. Data Recipient may terminate this agreement at any time by notifying the Data Provider and returning or destroying the LDS.

   c. Termination by Data Provider. Data Provider may terminate this agreement at any time by providing thirty (30) days prior written notice to Data Recipient.

   d. For Breach. Data Provider shall provide written notice to Data Recipient within ten (10) days of any determination that Data Recipient has breached a material term of this Agreement. Data Provider shall afford Data Recipient an opportunity to cure said alleged material breach upon mutually agreeable terms. Failure to agree on mutually agreeable terms for cure within thirty (30) days shall be grounds for the immediate termination of this Agreement by Data Provider.

   e. Effect of Termination. Sections 1, 4, 5, 6(e) and 7 of this Agreement shall survive any termination of this Agreement under subsections c or d.

7. Miscellaneous.

   a. Change in Law. The parties agree to negotiate in good faith to amend this Agreement to comport with changes in federal law that materially alter either or both parties' obligations under this Agreement. Provided however, that if the parties are unable to agree to mutually acceptable amendment(s) by the compliance date of the change in applicable law or regulations, either Party may terminate this Agreement as provided in section 6.

   b. Construction of Terms. The terms of this Agreement shall be construed to give effect to applicable federal interpretative guidance regarding the HIPAA Regulations.

   c. No Third Party Beneficiaries. Nothing in this Agreement shall confer upon any person other than the parties and their respective successors or assigns, any rights, remedies, obligations, or liabilities whatsoever.

   d. Counterparts. This Agreement may be executed in one or more counterparts, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument.

e. Headings. The headings and other captions in this Agreement are for convenience and reference only and shall not be used in interpreting, construing or enforcing any of the provisions of this Agreement.

IN WITNESS WHEREOF, each of the undersigned has caused this Agreement to be duly executed in its name and on its behalf.

DATA PROVIDER	DATA RECIPIENT
Signed: [signature]	Signed: [signature]
Print Name: Lakecia Hyman	Print Name: Joseph Bochniak
Print Title: Principal	Print Title: Technology Coordinator

Curriculum Vitae

Joseph Bochniak

Education

Walden University, Minneapolis, Minnesota 2014
Ed. D in Education, Concentration: Teacher Leadership

Dissertation: "The Effectiveness of Computer-Aided Instruction on Math Fact Fluency"

Walden University, Minneapolis, Minnesota 2009
M. Ed in Education
Concentration: Technology Integration

Richard Stockton College, Pomona, New Jersey 1995
Bachelor's Degree, Bachelor of Arts in Liberal Arts
Concentration: Education

Richard Stockton College, Pomona, New Jersey 1993
Bachelor's Degree, Bachelor of Arts in History
Concentration: History

New Jersey Teaching Certificate 1995
Elementary K-12 & Social Studies 7-12

Teaching Experience

XYZ Public Schools, Atlantic City New Jersey 1997-Present

Technology Coordinator 2008-Present
XYZ School

Social Studies Teacher 1997-2008
XYZ School
XYZ School

Committees & Organizations

School Leadership & PD Committees	2008-Present
Technology Club Advisor	2005-2010
XYZ School	
Social Studies Curriculum Taskforce	2005-2007, 2011
XYZ Public Schools	
XYZ Educational Association (ACEA) Board Member	1999-2012
Senior-Vice President	2006-2012