THE EFFECTS OF REFLEX MATH AS A RESPONSE TO INTERVENTION STRATEGY TO IMPROVE MATH AUTOMATICITY AMONG MALE AND FEMALE AT-RISK MIDDLE SCHOOL STUDENTS

by

Daphne Moore Sarrell

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

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ABSTRACT

The search for evidence-based math interventions that are easy to use and impact academic achievement are in demand, and the impact that these interventions can have on students who struggle with math achievement is of concern. In this study, the effects of Reflex math computerized intervention to improve the automaticity of basic math facts among male and female middle school students identified as at-risk for academic failure in mathematics was examined according to differences in mean scores and based on gender. A quasi-experimental pretest-posttest nonequivalent control group design was used for the purposes of the study. Convenience sampling among students receiving or qualifying for response to intervention services for math was used to determine the study participants. The Basic Math Operations Task (BMOT) served as the pretest and posttest against which differences in mean scores were determined with analysis of covariance used to examine the differences. Results as well as assumptions, limitations, and recommendations for the future are included.

Keywords, mathematics, achievement, interventions, at-risk, fluency, accuracy, automaticity, middle school, gender, Reflex math

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List of Abbreviations

Adequate Yearly Progress (AYP)

Analysis of Covariance (ANCOVA)

Annual Measurable Objectives (AMOs)

Basic Math Operations Task (BMOT)

Computer Assisted Instruction (CAI)

Cognitive Load Theory (CLT)

Cover, Copy, and Compare (CCC)

Criterion Referenced Competency Test (CRCT)

Elementary and Secondary Education Act’s (ESEA)

Improving America’s Schools Act (IASA)

Individuals with Disabilities Act (IDEA)

Institutional Review Board (IRB)

National Assessment of Educational Progress (NAEP)

National Mathematics Advisory Panel (NMAP)

No Child Left Behind (NCLB)

Response to Intervention (RtI)

Program for International Student Assessment (PISA)

Secretary’s Commission on Achieving Necessary Skills (SCANS)

Science, Technology, Engineering, and Mathematics (STEM)

Statistical Package for the Social Sciences (SPSS)

CHAPTER ONE: INTRODUCTION

According to the National Mathematics Advisory Panel (NMAP, 2008), in regards to computational fluency and accuracy, children from the United States lack the efficiency and speed of children from other countries, and many do not meet minimal mathematics proficiency by the time they leave school. This advisory panel stated that "all students can and should be mathematically proficient in grades pre-K through 8" (NMAP, 2008, p. 10) and that computational fluency must be enhanced. These statements in combination with the mandates imposed by the passage of the No Child Left Behind Act in 2001(NCLB; Public Law 107-110) and the reauthorization of the Individuals with Disabilities Education Act (IDEA) in 2004 have educators and administrators searching for effective instructional strategies and interventions to help improve the academic achievement of struggling students who are at-risk for failure to make academic progress in math as measured by the Criterion Referenced Competency Test (CRCT).

This dissertation used a quantitative quasi-experimental pretest-posttest nonequivalent control group design to determine the effects of Reflex math computerized intervention as to improve math automaticity scores as measured by the Basic Math Operations Task (BMOT) among students identified as at-risk for academic achievement in math. Changes in automaticity were measured by the differences between groups' posttest scores on the BMOT while using BMOT pretest scores as a statistical control. This study further examined the effects of this intervention on automaticity in terms of gender for those students receiving services in Tiers 2 through 4 of the Response to Intervention (RtI) pyramid. Chapter 1 includes an introduction to and background of the study, the purpose and significance of the study, a problem statement, and research questions as well as their corresponding hypotheses, identification and definition of variables, pertinent definitions, a summary of the research, and the assumptions and limitations associated with the study.

Background of the Study

In response to legislation and as a way to address remediation, the implementation of the tiered Response to Intervention (RtI) pyramid model was suggested. This tiered model is in part aimed at effective treatment or remediation to assist students who struggle so they can attain or maintain grade level academic performance amid the pressure of educational reform (Georgia Department of Education, 2011). Reasons for the lack of progress of at-risk students are varied, yet it is imperative to determine evidence-based interventions that will help these students succeed.

With the 2001 enactment of Public Law 107-110, better known as the No Child Left Behind (NCLB) Act, the federal government placed greater emphasis on early intervention, high quality instruction, and accountability for academic outcomes. The intent of this law was to enhance the educational process for all children by "closing the achievement gap and making sure that all students, including those who are disadvantaged, achieve academic proficiency" (U.S. Department of Education, 2004, Stronger Accountability for Results section, para. 1). As a component of this act, schools are held to the standard of making Adequate Yearly Progress (AYP) as measured by standardized test performance and are required to have 95% of all students demonstrate proficiency in mathematics by the year 2014. Despite legislative directives, most at-risk students and students with disabilities perform poorly on standardized math subtests. These students exhibit pervasive difficulties with basic computation and problem solving (Fuchs et al., 2005) and need additional strategies and interventions to support their academic deficits (Calhoun, Emerson, Flores, & Houchins, 2007). Educators and students are struggling to meet the myriad of requirements legislated by the 2001 passage of the NCLB mandate. According to the NMAP (2008), most students fail to meet minimal mathematics proficiency standards by the end of their formal schooling, and existing instructional tools and textbooks often are inadequate in adhering to important instructional principles for learning mathematics.

The mandate to maintain high quality academic programs requires school administrators to determine which supports work and which ones do not in an effort to reduce duplicating ineffective services while instead providing “best practice” instructional models. Therefore, much time and effort is devoted to evidence-based interventions that support the mathematical endeavors of students and better prepare them for subsequent mathematics classes and the competitive job market that looms ahead. As a result, educators are required to possess the skills and take the time to unearth and evaluate evidence-based instructional strategies or interventions to meet students’ academic needs. With limited options in the areas of mathematics as compared to those available for reading, there is much work to be done to meet the academic needs and challenges ahead (Greshem, 2004).

The curriculum, instruction, and assessment of mathematics need attention, and educators must recognize the importance of basic facts automaticity if they want to prevent or treat academic deficits (NMAP, 2008). When the task of learning basic multiplication facts during the elementary years is deficient, a significant deficit is placed upon concepts requiring a mastery of fractions, equations, and algebra. These students’ mathematics achievement will be severely limited if the lack of basic facts is not addressed and remediated with effective interventions, and these students may remain at-risk for academic failure or possibly be identified as in need of special education services. In fact, differences in addition fact fluency in the first grade can foretell future identification as a high versus low achiever in mathematics (Geary et al., 2009). As a result, educators need to provide interventions aimed at improving math computation and application abilities of all students with particular emphasis on the importance of mathematics fluency and accuracy, or automaticity. Advantages for students who possess automaticity of basic math facts include (a) the ability to engage in more complex tasks (Skinner, Fletcher, & Hennington, 1996), (b) attainment of higher achievement scores, (c) enhanced levels of retention (Singer-Dudek & Greer, 2005), (d) lower levels of anxiety (Cates & Rhymer, 2003), and (e) overall enhanced math engagement (Skinner, Pappas, & Davis, 2005). One evidence-based intervention that has been suggested as effective for improving automaticity in several settings and among some groups of students is Reflex math (Cholmsky, 2011). Reflex's approach is based on the well-researched Cover, Copy, and Compare procedure, "a simple, efficient, self-managed academic intervention that can be used to improve accuracy, fluency, and maintenance across students, curricula objectives, academic skill domains, and settings" (Skinner, McLaughlin, & Logan, 1997, p. 295). As a newer approach to math fact fluency, the Reflex math computerized intervention covers fact fluency from initial acquisition to automaticity while continuously adapting and differentiating instruction according to the student's ability level through the use of fun and motivating games (Cholmsky, 2011).

Research in the cognitive sciences support the need for a certain degree of automaticity in basic math skills in order to approach and succeed at higher levels of cognitive functioning (e.g. Baroody, Bajwa, & Eiland, 2009; Gagne, 1983; Poncy, Skinner, & Jaspers, 2006; Verschaffel, Luwel, Torbeyns, & VanDooren, 2009; Woodward, 2006). The cognitive learning theory or information processing theory emphasizes the importance of the automaticity of basic math facts and plays a central role when examining the topic of automaticity (Gagne 1983; Woodward, 2006). A more recent focus on the cognitive load theory asserts that cognitive capacity in working memory is limited, and if a learning task requires too much capacity, learning will be affected (de Jong, 2010). These theories play a significant role in automaticity since the automatic recall of basic math facts is needed in order to access higher order mathematical content and as the content becomes increasingly complex as students progress through middle school.

In an attempt to help students with mathematical deficits improve their achievement level and thus help their schools make AYP, math support classes as well as Response to Intervention (RtI) groups provide additional support. RtI is a logical system of data-based decision making that permits districts, schools, and teachers to evaluate the adequacy of ongoing mathematics instruction and to systematically devise a plan to accelerate learning in mathematics for all students and provide additional support for those who are at risk for failure without intervention (e.g. Barnes & Harlacher, 2008; Berkely, Bender, Peaster, & Saunders, 2009; Fletcher & Vaughn, 2009).

In addition to the impact that automaticity may have on academic achievement, the gender of students may play a significant role in the achievement of middle school students as well. In a recent report by the Southern Regional Education Board (2012), a proclamation was made that "For some students, the achievement gap begins in the middle grades; and, for those students who enter the middle grades achieving below grade-level, that gap continues to widen in grades six through eight" (p. 10). Lui and Wilson (2009) reported significant differences in standardized test scores when comparing middle grade boys to girls. Even with the current available data reporting on gender and academic achievement, research is encouraged to further examine how a lack of automaticity affects at-risk students based on gender.

With the federal government mandate to provide earlier intervention, higher quality instruction, and greater accountability for student outcomes, the increased demands for services to meet the academic needs of students, coupled with strained budgets and the importance of determining the best allocation of services, is of utmost concern. Educators need to get optimal services for minimal dollars for students and also need to determine which additional layers of math supports provide the most beneficial results for the greatest number of students by improving their academic achievement.

> Use should be made of what is clearly known from rigorous research about how children learn, especially by recognizing…the mutually reinforcing benefits of conceptual understanding, procedural fluency, and automatic (i.e., quick and effortless) recall of facts. (Principal Messages, NMAP, 2008, p. viii)

Problem Statement

Decades of research indicate that academically low-achieving students routinely have significant problems with the automaticity of basic math facts (Woodward, 2006). While limited research on effective instructional interventions to use for Response to Intervention models exists, it is limited concerning the effectiveness that these may have on math achievement for middle school students who are at-risk (e.g. Esch, 2009; Foegen, 2008; Gersten et al., 2009). Research is needed to compare the effectiveness of specific interventions and instructional strategies for this population. Whether the cause of low achievement is based on intellect, factors affecting motivation, or the lack of effective instruction, evidence-based instructional interventions and strategies are needed to help bridge the gap between the academic achievement of at-risk students and enable them to become proficient on mandated assessments and progress to the next grade level. Automaticity of basic math facts is needed so that students have the cognitive resources necessary to approach more complex math concepts and operations (Axtell, McCallum, Mee Bell, & Poncy, 2009). In addition to improved academic achievement as a result of a specific mathematics intervention, gender differences also need to be examined. As recently as 2009, reports indicated that middle school boys in the United States were still outperforming girls in most mathematic domains (OECD, 2010).

Purpose Statement

The purpose of this quasi-experimental pretest-posttest nonequivalent control group study was to determine if the use of Reflex math computerized intervention would significantly increase math automaticity of at-risk male and female north Georgia middle school students. The proposed research ascertained the effectiveness of a specific intervention aimed at improving automaticity and examined the differences that existed among males and females. If the strategy was more effective for one gender, additional support might be provided for the benefits associated with varying interventions that would be more gender specific. Information obtained would address issues such as the following: (a) the development of automaticity as a function of age, (b) the role that gender may play in the improvement of fluency, (c) the determination as to the effectiveness of Reflex math computerized intervention as a specific RtI strategy, (d) the willingness of teachers to use simple and effective strategies that are evidence-based, (e) the effect that an increase in automaticity may have on students who encounter more complex math problems, and (f) additional insight into the impact that rewards play in regards to math fact automaticity among middle school students.

Significance of the Study

A renewed interest in science, technology, engineering, and mathematics (STEM) education in recent years focuses on the lack of mathematics proficiency, computer skills, and problem-solving abilities among job applicants (National Research Council, 2011). Despite this renewal of concern and focus on STEM education, the majority of STEM projects target secondary and university level students, with very few targeting elementary and middle school students (Epstein & Miller, 2011). Currently, the need for STEM qualified workers is in demand, with fewer applicants than positions available, and this demand is projected to increase in subsequent years (Lacey & Wright, 2009). Common Core State Standards is one way to better prepare students for the increasing demands of math and science related jobs by focusing on fewer topics but in greater depth (NMAP, 2008), yet additional attention must be given to better preparing younger students to approach and become more proficient with complex math skills.

The study is significant because of the importance of math skills in the global marketplace and work force in which our students will enter and vie for jobs. Math concepts taught in earlier years are the foundation for those that follow, and it is important to ensure that foundations are present in order to build upon and promote successful lifelong math learners. Middle school students who struggle with automaticity will not be adequately prepared for the high school curriculum, may not progress to the next grade level, and may eventually drop out of school altogether (Axtell, McCallum, Mee Bell, & Poncy, 2009). With Georgia's high school cohort graduation rate at 67.4% in 2012, there is a great deal of work that needs to be done (Georgia Department of Education, 2012).

Findings from this study can provide insight into possible answers surrounding the question of how to best meet the needs of underachieving students in mathematics while balancing time and budget constraints. School systems may use information gleaned to make curriculum and instructional decisions that provide the most results for dollars allocated. Students may receive the extra help they need for the specific deficits they possess and experience the feeling of success when a more thorough understanding is gained in mathematics. Students who feel successful and empowered with knowledge tend to be more enthusiastic and engaged learners (Fredericks, et al., 2011). Educators may see an option for providing their at-risk students with the remediation they need for specific deficits while continuing to layer additional grade level math concepts.

The study is also significant because the automaticity associated with one math skill can improve automaticity in other areas and can provide a firm foundation for more complex problems (Woodward, 2006). Automaticity is crucial to solving complex problems in relation to both pacing and cognitive workload (e.g. Caron, 2007; Gagne, 1983; Poncy, et al., 2006). In addition, interventions intended to improve math ability can help avert future math difficulties (U. S. Department of Education, 2009). This study also provides additional research support and generalizability in regards to the specific impact of strategies addressing automaticity on subgroups of students, such as students with disabilities or those who are impoverished. By providing effective evidence-based interventions as part of the Response to Intervention pyramid, academic achievement gaps that separate at-risk students and their average performing peers may shrink and decrease the number of students that are eventually referred for special education evaluation.

Research Questions

The following are the research questions for the study:

RQ1: Is there a statistically significant difference in Basic Math Operations

Task scores between at-risk students who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk students who receive traditional Response to Intervention instruction while controlling for prior student knowledge?

RQ2: Is there a statistically significant difference in Basic Math Operations Task scores between at-risk males who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk males who receive traditional Response to Intervention instruction while controlling for prior student knowledge?

RQ3: Is there a statistically significant difference in Basic Math Operations Task scores between at-risk females who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk females who receive traditional Response to Intervention instruction while controlling for prior student knowledge?

Null Hypotheses

The following are the null hypotheses for the study:

H_{o1}: There is no statistically significant difference in Basic Math Operations Task scores between at-risk students who receive Reflex math as a Response to Intervention strategy and at-risk students who receive traditional Response to Intervention instruction while controlling for prior knowledge.

H_{o2}: There is no statistically significant difference in Basic Math Operations Task scores between at-risk males who receive Reflex math computerized instruction as a Response to Intervention strategy and at-risk males who receive traditional Response to Intervention instruction while controlling for prior knowledge.

$H_{o3:}$ There is no statistically significant difference in Basic Math Operations Task scores between at-risk females who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk females who receive traditional Response to Intervention instruction while controlling for prior knowledge.

Identification of Variables

The independent variable for this study was Reflex math computerized intervention as a tool to improve the automaticity of basic math facts. The dependent variable was automaticity scores and was assessed with the Basic Math Operations Task (Foegen & Deno, 2001), an outcome-based measure that specifically measures automaticity of math facts. The covariate for this study was the pretest as measured by the Basic Math Operations Task scores.

Definitions

Adequate Yearly Progress (AYP) - an annual measure of student participation and achievement of statewide assessments and other academic indicators that holds schools, school systems, and the state responsible for student achievement (Georgia Department of Education, 2011).

Automaticity **-** an unconscious ability to recall basic math facts with speed and accuracy (Baroody, et al., 2009).

Basic Math Operations Task (BMOT) - an instrument that measures automaticity of basic math facts of whole numbers for addition, subtraction, multiplication, and division in digits correct per minute (ppm) (Foegen & Deno, 2001).

Computer-assisted instruction (CAI) - the implementation of tutorials and/or drill-and-practice using the computer as mode of delivery, and oftentimes referred to as computer-based or computer-mediated instruction (Duhon, House, & Stinett, 2012).

Criterion Referenced Competency Test (CRCT) **-** statewide assessment used in the state of Georgia to assess the performance of each student based upon the knowledge and skills described in the Georgia Performance Standards (GPS) (Georgia Department of Education, 2011).

Evidence-based practice **-** when research supported interventions and instructional methods are recognized, shared, and accepted as beneficial (Kazdin, 2008).

Fluency **-** the speed and accuracy that a student employs in order to solve mathematical problems (Anderson, 1980).

Georgia Performance Standards (GPS) **-** standards established to provide clear expectations for instruction, assessment, and student work (Georgia Department of Education, 2011).

No Child Left Behind (NCLB) **-** an expressive name for Public Law 107-110 in which federal legislation was passed by Congress to create an accountability system that demands individual states to demonstrate student achievement in a variety of subcategories in order to close achievement gaps (U.S. Congress, 2002).

Reflex math **-** a computerized math fact fluency strategy that covers fact fluency from initial acquisition to automaticity while adapting and differentiating instruction according to the student’s ability level through the use of fun and motivating games (Cholmsky, 2011).

Response to Intervention (RtI) **-** a method of academic intervention designed to detect and provide early, effective assistance to children who are having difficulty learning and function as one part of an evidence-based process of identifying learning disabilities (Georgia Department of Education, 2011).

Response to Intervention, Tier 1 (Standards-Based Classroom Learning) **-** differentiated general education learning that includes universal screening and progress monitoring while adhering to Common Core Georgia Performance Standards (Georgia Department of Education, 2011).

Response to Intervention, Tier 2 (Needs-Based Learning) **-** this tier is combined with Tier 1 and adds additional research based interventions and more frequent progress monitoring for students identified in Tier 1 as needing additional specific skills support (Georgia Department of Education, 2011).

Response to Intervention, Tier 3 (SST-Driven Learning) **-** this tier is in addition to Tiers 1 and 2 and provides intensive individualized research based interventions to meet the specific needs of students while monitoring and analyzing progress more frequently than the prior tiers. Tier 3 involves the additional support of specialists to assist in the problem solving process for each student identified for support at this level (Georgia Department of Education, 2011).

Response to Intervention, Tier 4 (Specially-Designed Learning) **-** in combination with Tiers 1, 2, and 3, this tier supports students targeted as needing an additional layer of support that includes specialized programs, instructional models, and specific learning methodologies with even greater monitoring of progress in regards to how these students respond to specific research-based interventions (Georgia Department of Education, 2011).

Title I **-** a federal program that supports schools and districts with funds to help students who are disadvantaged to improve their academic achievement and meet challenging state standards (Georgia Department of Education, 2011)

Assumptions and Limitations

The assumption was made that participant's fluency practice with Reflex math computerized intervention was limited to the Response to Intervention segment each day, that teachers who participate in the study practice fidelity in regards to procedures, and that students previously identified as qualifying for additional support in math do have math deficits that put them at risk for academic failure in math.

Limitations of the study exist in terms of design, environment, participants, and instrumentation. Design limitations were associated with lack of random assignment due to intact groups of participants used for the sampling frame and the convenience sampling technique used. The participants and environment posed limitations in regards to ethnicity and geographic location since the study included predominantly Caucasian students in a small rural school, thereby limiting generalizability of results. Instrumentation was also a limitation because the BMOT is similar to other timed instruments that may have been used in the past.

Possible threats to internal validity include history, maturation, testing, instrumentation, selection, experimental mortality, experimental treatment diffusion, and compensatory rivalry by the control group. These threats were controlled with brief treatment intervention duration, use of a valid and reliable instrument, use of analysis of covariance (ANCOVA) for data analysis, and minimizing the association among the experimental and control groups.

Potential threats to external validity can be categorized as population, or experimental validity. These threats were controlled by identifying the population to which results were generalized prior to the study, by including precise experiment descriptions, by using staff familiar to the students, and having staff control verbal and nonverbal cues.

CHAPTER TWO: REVIEW OF THE LITERATURE

Literature related to math automaticity was examined to unearth information and prior research addressing the topic and the impact this may have on math academic achievement. Also, an exploration of the role that a specific computerized math intervention may have in enhancing automaticity of math facts for middle school students who are at-risk for academic failure was done as well as whether or not this intervention would provide support for struggling math students receiving services through various Response to Intervention (RTI) tiers. The first section provides a theoretical framework for the background of the study that serves as the foundation upon which the need for automaticity rests as well as the impact that motivation and rewards may have when using computerized interventions. The second section provides a brief history of mathematics education in the United States and discusses the guidelines and impact of recent legislation on schools and students. The third section explains the Response to Intervention (RtI) pyramid and its intent. The fourth section explores the working definitions of math accuracy, fluency, and automaticity and provides research exploring and documenting their roles in math achievement. The fifth section identifies the role that educational technology may have on learning outcomes specifically related to mathematics achievement. This section also explains the Reflex math computerized intervention and its aim at improving automaticity. The sixth section addresses the role that gender differences may have on automaticity and current research that provides support for these differences. The final section provides a brief synopsis of the entire review of literature.

Theoretical Framework

According to Whitehurst (2003), Director of the Institute for Educational Sciences, as part of a speech when launching the federal Mathematics Summit:

> Cognitive psychologists have discovered that humans have fixed limits on the attention and memory that can be used to solve problems. One way around these limits is to have certain components of a task become so routine and over-learned that they become automatic (speech).

In order to help students develop and sustain automaticity of math facts, an understanding of the origins and development of the cognitive load, information processing, and instructional hierarchy theories would be instrumental. How these theories help address limitations and potential interventions for students who struggle with math achievement in general and the automaticity of math facts specifically would shed light on some of the reasons for the persistent math achievement gap and ways to help close this gap for at-risk students. In addition to theories on cognition and instructional hierarchy, when the use of technology with a reward structure is posed as a possible intervention to address automaticity, operant conditioning and token reinforcement warrant some investigation as to the role they may play in advancing the automatic recall of math facts.

Cognitive Learning Theory

Also known as the information processing theory, cognitive learning theory purports that people have a limited amount of cognitive capacity, or the amount of information that can be processed at one time (Pegg & Graham, 2007), and this limitation makes it difficult to complete complex tasks. Working memory is generally defined as the ability to hold information within the brain while manipulating other information, (Tronsky & Royer, 2003) or as a mental workspace involved in controlling, regulating, and maintaining information needed to accomplish complex cognitive assignments. Combined with limited working memory, if a student has deficits with retrieval skills or a slower than adequate processing speed, their working memory reaches capacity (Pegg & Graham, 2007). Unfortunately, since all students need mastery of basic math facts and computational strategies in order to successfully solve problems and perform mental estimations and computations, the information processing theory emphasizes that these basic facts need to be automatic (e.g. Baroody, et al., 2009; Gagne, 1983; Poncy, et al., 2006; Verschaffel, Luwel, Torbeysn, & Van Dooren, 2009).

The cognitive learning theory, supported by some proponents such as Gagne, Klatsky, R. Lachman, B. Lachman, and Butterfield, suggests that human learning (a) is inherently meaningful, (b) is composed of physical stimulation converted into information, (c) involves transformations of information in "mental" processes such as attention and reinforcement, (d) includes "control" processes such as rehearsal, retrieval, and automatization, and (e) is dependent upon external stimulation being transformed into information that is learned (Gagne, 1983). These suggestions that attaining and retaining information are due to mental processes that are impacted by external organization, decision-making events of learners, and the contents of both short-term and long-term memory address the at-risk student who struggles with acquiring math facts.

Specifically regarding automaticity, Gagne (1983) reported that a good deal of consideration has been paid to this topic in light of continuing reports of the mathematics achievement decline of children in the United States as compared to other countries. With limitations on the amount of space available in working memory, when students are introduced to multistep math operations and need as much free working memory as possible to attempt these problems, other information needed to solve these problems need to be automatically available (Gagne, 1983). If a student struggles to perform the initial steps of a multi-step problem, it will be unlikely that they will be able to retain the number of steps necessary for successful completion of the task.

Cognitive Load Theory

When new material is introduced, students have to focus on and interact with the material in working memory before the knowledge can be stored in long-term memory (Sweller et al., 1998). Therefore, it is important to ease the transfer of information to working memory by reducing cognitive load. As a member of an expanded collection of limited capacity theories, the cognitive load theory (CLT), like its corresponding cognitive learning theory, is founded in the notion that working memory is limited when posed with new information, yet long-term memory is limitless (vanMerriënboer & Ayres, 2005). With the cognitive capacity in working memory limited, when a learning task is heavily dependent on cognition, learning will be hindered (de Jong, 2010).

Research by Chandler and Sweller (Chandler & Sweller, 1991; Sweller, 1988) provides a foundation for the currently held CLT in regards to education. Their assertions about intrinsic, extraneous, and germane cognitive load provide some clarity as to how CLT can be used to guide instructional design (de Jong, 2010). Intrinsic cognitive load, also known as "ineffective cognitive load," depends upon the concurrent number of items being learned and is influenced by the students' prior experience as well as the difficulty level of the material (e.g. Artino, 2008; Gerjets & Schieter, 2003; Sweller et al., 1998). The knowledge that the learner brings to the instructional environment and how this prior information affects eventual knowledge acquisition may help educators better coordinate and utilize instructional supports that are built upon an understanding of cognitive load (Artino, 2008). Unlike intrinsic cognitive load, which is not influenced by instructional methods or external forces (Hasler, et al., 2007), the instructional tools and methods used to teach content influence extraneous load. According to van Merrienboer and Sweller (2005), “extraneous cognitive load is load that is not necessary for learning and that can be altered by instructional interventions” (p.150). Particularly for at-risk students who struggle with mathematics, cognitive resources saddled with extraneous load should not be wasted, and interventions should be identified that will enhance learning without unnecessary cognitive overload. Germane cognitive load, also known as “effective cognitive load” is dependent upon the weight of the learning events and occurs when learners have available cognitive resources to invest in pertinent learning (Artino, 2008). This load is only available when intrinsic and extraneous load is sufficiently restricted and makes working memory accessible (Sweller et al., 1998).

Based on the cognitive demands on the working memory of struggling students, CLT researchers suggest the reduction of unnecessary cognitive load. They also stress the importance of encouraging learners to retrieve the resources they have available in both long-term and short-term memory in order to solve math problems. This theory supports the belief that

> automaticity in math facts is fundamental to success in many areas of mathematics, and that without the ability to retrieve facts directly or automatically, students are likely to experience a high cognitive load as they perform a range of complex tasks (Woodward, 2006, p. 269).

Working memory plays a central role in learning mathematics (e.g. Bull, Epsy, & Wiebe, 2008; Geary, 1994; Menon, 2010; van der Sluis, van der Leij, & de Jong, 2005) particularly during childhood and adolescence when neurodevelopmental changes are prominent. As children are introduced to more complex mathematics operations, a sound working memory is needed so that information can be held while other higher order tasks are performed (Geary, et al., 2007;

Passolunghi & Siegel, 2004). Without a well-developed working memory, children resort to using undeveloped or incorrect strategies (Geary & Damon, 2006) and as a result, increased levels of anxiety may arise (Beilock & Carr, 2005). When children routinely memorize math facts through repetition, semantic memory becomes active; therefore, strategies and interventions that include repeated performance aimed at improving automaticity may help lessen processing load and free up working memory that can be dedicated towards more complex cognitive tasks (Menon, 2010).

Instructional Hierarchy Theory

An additional learning theory that supports the importance of the automaticity of math facts in order to access more complex math operations and problem-solving tasks is the instructional hierarchy theory proposed by Haring and Eaton (1978). The theory proposes that students learn skills via four stages that begin with acquisition, move through a fluency development stage, progress to a stage that includes generalization, and culminates with the ability to apply the learned skill. As it applies to the automaticity of math facts, during the acquisition stage, students would learn a series of math facts with the focus on obtaining the correct answer regardless of the length of time required (Cates & Rhymer, 2003). The second stage utilizes repeated drill and practice to reach proficiency with the learned facts so that they can be automatically recalled with minimal effort (Haring & Eaton, 1978). Improving fluency frees up some of the cognitive resources available in short-term memory and allows students greater access to perform more difficult problems when basic math fact accuracy is the foundational piece needed for these complex tasks (Delazer et al., 2003; Poncy et al., 2006). The third stage includes opportunities for the students to generalize math facts to alternate scenarios yet retain automaticity. The goal of this stage is to practice the skill with regularity so that discrimination can be made between this learned skill and others that may be different yet related. The final stage of the instructional hierarchy theory allows students the chance to apply the facts that they have learned to novel math tasks that rely on fluency for successful completion (Haring & Eaton, 1978). The stages are traversed in succession with progression to a subsequent stage dependent on mastery of the previous stage. As it applies to math instruction generally and automaticity specifically, this model indicates that a student who masters basic math facts is more likely and better equipped to approach more complex mathematical operations as they occur (Haring & Eaton, 1978).

Operant Conditioning and Reward Token Economy

Operant behavior is behavior that is manipulated by its consequences, whether they are rewards or punishments (Staddon & Cerutti, 2003). Though originally named by B. F. Skinner in 1937, operant conditioning (also know as instrumental conditioning) includes many methods that were first explored by E. L. Thorndike and based on his law of effect (Skinner, 1938). The law of effect suggested that rewards encourage the repetition of behaviors needed in order to receive the reward, thus speeding up the anticipated behavior instances. In essence, when a behavior is reinforced, it tends to be repeated because positive reinforcement is one of the most effective ways to change or modify behavior when it is properly applied (Myers, 2002).

Operant conditioning methods have many applications that have been proven effective for a variety of classroom situations. For example, computer assisted instruction allows students to receive feedback on the progress they are making in regards to a concept or skill while conditioning their behaviors in regards to the application of these skills in other areas (Flora, 2004). Students will typically receive a reward or token for correct efforts through process called token reinforcement, and will then use these rewards or tokens in exchange for more interesting forms of reinforcement. Tokens are “objects or symbols that are exchanged for goods or services” (Hackenberg, 2009, p. 257) and are the foundation upon which transactions involving currency are historically based. Structures that include the use of tokens via conditioned reinforcement have been effective as ways to manage behaviors and motivate people since the early 1800s (Kazdin, 1982) with pioneers Azrin, Paul, Krasner, and Ayllon, who actually coined the term “token economy” while working with institutionalized patients with mental illness (Liberman, 2000).

Related Literature

History of Mathematics Education in the United States

Historically, “changes in mathematics curriculum have generally been associated with some national movement: individualized learning, the discovery approach, New Math, and Back to Basics, with attempts at integration now and again” (Howden, 2000, p. 304). These variations in the method of mathematics instruction were wrought with opposing viewpoints about which ones could be deemed “best practices,” and each variation brought mixed results in the form of test scores. The advent of the space age in the 1950s and then into the 1960s evoked concerns regarding the proficiency of Americans in mathematics and sciences. As a result, an era of reform evolved, in which substantial funds were allocated towards an excellence in education movement that focused primarily upon the teacher guided concept of discovery learning (Woodward, 2004). Repetition and memorization lost emphasis because they were deemed old-fashioned and monotonous. After two decades, it was apparent that the new math era had not met the needs of students (Burris, 2005) and in its place came the “Back to Basics” movement. Although this math model encouraged students to guide their own education, with a renewed emphasis on reading, writing, and mathematics, test scores continued to suffer. During the 1970s and 1980s, the information processing theory and problem solving approach to mathematics were at the forefront of education (Woodward, 2004), and much was unearthed about the way children learn.

In 1989, the NCTM presented guidelines for mathematics instruction for school age children that stressed the inclusion of manipulatives and technology at the cost of the importance of memorization through repetition, and as a result, several policies and reports were drafted that addressed the need to bolster mathematics education and reform (Woodward, 2004). Discontent with traditional approaches to mathematics education along with publication of the Secretary's Commission on Achieving Necessary Skills SCANS report (1991) incited a new vision of instructional models that would help convert the United States from a postindustrial to an information economy. A new era rich with technology would call for a workforce with the necessary skills to compete in a global economy.

Legislation

The underpinnings of NCLB may well have their basic foundations in the 1983 release of *A Nation at Risk.* This report epitomized prior demands for the improvement of educational standards, outlined the current state of education when compared to other industrialized countries, and called for an elevation of expectations among teachers and students that would help provide these students with the skills necessary to compete for and secure jobs in the 21st century.

> Our nation is at risk. Our once unchallenged pre-eminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world…We report to the American people that … the educational foundations of our society are…being eroded by a rising tide of mediocrity that

> threatens our very culture as a nation and a people. What was unimaginable a generation ago has begun to occur – others are matching and surpassing our educational attainments. (National Commission on Excellence in Education, 1983, p. 5)

According to research, the shift towards accountability for outcomes as well as progress monitoring of students has transpired since the early 1960s (McDonnell, 2005) when the Elementary and Secondary Education Act's (ESEA) Title I program, as part of Lyndon Johnson's Great Society program, was enacted to help equalize the opportunities for students from high-poverty schools with their peers in schools not suffering from extreme poverty (Mills, 2008). The Title I program continued to survive reauthorization through the Clinton administration when Congress passed the Improving America's Schools Act (IASA), which was intended to shift some of the responsibilities of education policy into the hands of local school boards and state departments of education (Mills, 2008). This move laid the additional groundwork that enabled Ted Kennedy and George W. Bush to ratify major reform, Public Law 107-110, known widely as the No Child Left Behind Act in 2001 (Verbruggen, 2012).

No Child Left Behind is founded upon four pillars that address (a) the need for stronger accountability for greater outcomes, (b) more flexibility in how states and communities spend federal funds designated for education, (c) enhanced choices for parents in regards to school choice, and (d) proven scientific based research methods (U. S. Department of Education, 2004).

Stronger accountability. The intent behind the first of the four pillars for more stringent accountability standards is aimed at narrowing the achievement gap in an effort to ensure that all students achieve academic proficiency. Schools are required to demonstrate adequate yearly progress (AYP) as measured by standardized test results of their students. These goals as well as other indicators such as attendance or graduation rate—these vary among systems—are considered to determine whether or not a school has made AYP. As a requirement to make AYP, 95% of students in subgroups must participate in standardized testing and they must meet or exceed test standards to demonstrate that the students are competent in the areas of math, reading, and language arts. AYP results about school progress are published in the form of district report cards, and schools that do no make AYP must offer additional services to their students to help the schools make AYP on subsequent tests, or these schools face additional reform measures (U. S. Department of Education, 2004).

Additional freedom for states and communities use of funds. The second pillar of NCLB permits unparalleled flexibility in how local districts can allocate up to 50% of federal formula grant funds. Districts are allowed to spend funds without seeking prior approval in order to meet the specific needs that may exist in their schools (U. S. Department of Education, 2004).

Enhanced choices for parents. The third pillar is one that affords additional options to the parents of students in low-performing schools. When schools fail to meet the state standards for no less than two consecutive years, parents may choose to transfer their children to another public or charter school within the district that is performing better. As part of this option, Title I funds will be utilized to provide transportation to and from alternate schools. If students from low-income families remain in low-performing schools and the school does not meet the required state standards for three years, then additional services such as tutoring and summer school are to be offered to those students. As a final option, parents of students attending a low-performing school can request a change of schools if the current school is in a dangerous locale or if the student has been a victim of a violent crime at the school (U. S. Department of Education, 2004).

Proven scientific-based research methods. The final of the four pillars places emphasis on identifying which methods, interventions, and practices are supported by scientific research. Research-based interventions and supports identified as those that enhance student academic achievement will be entitled to federal funds for implementation. This requirement to provide evidence-based instruction is also a component of the reauthorized Individuals with Disabilities Act of 2004 (IDEA; 2004). In 2004, when Congress reauthorized the Individuals with Disabilities Act (PL 108-446), the suggestion was made that states use Response to Intervention (RtI) as a means to both identify students with disabilities and provide the necessary layers of support for students with academic difficulties even though they may not be classified as having a disability (Gersten, et al., 2009). As the governing board for the provision of special education services, the IDEA Act placed renewed emphasis on services aimed at early intervention and required school districts to implement service delivery models that would focus on multi-tiered levels of support for struggling learners (Fletcher & Vaughn, 2009).

Response to Intervention (RtI)

In response to the overidentification and underidentification of students for special education services based on the discrepancy model as means for determination and the variations among states when defining this model, the RtI model emerged as an alternative to an antiquated “wait to fail” approach (Fletcher et al., 2002). RtI emphasizes both prevention and effective teaching practices that may lessen the over-identification of students as having a learning disability (Jimenez, 2010). Schools should provide targeted and systematic interventions to students precisely when the need becomes evident and not wait until academic deficits are severe enough that they will qualify for special education services (Buffman, Mattos, & Weber, 2010).

RtI is “a process of systematically integrating assessment and instruction to evaluate and address student needs through the use of research-based instructional practices” (Crawford & Ketterlin-Geller, 2008, p. 5). This multi-tiered model of delivery is used to provide varying layers of instructional interventions that vary in intensity and frequency depending upon the progress of the student (Fletcher & Vaughn, 2009). Regardless of whether states utilize a three-tier or four-tier model to guide the implementation process, all models should include the following core components: (a) a screening tool to identify students of concern, (b) multi-layered tiers for interventions, (c) research-based interventions and instructional strategies, (d) progress monitoring techniques to allow data-based decision making, (e) fidelity throughout the process, and (f) the involvement and support of parents (Lembke, Hampton, & Beyers, 2012; Shapiro, 2012).

Tiers of intervention. Georgia’s four-tiered Pyramid of Intervention (see Figure 1) begins with all students in Tier 1 receiving effective differentiated classroom instruction that is rigorous and founded upon standards-based grade-level curriculum. For students who need additional instruction or acceleration, extended time for practice, and the support of smaller groups, there is a second tier. Research by D’Agostino and Murphy (2004) support the benefits of small group instruction when students are working towards mastery of basic skills. The movement between the first two tiers is fluid with a reasonable amount of time allowed to determine whether or not progression to the next tier is warranted (Georgia Department of Education, 2008). The second tier is for the application of pre-planned, layered supplemental instruction or interventions for one to two hours a week in 20-40 minute segments. Progress monitoring is extremely important at this level of support so data-based determinations can be made as to the benefit of the instruction or intervention and whether students in this tier are progressing. According to Gersten et al. (2009), "Student responses to intervention are measured to determine whether they have made adequate progress and: (a) no longer need intervention, (b) continue to need some intervention, or (c) need more intensive intervention" (p. 4).

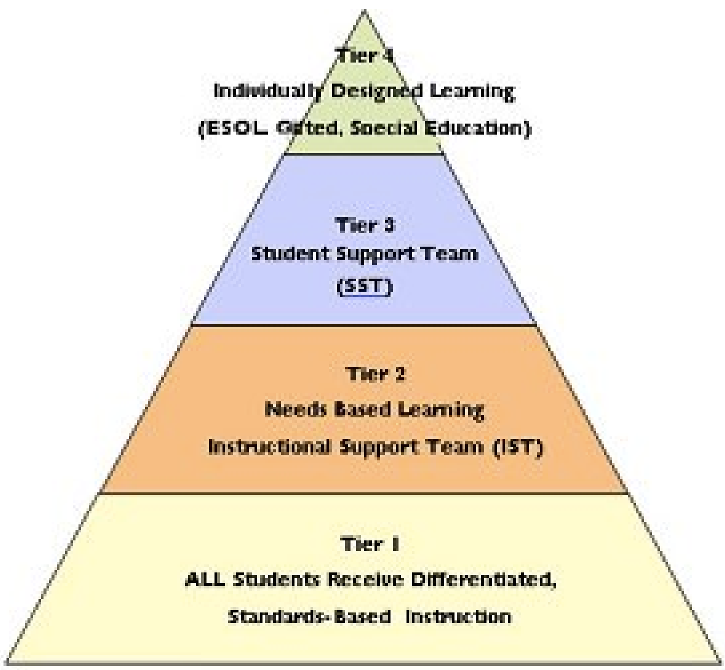

Figure 1. Georgia Department of Education Pyramid of Intervention. All rights in and to the material in this image belong to the Georgia Department of Education. Permission to reproduce here has been granted (see Appendix K), but no other form of reproduction beyond this dissertation is permitted without acquiring permission from the Georgia Department of Education.

When students need more intensive intervention than those available in Tier 2, they will move on to Tier 3 support in addition to Tiers 1 and 2. RtI guidelines for the state of Georgia report that:

tier three is a unique individual, diagnostic, data driven instructional problem

> solving process where the question about a student expands to include the why as well as the what. This is the point where specialists (school psychologists, intervention specialists, behavior specialists, counselors, social workers, speech-language pathologists, etc.) participate in the problem solving process if they have not already been involved at Tiers 1 and 2. (Georgia Department of Education, 2008, p. 45)

Tier 3 is driven by a student support team and requires an intensified use of research-based interventions to meet the individual needs of the student and can be done by increasing the duration and frequency with which the interventions are applied as well as reducing the student-teacher ratio (Mellard, 2004). A problem-solving approach is needed because students at this level often have a myriad of complex needs (Buffman, Mattos, & Weber, 2010). Progress monitoring continues but is done more frequently, and the intent is to provide specific feedback as to the effectiveness of individualized interventions that are being utilized. According to Sornson, Frost, and Burns (2005), "When all students have guaranteed access to rigorous curriculum and effective initial teaching, targeted and timely supplemental support, and personalized intensive support from highly trained educators, few will experience failure" (p. 28).

For students who continue to exhibit impediments to learning despite support at each tier, a Section 504 eligibility may be in order, and the team must consider whether or not the student is experiencing internal factors that may be the cause of their limited academic progress. If a 504 eligibility placement with its specialized modifications and accommodations are still inadequate for meeting the academic and or emotional needs of the student, a special education referral may be initiated.

Once students are identified as having a disability that qualifies them for special education services, they transition to Tier 4 and receive specially designed instruction along with benefits from Tiers 1, 2, and 3. These students will benefit from specialized programs, research-based and data-driven methods of instruction and modes of delivery, and an Individualized Education Program (IEP) for the student will be created (Georgia Department of Education, 2008).

Evidence-based instruction and intervention. The "child find" provision portion of Public Law (P.L.) 94-142, the Education of All Handicapped Children Act, requires that teachers strive to recognize students who need additional assistance and then find instructional methods or interventions that would promote achievement (Newman-Gonchar, Clarke, & Gersten, 2009). The curriculum and mode of instruction are adapted or modified so that students receive quality instruction that is based on research (NASDSE, 2006). In order to determine whether progress is made within the tiered delivery RtI model, effective research-based interventions need to be included and determinations made as to which interventions are most beneficial, produce the greatest results, and for which students. Only then can educated decisions be made that will provide additional layers of support for students in need or determine the appropriate level of help that is most beneficial for individual students. With the limited research on effective math interventions, it seems as though most states have not thoroughly explored the need or application of research-based interventions across the tiers of intervention (e.g. Baker, Gersten, & Lee, 2002; Berkeley, Bender, Peaster & Saunders, 2009; Fletcher & Vaughn, 2009; Newman-Gonchar et al., 2009).

Screening and progress monitoring. Universal screening of all students is a main component of the RtI process. Research-based screening is administered to identify students that may be at-risk for academic failure so that early interventions can be applied (U. S. Department of Education, 2009). The screening instrument may be norm- or criterion-referenced but needs to be as sensitive and specific as possible in order to prevent the overidentification of students that may label them at-risk and subject them to additional layers of instructional interventions and routine progress monitoring when it is not needed (Fletcher, Lyon, Fuch, & Barnes, 2007). Curriculum-based measurements are commonly used because they are readily available, quick to administer, easy to interpret, and can provide immediate evidence of instructional deficits (Fuchs, Deno, & Mirken, 1984). Once screened and grouped according to academic or behavioral needs, routinely assessing the progress of students who are receiving additional instruction with outcome- and curriculum-based measures provides teachers with the data needed to make instructional changes to support supplemental instruction (U. S. Department of Education, 2009). It is suggested that progress should be monitored no less that once a month with general outcome-based measures (Lembke, Hampton, & Byers, 2012). This data is used to move students among the tiers of support as dictated by evidence, to regroup students based on instructional needs, and is the best way to make sure that students are receiving specific instructional interventions tailored to their specific needs (Crawford & Ketterlin-Geller, 2008). The intensity and frequency of progress monitoring increases as students move through the tiers of the intervention pyramid until their needs are met and adequate achievement is made or they are recommended for special education services.

Math Fact Recall

A 2008 report from the National Mathematics Advisory Panel (NMAP) revealed that many children living in the United States were unable to solve basic single-digit math problems as quickly and accurately as their foreign contemporaries. This lack of automaticity makes is difficult for students to understand and make connections among foundational math concepts and limits their access to grade level curriculum, especially when it includes more challenging problem-solving tasks (Gersten et al., 2009). The ability to fluently compute basic math facts is also a critical math developmental skill needed for independent living (Patton, Cronin, Bassett, & Koppel, 1997) as well as economic success. With the recent national focus on improving the educational system as a whole with a particular focus on math, the National Mathematics Advisory Panel (2008), Common Core State Standards Initiative (2010), and National Council of Teachers of Mathematics (2006) came to the consensus that the automaticity of math facts was a foundational math skill needed to access more advanced levels of learning. According to Gersten et al. (2009), "The weak ability to retrieve arithmetic facts is likely to impede understanding of concepts students encounter with rational numbers" (p. 37) as well as limit the ability to estimate and perform mental computations. In fact, the ability to rapidly recall math facts has been shown to be an indicator of mathematics achievement performance. Since math tasks become increasingly complex as students transition to higher grades, advanced levels of math competency are required for this technology-based world or opportunities for advancement may dissipate. Societal, economic, and academic achievement rests firmly on a sound mathematical foundation. Proof that mathematics achievement is directly related to automaticity of math facts would shed light on causes of and early indicators for those students who experience math difficulties and thus provide valuable information that educators could use to design and implement effective interventions for students struggling for automaticity.

Many researchers are in general agreement that the learning of math facts evolves through the several stages. The first stage, or the procedural stage, focuses on learning strategies for figuring out the answers to various math facts and requires an understanding of the procedures involved with learning math facts (Garnett, 1992; Hasselbring, Lott, & Zydney, 2006). It is during this stage that students begin to experience difficulty with basic counting skills that will impact the automaticity of math facts (Geary, 1994). The second stage, generally coined the conceptual stage, includes emphasis on approaches for remembering the facts that have been learned through strategies such as fact families, linking of similar facts, and the commutative property, with the end goal of accuracy (Garnett, 1992; Hasselbring, Lott, & Zydney, 2006). It is during this stage that practice opportunities should be enhanced. The final stage, declarative knowledge, is one in which mastery, overlearning, or automaticity is achieved and when the student can recall math facts effortlessly and unconsciously without distraction. This stage of math facts acquisition has received very little attention from researchers although math fact practice using a small number of facts at a time has been successful. It has been suggested "greater fluency can be achieved when the instructional load is limited to only a few new facts interspersed with a review of other fluent facts (Cooke et al., 1993, p. 222).

Fluency. Math fact fluency is defined as the ability to accurately and quickly recall basic addition, subtraction, multiplication, and division facts (e.g. McCallum, Skinner, Turner, & Saecker, 2006; Poncy, Skinner, & Jaspers, 2006). It is generally calculated by digits correct per minute (dcpm) or problems per minute (ppm) for a specific set of facts and is also referred to as mental chronometry, the measurement of speed with which a given fact can be recalled (Cholmsky, 2011). A student is considered fluent when he or she can provide a correct answer to a basic math fact problem in two seconds or less, and these students tend to have greater cognitive resources available to learn more complex concepts (McCallum, et al., 2006; Poncy, et al., 2006). These students also understand the concepts involved with the four basic math operations and have strategies that help them solve math problems when needed (Frawley, 2012), and when these strategies are routinely practiced, automaticity occurs. Unfortunately, "if basic multiplication facts are not acquired during the primary school years, it is highly unlikely they will be practiced in a structured manner in secondary school" (Wong & Evans, 2007, p. 89) and without the ability to recall math facts, working memory is overworked with the easiest of mathematical problems.

Among some of the recent technological interventions that address fluency and automaticity of math facts, Math Facts in a Flash and SkillsTutor have reported positive results. Research regarding the effectiveness of Math Facts in a Flash as a computer-delivered math fact intervention for students at risk for mathematics achievement reported large gain scores as well as a reduction in the number of these students who continued to need services for at-risk performance when used for an average of three times a week for eight to fifteen weeks (Burns, Kanive, & DeGrande, 2012). Additional support was provided with a study conducted by Ysseldyke and colleagues (2005) in which a computer-based intervention to enhance math fact fluency improved the fluency performance among students who received the interventions in contrast to those who did not. Another frequently used online tool to enhance math fact automaticity is SkillsTutor Math Fact Fluency. Pre-test and post-test scores for 273 students reported a 41% gain in fluency during the 2010-2011 school year when used for approximately two hours per week (Stebbins, 2012).

Automaticity. Automaticity is evident when the ability to recall basic math facts with speed and accuracy can be done with no deliberate effort (e.g. Baroody, Bajwa, & Eiland, 2009; Poncy et al., 2006; Woodward, 2006). The answer must come as a result of direct retrieval rather than relying on a procedure that was learned during the initial stage of learning math facts because relying on procedures requires mental effort that in turn impedes solving the problem in which the fact is included (Crawford, 2002). Research suggests that when students respond in less than one second (400 to 900 milliseconds) they are considered to possess automaticity of a particular math fact (Crawford, 2007). Research by Miller and Heyward (1992) reported that

> students who are able to computer basic facts at a rate of 30-40 problems correct per minute continue to accelerate their rates as tasks in the math curriculum become more complex… [However] students whose correct rates were lower than 30 per minute showed progressively decelerating trends when more complex skills were introduced (p. 100).

Though there is a general agreement on the importance of math fact automaticity, there is a lack of consensus as to the exact grade level at which it should be demonstrated. The National Mathematics Advisory Panel (2008) feels as though automaticity for basic addition and subtraction facts should be exhibited at the end of the third grade. The Common Core State Standards Initiative (2010) suggests automaticity of basic addition facts by the end of second grade with the ultimate goal of automaticity for basic math facts for all four math operations, including multi-digit numbers no later than the end of fifth grade (Stickney, Sharp, & Kenyon, 2012). Some literature even indicates that at-risk children may learn math facts more effectively at more advanced ages than is generally expected (Campbell, 2005). Regardless of the grade level at which the automatic recall of math facts should be demonstrated, the fact is that children who are at risk for mathematical difficulties or who have math disabilities exhibit fact-retrieval deficits throughout their elementary years (Olstad, 1998) only for these deficits to be compounded with the introduction of multi-step complex operations that are part of the middle school math curriculum.

The ability to respond accurately, quickly, and automatically has advantages such as the ability to finish more complex content (Skinner, Fletcher, & Hennington, 1996) and obtain higher scores on advanced achievement tests (Skiba, Magnusson, Marston, & Erikson, 1986). Students with automaticity also maintain levels of proficiency over longer periods of time (Singer-Dudek & Greer, 2005), are more able to apply their proficiency to more advanced tasks (VanDerHeyden & Burns, 2008), and exhibit lower anxiety levels when compared to at-risk students with automaticity deficits (Cates & Rhymer, 2003). One of the essential ingredients for the development of automaticity is the need for repeated practice of learned facts, or "overlearning" (Moors & DeHouer, 2006).

Educational Technology

With the extensive access to computers in schools today, it is critical that teachers are aware of the options available in educational technology and understand which programs provide the greatest benefit to students (Duhon, House, & Stinnett, 2012). Computers and the Internet provide alternative and innovative modes of delivering mathematics instruction that may enhance academic achievement (Roblyer & Doering, 2009). There are many benefits of using educational technology that include individualized instruction with instantaneous feedback, specific skills instruction, convenient progress monitoring, and improved achievement (Duhon, House, & Stinnett, 2012).

Technology-driven curriculum changes have added new interest to some otherwise mundane tasks such as mastering math facts with research that supports increased levels of achievement. Some of the improvement in academics may be attributed to the increased levels of motivation among some hesitant learners (Chang, Chen, & Huang, 2008). Historically, at-risk students are less motivated to try mathematical problems and, as a result, experience heightened levels of anxiety that hinder mathematical progress (Ashcraft, 2002).

Even with the advances and opportunities of educational technology and a promising outlook in regards to learning outcomes, there are concerns and limitations regarding the educational use of technology (Egenfeldt-Nielsen, 2007). Though much data supports the use of classroom technology to improve academic performance (Cates, 2005), the training and support for teachers who are implementing the technology is often as important as the technological intervention itself. Regardless of whether the intent is training or learning, recent reviews espouse the potential of computer-assisted instruction (CAI) to serve as a tool to teach math content, provide interactive exposure to learning materials, and boost feelings and motivation towards mathematics (Van Eck & Dempsey, 2002). Improved motivation as a result of technology may further engage students who may otherwise be disinterested learners. Technology may also support and accommodate for the needs of at-risk students while increasing student achievement (Traynor, 2003) and promote motor, intellectual, affective, and social development (Gros, 2003) with benefits for mainstream students as well as those with disabilities.

Computer-assisted instruction. At the outset of computer-assisted instruction (CAI), the emphasis was on drill and practice, tutoring, or the testing of students, but it has since evolved (Kulik & Kulik, 1991). With the accessibility of computers by the majority of U.S. students, CAI now has the potential for enhancing initial math instruction (Roblyer & Doering, 2009) through a variety of visual approaches (Mahmood, 2006) both in school and at home. Current trends support the benefits of CAI on learning for all students and particularly those who are at-risk for academic achievement in mathematics, though proof continues to be limited in its scope in regards to studies that involve middle school students and that meet the federal definition of scientifically-based research (Tienken & Maher, 2008). A recent meta-analysis reported large effect sizes for computer-assisted mathematics instruction that addressed basic math computation skills (Slavin & Lake, 2008), and prior studies found that CAI improved math performance and enhanced specific skills (e.g. Hannafin & Foshay, 2008; Holmes, et al., 2006; Springer, et al., 2007; Ysseldyke et al., 2005). In addition, Tienken and Wilson (2008) reported that CAI drill and practice improved computational problems included on the McGraw Hill TerraNova full battery mathematics test for seventh grade students.

Important among the commonly identified computer software delivery methods is drill and practice. The intent of this mode of addressing academic achievement is to assist with the memory of isolated facts (Roblyer & Doering, 2009). For students who are at-risk for academic performance in mathematics, computer assisted instruction and interventions must target specific deficiencies to be effective (Burns, VanDerHeyden, & Boice, 2008). Interventions that address fluency through repeated practice are essential since at-risk students routinely struggle with math fact recall and fluency (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007). In addition, Traynor (2003) reported that students with disabilities showed an improvement in mathematics achievement when CAI was used instead of traditional mathematics instructional techniques. Research in math fluency interventions that address students who have difficulties learning report that these students remember and generalize math facts and approach levels of automaticity commensurate with their age peers (Burns, 2005).

Gender and CAI. When used in conjunction with traditional classroom instruction, enhanced levels of mathematical performance are reported with a disparity of results in regards to gender differences (Mahmood, 2006). According to Bontempi and Warden-Hazlewood (2003), the key influences of gender in regards to CAI include (a) math anxiety, (b) the social connections among students and families, and (c) gender bias of software interventions and programs. Additionally, some researchers found that more males than females prefer technology for learning and play, and both genders tend to think that computers and video games suit males the best (Cooper, 2006).

Research suggests gender differences math anxiety regarding CAI due in part to male dominated courses taught with computers and about educational technology (Bontempi & Warden-Hazelwood (2003). Historically, influential adults who can either perpetuate confidence or the lack thereof mold attitudes towards education, ability, and possibilities. Further shaping occurs as a result of the majority of computer games being purchased for males and dominated by male characters. Males tend to have more positive attitudes towards the use of computers, and this stimulates their motivation towards and engagement in CAI opportunities (Bontempi & Warden-Hazelwood, 2003) while decreasing motivation and engagement among females.

Edutainment. "Play is a very serious matter… It is an expression of our creativity; and creativity is at the very root of our ability to learn, to cope, and to become whatever we may be" (Rogers & Sharapan, 1994, p. 13). According to Buckingham and Scanlon (2008), *edutainment* is an interactive pedagogy composed of vast amounts of colorful animation intended to hold the attention of the learner. Edutainment is a category of educational computer games founded on learning theories supported by behaviorism and cognitivism (Egenfelt-Nielsen, 2007) and is based upon the notion that learning can be fun, and when this is so, learning is enhanced. Children who are having fun are more relaxed, energetic, attentive, receptive, less apprehensive, and more likely to learn (Baranich & Currie, 2004). These games most likely teach children something but are more focused on the training aspect of education and not teaching the player skills or content, and as a result, memorization rather than deep understanding will occur (Egenfeldt-Nielsen, 2007). The benefits of edutainment are that these games are relatively inexpensive to produce, do not require any guidance, and require minimal intrinsic motivation. The limitations include a lack of integration between the learning and playing experience, as well as being composed of primarily simple drill-and-practice training. One concern over the use of material deemed “edutainment” is that the interest and motivation exhibited by the student may be focused on the computer game itself and not knowledge acquisition since a characteristic of the game format relies on extrinsic motivation through a clearly identifiable reward structure (Egenfelt-Nielsen, 2007). Yet with their limitations, edutainment games can be useful tools for the right tasks.

Game-assisted learning. In an attempt to improve education, effective learning standards woven into engaging game environments are expanding the practices of education (Cameron, 2008) with game-assisted learning rapidly transpiring into one of the most widely touted approaches for educational instruction (Wu et al., 2012). Research results indicate that students who participate in game-assisted learning exhibited improved rates of retention, and this mode of learning stimulates chemical changes within the brain that precede the memory storage process that enhances learning (Jovanovic et al., 2008).

According to Klopfer, Osterweil, and Salen (2009), a game is structured play with steps that must be followed in order to obtain the goal. It is believed that when games rely on an action format as opposed to an explanatory one, learning and performance may be enhanced or assisted (Coller & Scott, 2009; Kebritchi & Hirumi, 2008; Pasin & Giroux, 2011). Game-assisted learning seeks to advance students’ engagement in both learning and motivation, has become an influential approach to assisted instruction, and is defined by Cameron (2008) as “the outcome of integrating effective learning principles into game environments for the purpose of utilizing engaging elements as a means for improving the quality of education” (p. 8). It has become an important movement in education and has drawn the attention of researchers (Annetta, Minogue, Holmes, & Cheng, 2009; Huang, Huang, & Tschopp, 2010; Wu, Chiou, Kao, Hu, & Huang, 2012). Initial research results dating back to the 1960s and 1980s were limited and suggested "game assisted learning was found to encourage exploration of new skills, promote self-esteem, help develop practice skills and improve attitudes toward learning" but was not necessarily the favored method of instruction (Wu et al., 2012, p. 1154).

A recent meta-analysis examined the influence of current learning theories that may play a role in the wave of attention that is currently being placed on using computer games for learning (Wu et al., 2012). This current literature review suggests that game-assisted learning should include games that enhance learning, be based in an environment that integrates effective learning philosophies and interactivity among the player and the game, are fun as well as motivational, and allow the opportunities to learn by making mistakes (Wu et al., 2012). Additional research supports the notion that games and interactive learning opportunities produce greater gains in cognition (Vogel et al., 2006) and that the best results will be obtained when the student, the information to be learned, and the design of the game are carefully assimilated (Ke, 2009).

Reflex math. As a new generation of fluency preparedness, Reflex is a computerized learning option that facilitates math fact recall in addition, subtraction, multiplication, and division. The Reflex math computerized intervention is based on the Cover, Copy, and Compare (CCC) procedure to address the accuracy of basic math facts recall. The original intent for CCC was to improve spelling accuracy (Hanson, 1978) and was then adapted by C. Skinner and associates to address accuracy of basic math facts recall (Skinner, Turco, Beatty, & Rasavage, 1989). According to Paul Cholmsky, Vice President of Research and Development with

ExploreLearning, Reflex assesses and tracks math fluency, measures response speed, and continuously adjusts instruction to align with progress (Cholmsky, 2012). Students gain math fact fluency via online games that reward the acquisition of facts while providing informative reports that teachers can use to track performance and usage (Cholmsky, 2011). Guided by research on automaticity, Reflex (a) introduces students to small sets of facts using common strategies, (b) provides opportunity for the students to become proficient with recalling newly learned facts, (c) introduces a timed component and regulates the complexity of the facts, and (d) ends each session with game-based practice (Cholmsky, 2011). It also individualizes progress, provides visible and continuous growth of math fact mastery, and delivers immediate feedback while ensuring a differentiated customization of content and method specifically tailored to the needs of each student, thereby encouraging success for all (Cholmsky, 2011).

Supported by additional research by Logan and Klapp (1991) and based upon the assumption that memory is the reason for limited automaticity, it was purported that facts learned in small groups would allow for the development of automaticity. Logan and Klapp (1991a) suggested "automaticity can be attained very quickly if there is not much to be learned. Even if there is much to be learned, parts of it can be automatized quickly if they are trained in isolation (p. 193). Along with small groups of facts, a review of the literature suggests that basic facts may be best learned by the following: timed-practice, the formation of concepts, and a combination of timed-practice and interventions associated with abstract concept development with the combination approach receiving the greatest affirmation.

The foundation upon which the Reflex math computerized intervention was built includes the notion that by developing the automaticity of math facts, cognitive memory becomes available that can be used to approach more complex math tasks. In order to commit learned facts to memory, extended practice or overlearning is needed (Willingham, 2004). In addition to the importance of freeing up of cognitive memory, Reflex is also built upon the need to improve processing speed to the point of automaticity when conscious effort is no longer needed to recall math facts. Rapid fact recall not only improves automaticity but also "predicts performance on math concept problems, word problems, data interpretation problems, and mathematical reasoning items" (Cholmsky, 2011, p. 3).

Math Differences Based on Gender

The notion that boys are better than girls at mathematics is a commonly disputed topic yet one that remains of paramount concern in light of the underrepresentation of women in positions of authority in science, technology, mathematics, and engineering (STEM) fields (Ceci & Williams, 2010; Halpern et al., 2007; National Science Foundation, 2011; Wang, Eccles, & Kenny, 2013). According to high school graduation rates, the reduction of the gender gap in formal education has been noteworthy for countries included in the Organization for Economic Co-operation and Development (OECD, 2004b), yet college graduation statistics indicate that only 30% of those who obtain mathematics and science degrees are women (OECD, 2004b). Although the number of females employed in the fields of science has increased, they continue to lag behind their male counterparts in jobs that require rigorous use of mathematical skills with explanations for this disparity related to differences in spatial ability, discrimination in regards to hiring, publishing, and funding, as well as the predilections of women (Ceci & Williams, 2010). Wang, Eccles, and Kenny (2013) conducted a longitudinal study that suggested it may not be the lack of math ability that deters females from seeking STEM occupations, but it may be the fact that females with high math abilities have correspondingly high verbal abilities and may simply choose non-STEM jobs because their options are greater.

Historical trends. According to a meta-analysis conducted in the 1990s, gender differences in mathematics were on a downward trend for children in the United States (Hyde, Fennema, & Lamon, 1990) and results from the Trends in International Mathematics and Science Study (TIMSS) from 1995-2003 reported no significant differences in overall math performance between girls and boys (Neuschmidt, Barth, & Hastedt, 2008). However, in 2005, girls fell behind boys by three points in mathematics on the National Assessment of Educational Progress (NAEP) assessment and as recently as 2009, according to the Program for International Student Assessment (PISA), test results indicate that middle school boys continue to outperform girls in most mathematic domains (OECD, 2010). Although the focus for these assessments varies—TIMSS assesses mathematics curriculum learned and PISA assesses mathematics literacy—there remains an overall concern for an assurance of gender equity (Else-Quest, Hyde, & Linn, 2010).

Theories. Assumptions abound regarding theories that address possible math differences based on gender. Some of the proposed differences that are most often researched include spatial abilities (e.g. Geary, 1996; Geary, Saults, Liu, & Hoard, 2000; Halpern, 2004), social and motivational factors (e.g. Eccles, 1994; Hyde, Fennema, & Lamon, 1990), and computational fluency (e.g. Carr, Steiner, Kyser, & Biddlecomb, 2008; Geary et al., 2000).

Some research indicates that boys may have advantages over girls in spatial cognition (three-dimensional shapes and diagrams) and that this advantage is a precursor to success with problem solving approaches to complex math operations that include arithmetic reasoning (Carr, et al., 2008; Geary et al., 2000). The controversy over whether or not boys truly have advantages over girls in regards to spatial cognition is currently being debated, yet according to an analysis of academic achievement, boys performed better than girls in the United States in first and fifth grades on mathematics subtests assessing word problems and visualization (Geary et al., 2000).

In addition to the impact that spatial cognition may have on gender differences in mathematics, social and motivational factors, including confidence, are thought to interfere with girls' participation in math classes, with most of the research addressing middle and high school girls (Hyde, Fennema, Ryan, Frost, & Hopp, 1990). Although research suggests that most gender differences associated with social and emotional factors materialize in middle grades and high school, these factors may be more apparent in the elementary years of education than previously thought and emerge as predictors of early gender differences in mathematics achievement (Carr et al., 2008). As early as first grade, boys tend to believe that they are more capable than girls (Hyde, Fennema, & Lamon, 1990; Wigfield & Eccles, 1994).

A final significant factor related to possible differences in math abilities and/or achievement among boys and girls is that of automaticity. One side of the automaticity debate is supported by Royer, Tronsky, Chan, Jackson, and Marchant (1999) who professed that the ability to accurately and fluently recall basic math facts from long-term memory is the fundamental explanation for the mathematical advantages that some boys tend to have over girls. The alternate side of the debate focuses on research that asserts the advantage that girls have when posed with tasks that require the quick and correct recall of math facts. This hypothetical advantage is due in part to the fact that girls tend to be more proficient with verbal processing, which aids in retrieval of data from their long-term memory (Halpern, 2004). Geist and King (2008) strongly supported this notion and assert that "girls tend to be the storehouse of knowledge, while boys are more comfortable at applying the knowledge" (p. 47). Regardless of which side of the debate one chooses to espouse, what is known is that the automaticity of math facts is a critical component of mathematics education, and evidence of basic differences between girls and boys are apparent as early as first grade. Continued research needs to determine whether or not these differences progress into the middle school and high school years (Carr et al., 2008).

Summary

As required by NCLB in 2001 and the reauthorization of the IDEA Act in 2004, states are mandated to hold students to high levels of accountability and thus will be tested to ensure academic achievement for all students in the areas of reading, language arts, and math by 2014. As a way to promote achievement and monitor progress of all students and to aid in the identification of students with disabilities, states were encouraged to implement a tiered Response to Intervention model using evidence-based interventions to help students with the greatest needs.

One of the most significant mathematical needs of students is the ability to automatically recall math facts. Many children in the United States never achieve mathematical fluency (NMAP, 2008). Among those who do, it is generally demonstrated at an age older than grade level peers in nations whose performance levels in math are superior (Gersten et al, 2009; NMAP, 2008). Not only does the speed and accuracy at which a child recalls math facts predict academic performance in regards to computation, it also provides information concerning proficiency on word problems, data interpretation, and reasoning skills (Cholmsky, 2011). Classrooms in the 21st century need efficient methods and strategies for math fact instruction as well as effective means for the practicing of these facts until automaticity is achieved. Differentiation for the varying levels of fluency within a classroom, the ability levels and interests of the students, and the learning styles among them should be taken into account. Dismal mathematics achievement among many middle school students coupled with the need for math fact automaticity to improve achievement needs the focus and attention of educators and researchers.

The need to address the automaticity of math facts, supported by recommendations of the National Math Advisory Panel's Final Report (2008), suggests that using computer-based interventions and strategies could help address some of the mathematical deficits that are affecting middle school students. Therefore, Reflex math is a possible solution. With its focus on acquisition to automaticity, this computer based adaptive system assesses fluency, measures response speed, and tracks fluency development, all while altering instruction and practice (Cholmsky, 2012). Research may support the effectiveness of this instructional intervention for students requiring the additional support provided in Tiers 2 and 3 of the RtI pyramid and help minimize the achievement gap as well as lessen the number of special education referrals.

Also important in the context of this study is the continued focus on research indicating that boys still outperform girls in many areas of mathematics (e.g. Else-Quest, Hyde, & Linn, 2010; Juvonen, 2004; OECD 2010). The potential gender gap and its complications impact the math achievement of all students in general and at-risk students specifically (Jacob & Rockoff, 2011) and therefore needs further exploration to determine whether or not the Reflex math computerized intervention is a beneficial solution to address math automaticity and what if any role gender may play in math achievement.

CHAPTER THREE: METHODOLOGY

The purpose of this study was to determine if the use of the Reflex math computerized intervention would significantly increase math automaticity of at-risk male and female north Georgia middle school students. The following methodology chapter includes a description of research design, research questions and their corresponding hypotheses, participants, setting, instruments, as well as the procedures used for collecting and analyzing data.

Design

A quasi-experimental pretest-posttest nonequivalent control group research design was used for the purposes of this study because random assignment was not possible, and a pretest and posttest was administered. According to Gall, Gall, and Borg (2007), this type of design is useful when random assignment is not possible because it can still provide useful information if carefully planned. Each grade level in the middle school had an experimental and control group comprised of students willing to take part in the study who had previously been identified as those requiring additional math interventions and receiving services in Tiers 1 through 4 of the Response to Intervention (RtI) pyramid. The experimental group received Reflex math computerized intervention as a RtI strategy to improve the automaticity of basic math facts while the control group engaged in other assignments aimed at addressing math deficits but not specifically the automaticity of math facts. A posttest determined differences in mean scores between the experimental group who received the treatment and the control group who did not receive the treatment while a pretest was used as a statistical control.

Research Questions

The following were the research questions for the study:

RQ1: Is there a statistically significant difference in Basic Math Operations

Task scores between at-risk students who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk students who receive traditional Response to Intervention instruction while controlling for student prior knowledge?

RQ2: Is there a statistically significant difference in Basic Math Operations Task scores between at-risk males who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk males who receive traditional Response to Intervention instruction while controlling for student prior knowledge?

RQ3: Is there a statistically significant difference in Basic Math Operations Task scores between at-risk females who receive Reflex math computerized instruction as a Response to Intervention strategy and at-risk females who receive traditional Response to Intervention instruction while controlling for student prior knowledge?

Null Hypotheses

The null hypotheses were as follows:

H_{o1}: There is no statistically significant difference in Basic Math Operations Task scores between at-risk students who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk students who receive traditional Response to Intervention instruction while controlling for previous knowledge.

H_{o2}: There is no statistically significant difference in Basic Math Operations Task scores between at-risk males who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk males who receive traditional Response to Intervention instruction while controlling for previous knowledge.

$H_{o3:}$ There is no statistically significant difference in Basic Math Operations Task scores between at-risk females who receive Reflex math computerized intervention as a

Response to Intervention strategy and at-risk females who receive traditional Response to Intervention instruction while controlling for previous knowledge.

Participants

The accessible population included all middle school students who were enrolled in the north Georgia middle school that was the focus for the study during the 2013-2014 school year. The middle school served 643 students, of which 304 were female and 339 were male. The students were separated according to grade levels and teams within each grade level that consisted of content teachers for math, language arts, science, and social studies. The composition of the accessible population was predominantly Caucasian (94%), with 57% of the students eligible for free or reduced lunches, 14% of the students classified as students with disabilities, and less than 1% of students with limited English proficiency. A criterion sampling technique was used because the RtI remedial math groups used in the study existed prior to the study. Students previously identified as at-risk for math achievement for failing the CRCT based on the previous years test scores along with a computerized math assessment and already placed into RtI intervention groups or math support classes were invited to participate in the study. The pre-existing groups of students at each grade level that met the criteria for the study were assigned to either the group to receive the intervention or the control group. Of the students who agreed to participate, approximately 60% were economically disadvantaged, as identified by participation in the free or reduced lunch program, 99% were Caucasian, and approximately 30% were students with disabilities. In order to attain statistically significant results, the study needed approximately 32 girls and 32 boys for a total of 64 (N = 64), as the minimum number of participants for this design would be 64 at a .05 alpha level with a power of .80 in accordance with Cohen's *d* tables (Cohen, 1988).

Setting

The setting of this study was a school located in a small, rural, Title I school district in north Georgia. The local system consisted of separate schools for pre-kindergarten, primary, elementary, middle, and high school. The system also included a comprehensive school in a remote location and an alternative school that housed students from several neighboring counties. Except for one remote comprehensive school, all other system schools were located on the same tract of land. There were 41 teachers, all highly qualified, seven paraprofessionals, one counselor, and two administrators. Among the highly qualified content area teachers, 17 had reading endorsements, and 16 were certified to teach the gifted. Both the principal and assistant principal of the school were new to their positions. Among the county schools that participated in Criterion Referenced Competency Testing (CRCT), all have made Adequate Yearly Progress (AYP) each year since its implementation except for 2002 when the middle school failed to make AYP due to the math subtest scores for the students with disabilities subgroup. Based on the results of the previous years' CRCT, a computerized math assessment, and administrative decisions, RtI groups were developed to meet students' academic needs. Each middle school student was assigned to a group that was taught, guided, and monitored by a highly qualified teacher. The RtI and math support groups used for the purpose of the study were composed of students who qualified for math intervention due to low achievement. Each grade level, grades 6-8, had several math remediation groups from which participants were sought. The groups to which participants were assigned were created to address math deficits, and these groups were heterogeneously mixed and grouped according to grade level. Students remained in grade level groups, met in familiar classroom locations, and had familiar teachers for the entire school year. RtI groups for all middle school students met for intervention purposes four days per week for approximately 50 minutes. Additional math support classes met daily as electives for those who needed additional math support. It was during one of these times that the treatment as well as data collection took place. The treatment group went to the computer lab four days each week for a 20 minute long Reflex math computerized intervention session. The computer lab and its equipment were familiar to the students, and they were assigned seats for the purpose of this study. In a separate classroom, the control group received instruction, remediation, and practice on identified areas of difficulty to include all mathematical topics except fluency.

Instrumentation

The instrument that served as both the pretest and posttest for both the experimental and control groups was the Basic Math Operations Task (BMOT). The BMOT is an instrument designed to measure automaticity of basic math facts of whole numbers (0-9) for addition, subtraction, multiplication, and division in digits correct per minute (dcpm; Foegen & Deno, 2001). The BMOT was designed to determine students' accuracy and fluency in mental computation of whole number facts. Foegen and Deno (2001) reported that the BMOT was a reliable gauge of mathematics proficiency among middle school students, and Foegen (2008) conducted a study that documented the use of the BMOT as a curriculum-based measurement for progress monitoring. An RtI or remedial math teacher administered a one-minute probe to participants that was composed of 80 problems arranged randomly with 20 single-digit computations for each of the four basic operations: addition, subtraction, multiplication, and division. Two forms of the BMOT were developed, and the reliability on forms one and two were as follows: (a) internal consistency as measured by Cronbach's alpha was .92 and .91, respectively; (b) test-retest as computed by Pearson's *r* was .80 and .84, respectively; and (c) parallel forms also computed by Pearson's *r* was .79 and .80, respectively (Foegen & Deno, 2001). Each correlation was significant at $p < .01$. Criterion validity for the BMOT math computation subscale was .63, moderately significant at p <. 01. Though stronger evidence of validity is desired, these results were similar to those of many outcome-based measures used for middle school students.

Procedures

The Institutional Review Board (IRB) reviewed the IRB application and approved the research prior to the study's inception. Permission was obtained from the superintendent, assistant superintendent, and school administration to conduct the study within the school and among the population of students sought for the study (see Appendix A). Once permission was received, teachers with math RtI groups and the support math teacher were introduced to the study and then asked to participate (see Appendix B). After explaining the importance of the research to students in the RtI groups and support classes, consent forms to participate in the study were sent home to parents of all students in the math remediation groups. These forms provided the background, significance, and guidelines for the study, as well as procedures to ensure the anonymity of student names and data (see Appendix C). Student assent forms were provided to the participants who return the signed parental consent form (see Appendix D). Two weeks were allowed for the return of all forms with incentives provided for speedy return and also for willingness to participate. Students who did not agree to participate in the study received regularly scheduled RtI services along with all other students in the school. Students who agreed to participate in the study were assigned to either receive the Reflex math computerized intervention as a treatment or not to receive the treatment. The groups of participants were physically separated in classrooms as far from each other as possible. Teachers for the experimental group who used the Reflex math computerized intervention strategy received training on the intervention, and then students were taught how to use the intervention (see Appendix E). All students participating in the study received an introduction to the testing procedures via administration guidelines (see Appendix F), and a sample probe was provided for demonstration purposes (see Appendix G). Students in both the treatment and control groups took the pretest (see Appendix H). Reflex math computerized intervention was utilized by the students assigned to the experimental group for 20 minute sessions four days per week for six weeks in the computer lab, and the control group received teacher generated lessons to address deficits in math computation and application for the same amount of time while remaining in the classroom. The control group lessons varied from teacher to teacher but did not include Reflex math computerized intervention or any other strategy aimed specifically at improving automaticity of math facts.

Initially, students in the treatment group met Crabby the Reflex guide and created their avatar. Each session began with the Speed Cube Challenge, a short assessment that determined the student's level of fluency. After the assessment was complete, students were taken to "Reflex Island," where they chose a game to play. It was during this phase of the session that students were taught new facts and families through a short study segment followed by practice time. Once they learned the facts, students interacted with facts they had previously learned and answered them repeatedly via fluency games of their choice. As participants used Reflex, they earned tokens for mastering math facts with fluency. A list of the procedures to follow during treatment session and directions for the securing of any documents and materials were provided to the teacher of the treatment group.

Over the course of six weeks, Reflex math was used by the treatment group during RtI time four days per week for 20 minute sessions because researchers found that the automaticity could be obtained in as few as 20 sessions (Cholmsky, 2011). During this same time frame, the control group along with all other RtI or math support students who were non-participants followed general RtI intervention guidelines that included practicing and reviewing concepts that aligned with classroom instruction and addressed academic deficits in math at each grade level all within the classroom. In the week following the conclusion of the strategy intervention, the posttest was administered on the same day for both treatment and control groups (see Appendix I). Data was collected and analyzed with Statistical Package for the Social Sciences (SPSS) software version 22.0.

Data Analysis

According to Gall, Gall, and Borg (2007), the initial procedure of data analysis was the computation of descriptive statistics so that the numerical data could be summarized and reported for each group in the study. Next, a one-way analysis of covariance (ANCOVA) was conducted to study the differences in mean math achievement scores between students receiving Reflex math computerized intervention and those in the control group not receiving the intervention while controlling for prior knowledge. ANCOVA was the analysis method of choice because the experiment lacked random assignment and the researcher needed to ascertain whether or not differences between the groups could be explained by some other difference between the groups, such as gender, and then control for initial differences between the groups being compared (Gall, Gall, & Borg, 2007). Basic Math Operations Task (BMOT) results were used as pretest scores and served as a statistical control since the difference between the intervention and control groups could differ in terms of math achievement prior to the study. Using the pretest scores as a covariate helped account for pre-existing differences in math automaticity. The BMOT posttest scores of all study participants served as the dependent variable. The treatment, Reflex math computerized intervention, and control, interventions other than Reflex math computerized intervention, served as the independent variable.

Additional one-way ANCOVAs were examined for differences in mean math achievement scores based on gender while controlling for prior student knowledge. BMOT pretests scores for automaticity served as the control variable, and posttest scores served as the dependent variable, with gender serving as the independent variable.

For all ANCOVAs, assumptions of normality were determined by creating histograms since the achievement results were continuous scores (Gall, Gall, & Borg, 2007). A Levene's test was conducted to test for homogeneity of variances in order to verify the assumption that variances among different samples were equal. Scatter plots for linearity and univariate tests were conducted to ensure the homogeneity of regression slopes. An alpha level of .05 was used to determine whether to reject the null hypotheses. One of the easiest ways to measure the magnitude of the effect size was through partial eta squared (Howell, 2011) and this was interpreted according to Cohen's *d* table of values (Cohen, 1988). This calculation was conducted via SPSS as part of the ANCOVA test.

CHAPTER FOUR: FINDINGS

The purpose of this study was to evaluate the effectiveness of the Reflex math computerized intervention on the automaticity of math facts among at-risk middle school students. Specifically, the study examined the differences in basic math fact automaticity scores for at-risk students who participated in the Reflex math computerized intervention to address math deficits and at-risk students who participated in a traditional program of interventions to address deficits. It was also the purpose of this study to examine the differences in basic math fact automaticity scores among at-risk males who did and did not use the Reflex math computerized intervention as well as at-risk females who did or did not use the computerized intervention.

Chapter four is arranged into four sections. Initially, the demographic data for the participants is provided. Next, an explanation for the testing of the hypotheses is detailed. This is followed by the results section which includes assumption testing followed by the results of an initial one-way analysis of covariance (ANCOVA) to analyze the differences in math fact scores of students who used the Reflex math computerized intervention to address deficits in math automaticity and those who received traditional math interventions. Two additional one-way ANCOVAs and their preliminary assumption testing were then conducted to examine the differences in basic math fact scores of at-risk males who did and did not receive the Reflex math computerized intervention as well as females who did and did not receive the Reflex math computerized intervention. The concluding section summarizes the results of the study.

Demographics

Eighty-nine at-risk students from a north Georgia middle school completed the study. All students were considered at-risk for academic achievement in math based upon failing or borderline scores on the previous year's Criterion Referenced Competency Test (CRCT) math subtest along with the results of a computerized math assessment administered at the beginning of the 2013-2014 school year. Of the 89 students who participated, 45 students served as the experimental group and used the Reflex math computerized intervention to address math deficits associated with automaticity. The remaining 44 received traditional interventions to address these deficits. Among the participants, there were 47 boys and 42 girls. There were 36 eighth grade students, 27 seventh grade students, and 26 sixth grade students who completed the study. One student was African American, three were Hispanic, and the remaining students were Caucasian with a proportionate representation among the experimental and control groups.

Testing the Hypotheses

Since students had already been identified as in need of additional math interventions and supports, a quasi-experimental pretest-posttest nonequivalent control group design was used for this study. When random assignment of participants is not possible due to existing groups from which participants will be sought, a quasi-experimental design can still provide useful information when planned carefully (Gall, Gall, & Borg, 2007). An analysis of covariance (ANCOVA) procedure was used to verify whether or not statistically significant differences existed in basic math fact scores between the different methods of intervention among all students and then in regard to gender. This procedure provided some degree of statistical control and a way to explain differences in the dependent variable because random assignment was not possible, and the pretest served as an extraneous variable or covariate that was related to the dependent variable (Mertler & Vanetta, 2005). The increased statistical power and control provided by an ANCOVA is only reliable when a good covariate is used. As detailed in the instrumentation section, reliability was confirmed through Cronbach's Alpha for internal consistency, Pearson's *r* for test-retest and parallel forms, and criterion validity for the Basic Math Operations Task (BMOT) math computation subscale.

The automaticity of math facts was measured before the treatment with the pretest, which served as the covariate. Automaticity was then measured after the treatment with the posttest, with these scores serving as the dependent variable. All analysis was done with the Statistical Package for the Social Sciences (SPSS) version 22.0 and an alpha level of .05.

Results

Hypothesis One

A one-way ANCOVA was conducted to determine if there was a statistically significant difference in mean scores on the Basic Math Operations Task (BMOT) for students who used the Reflex math computerized intervention and those who received traditional math interventions. The independent variable, method of intervention, consisted of either receiving Reflex math computerized intervention as a specific math intervention or receiving other traditional interventions instead of Reflex math. The BMOT posttest served as the dependent variable, and the BMOT pretest served as the covariate. Once ANCOVA adjusted the mean posttest scores that existed for any initial differences among the groups on the pretest, posttest scores were evaluated to determine the automaticity of math facts by the method of intervention.

Prior to statistical testing, assumptions underlying the ANCOVA were conducted and satisfied. The dependent variable, BMOT scores, were measured on a ratio scale and independent observations existed because the control and experimental groups. Histograms in Figure 2 and Figure 3 indicate that pretest and posttest scores for both groups appeared relatively unimodal and symmetric without skewness, thereby supporting the reporting of mean scores as representative of average performance and satisfying the assumption of normality.

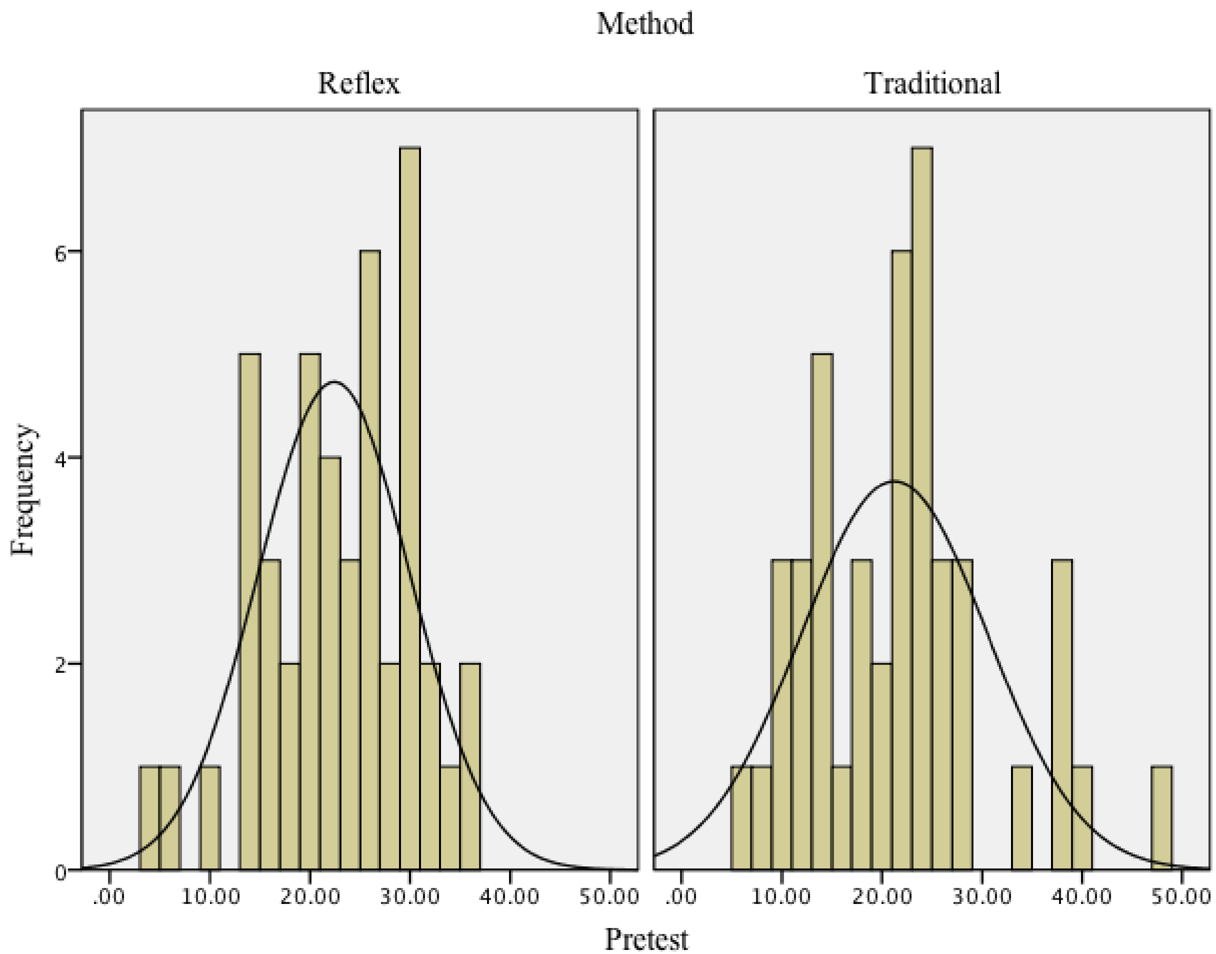

Figure 2. Histogram of pretest scores by method for the treatment and control groups.

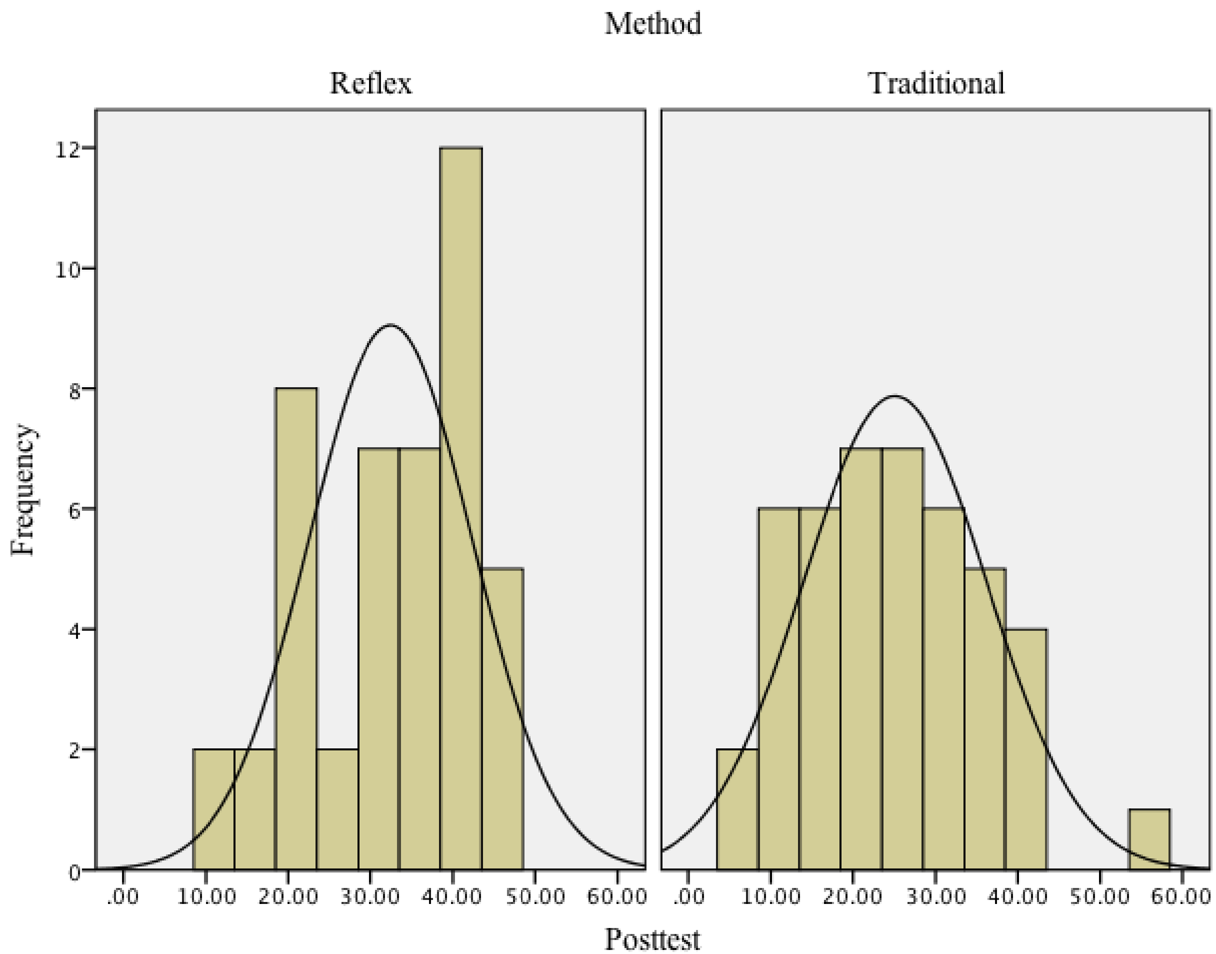

Figure 3. Histogram of posttest scores by method for the treatment and control groups.

The results of Levene's test, $F(1,89) = 3.05$, $p = .08$ indicates that the variances among the groups were not significantly different and that the two populations are assumed to be approximately equal. This supports the assumption that the homogeneity of variances was not violated and provides confidence in the validity of the *F* test result.

The scatterplot in Figure 4 supports the assumption of linearity. The relationship between the dependent variable and covariate is linear with similar lines of best fit reflecting this relationship among scores for each group. Similar slopes traveling closely together and in the same general direction support the assumption that there is no interaction between the treatment and the covariate. The scatter plot also indicates that the homogeneity of regression slopes assumption was not violated. The similar lines of best fit support the lack of interaction between the dependent variable and the covariate. A more precise statistical analysis to look for an interaction between the treatment and covariate, the test of between-subjects effects, verified that the assumption of homogeneity of regression slopes was not violated with an interaction that was not significant, $F(1, 85) = .637$, $MS = 22.50$, $p = .43$ with a partial n^2 of .007.

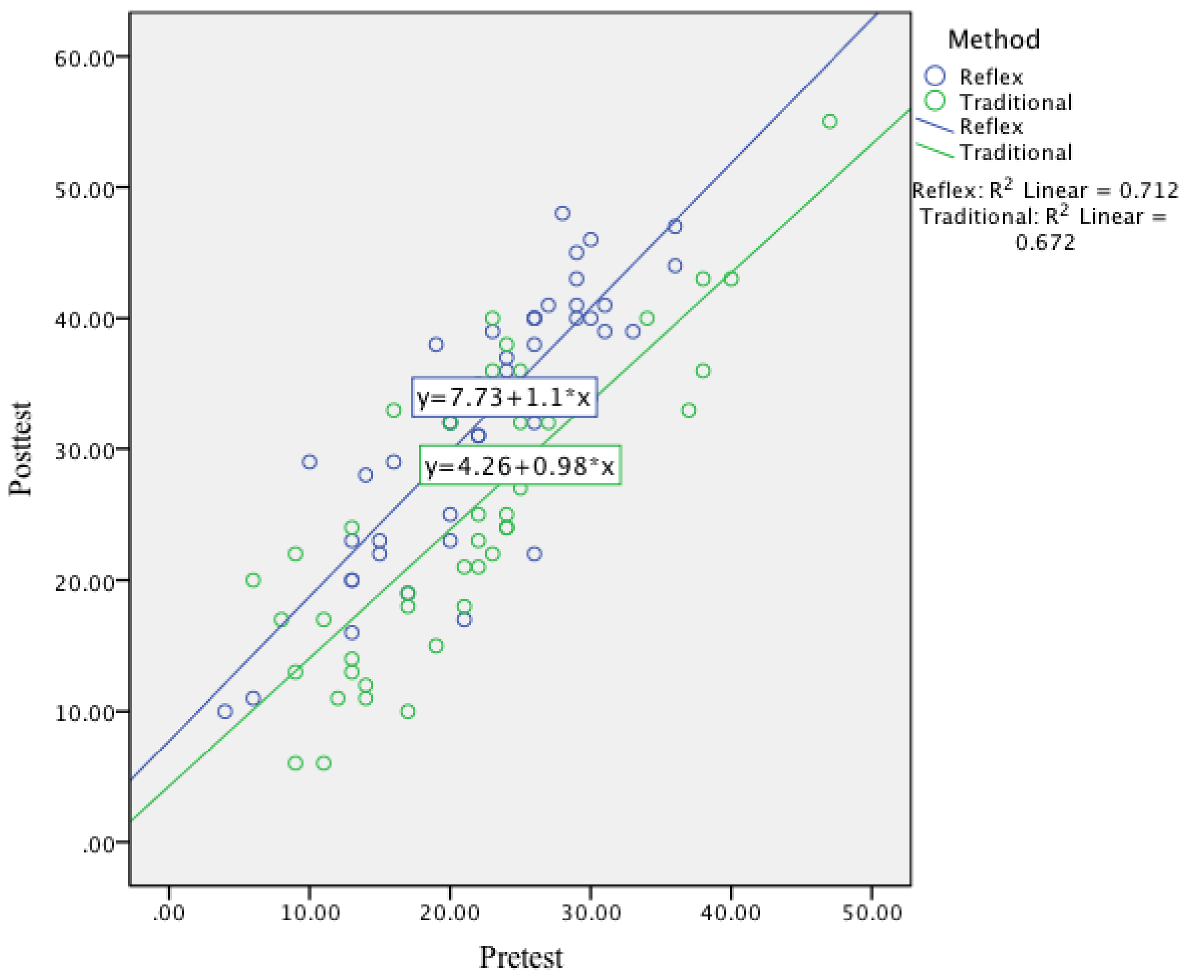

Figure 4. Scatterplot of pretest and posttest scores.

A determination that no assumptions were violated allowed for an ANCOVA analysis to be conducted testing for the first null hypothesis, H_{o1}: There is no statistically significant difference in Basic Math Operations Task scores between at-risk students who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk students who receive traditional Response to Intervention instructional strategies while controlling for previous knowledge.

Descriptive statistics for BMOT pretest scores after participants received either Reflex math computerized intervention or traditional intervention are outlined in Table 4.1 followed by the posttest scores for the same groups in Table 4.2.

Table 4.1

Descriptive Statistics of Basic Math Operations Task Pretest Scores by Intervention

Intervention Method	*n*	*M*	*SD*
Reflex Intervention	45	22.40	7.59
Traditional Intervention	44	21.23	9.32

Table 4.2

Descriptive Statistics of Basic Math Operations Task Posttest Scores by Intervention

Intervention Method	*n*	*M*	*SD*
Reflex Intervention	45	32.42	9.9
Traditional Intervention	44	25.07	11.15

After adjustments for BMOT pretest scores, the mean score for at-risk students receiving the Reflex math computerized intervention was 31.83 facts correct per minute, and for at-risk students taking part in the traditional intervention, the mean score was 25.68 facts correct per minute. There was a statistically significant difference in groups at an α = .05 level, $F(1, 86)$ = 23.78, p = .000, with a partial η^2 of .22. The results indicate that the Reflex math computerized intervention group had a significantly higher mean score on the BMOT posttest and that the groups are significantly different from one another. According to Cohen (1988), the effect size of .22 is large and suggests a strong relationship between method of intervention and posttest scores with approximately 22% of any variance in posttest scores attributed to participation in the Reflex math computerized intervention group. An observed power of .998 indicates the likelihood of a Type I error is minimal, and therefore the null hypotheses was rejected. There is a statistically significant difference in Basic Math Operations Task scores between at-risk students who received Reflex math computerized intervention as a Response to Intervention strategy and at-risk students who received traditional Response to Intervention instruction while controlling for previous knowledge.

Hypothesis Two

The differences in mean scores on the BMOT among males who either participated in the Reflex math computerized intervention or in other traditional math interventions were inspected using a one-way ANCOVA. The independent variable was the male gender and the dependent variable was the BMOT posttest scores. The BMOT pretest scores for the male gender served as the covariate to control for previous math automaticity.

Initially, assumptions were evaluated to establish normality, homogeneity of variances, linearity, and homogeneity of regression slopes. Normality was evaluated in accordance to the histograms depicted in Figure 5 and Figure 6, which illustrate a unimodal and approximately symmetric normal distribution of scores.

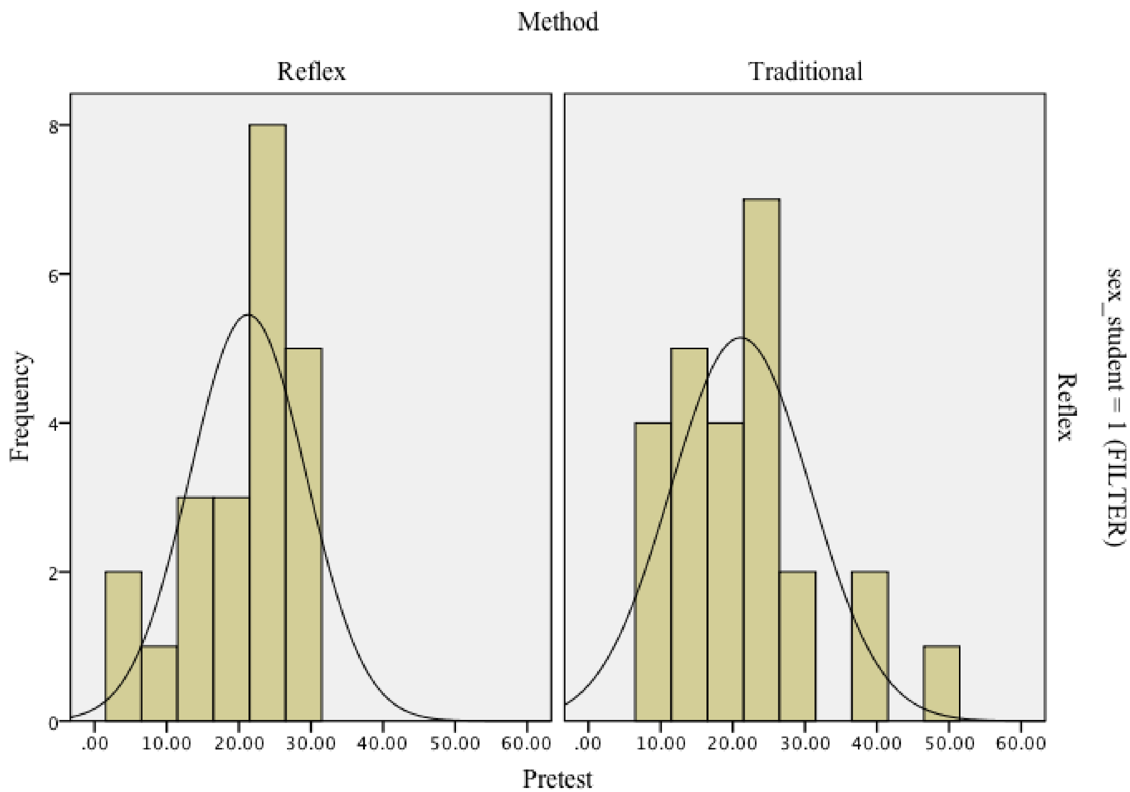

Figure 5. Histogram of pretest scores of males by method.

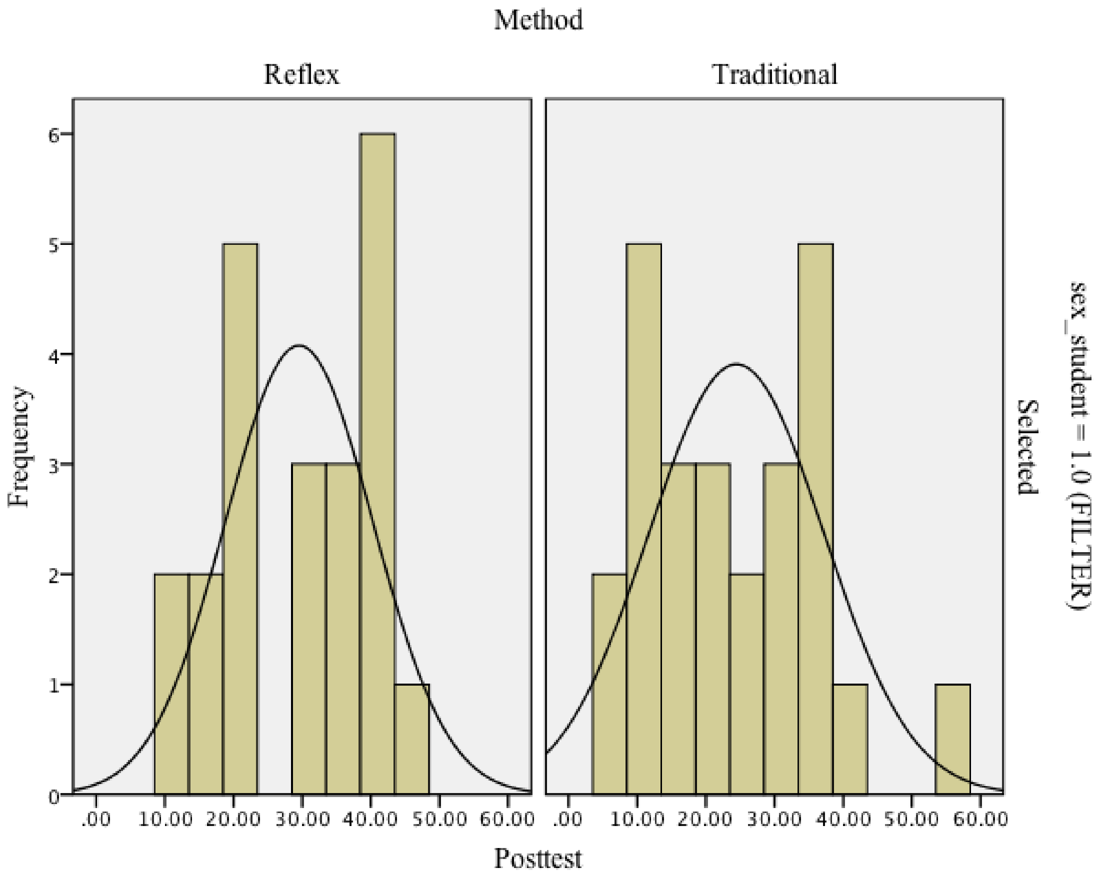

Figure 6. Histogram of posttest scores of males by method.

The results of Levene's test, $F(1,47) = .164$, $p = .69$ indicates that the variances among the groups were not significantly different and that the two populations are assumed to be approximately equal. This supports the assumption that the homogeneity of variances was not violated and provides confidence in the validity of the *F* test result. A scatterplot illustrated in Figure 7 provides a model that supports the assumption of linearity. The linear relationship between the dependent variable and the covariate with the line of best fit traveling in the same general direction indicate there is no interaction between the treatment and the covariate. Statistical support for this lack of interaction was provided with a test of between-subject effects that validates the assumption of homogeneity of regression slopes was not violated as a result of an interaction that was not significant at an $\alpha = .05$, $F(1, 43) = .04$, $MS = 1.73$, $p = .83$ with a partial n^2 of .001. The small effect size indicates that the mean differences in posttest automaticity scores varied minimally as a function of the pretest automaticity scores.

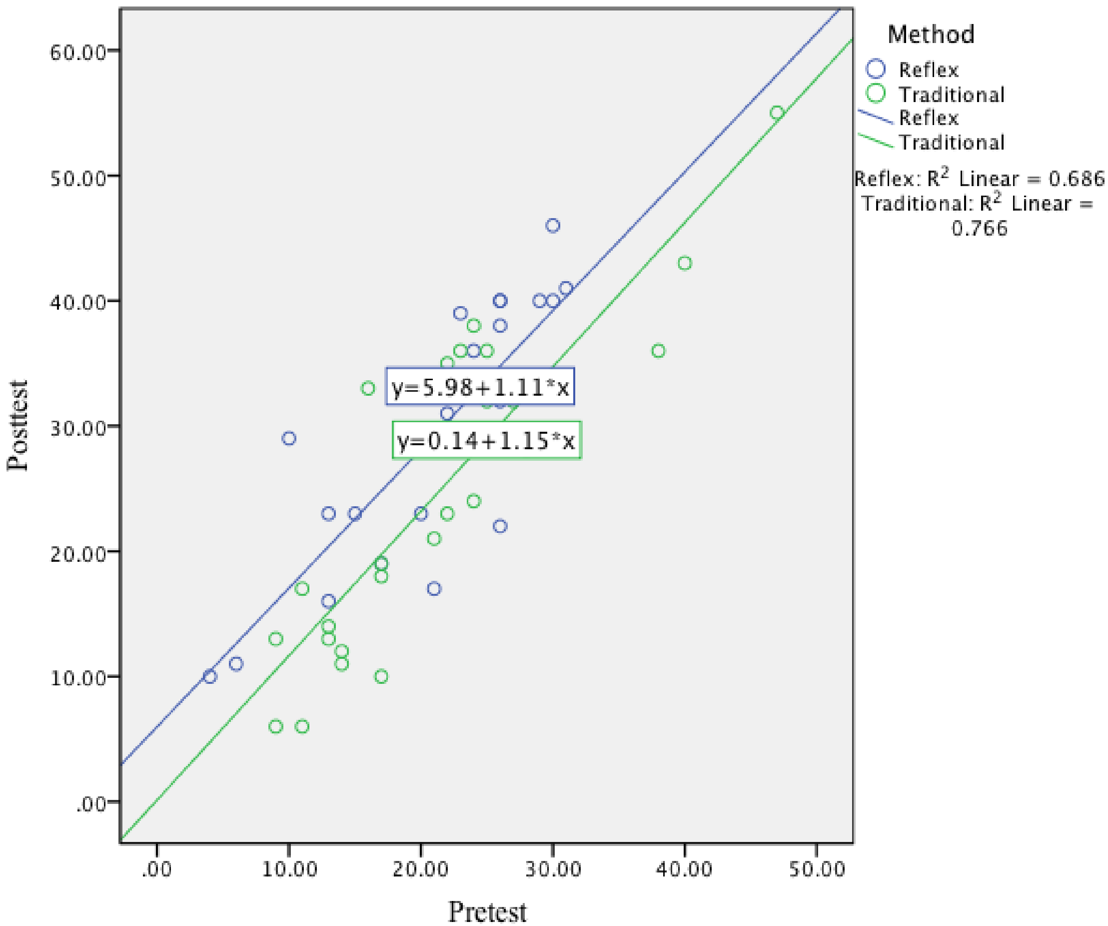

Figure 7. Scatterplot of pretest and posttest scores of males by method.

Since no assumptions were violated, an ANCOVA was conducted to test for the second null hypothesis, H_{o2}: There is no statistically significant difference in Basic Math Operations Task scores between at-risk males who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk males who receive traditional Response to Intervention instruction while controlling for previous knowledge.

Descriptive statistics for the BMOT pretest scores of males are presented in Table 4.3, and posttest scores for males are presented in Table 4.4.

Table 4.3

Descriptive Statistics of BMOT Pretest Scores by Intervention Method Among Males

Intervention Method	*n*	*M*	*SD*
Reflex Intervention	22	21.27	8.05
Traditional Intervention	25	21.08	9.69

Table 4.4

Descriptive Statistics for BMOT Posttest Scores by Intervention Method Among Males

Intervention Method	*n*	*M*	*SD*
Reflex Intervention	22	29.55	10.76
Traditional Intervention	25	24.44	12.76

After adjustments for BMOT pretest scores, the mean score for males receiving the Reflex math computerized intervention was 29.43 facts correct per minute, and for males taking part in the traditional intervention, the mean score was 24.54 ppm correct. There is a statistically significant difference between males by intervention method at an $\alpha = .05$ level, $F(1, 47) = 7.31$, $p = .01$, partial $n^2 = .14$. According to Cohen's interpretation, the effect size of .14 is large and indicates that approximately 14% of any variance in posttest scores can be attributed to participation in the Reflex math computerized intervention group. An observed power of .753 indicates the likelihood of a Type I error is minimal, and therefore the null hypotheses was rejected. There is a statistically significant difference in Basic Math Operations Task scores between at-risk males who received Reflex math computerized intervention as a Response to Intervention strategy and at-risk males who received traditional Response to Intervention instruction while controlling for previous knowledge.

Hypothesis Three

The differences in mean scores on the BMOT among females who either participated in the Reflex math computerized intervention or in other traditional math interventions were inspected using a one-way ANCOVA. The independent variable was the female gender, and the dependent variable was the BMOT posttest scores. The BMOT pretest scores served as the covariate to control for previous math automaticity.

Initially, assumptions were evaluated to establish normality, homogeneity of variances, linearity, and homogeneity of regression slopes as well as the histograms depicted in Figure 8 and Figure 9, which illustrate a unimodal and approximately symmetric normal distribution of scores.

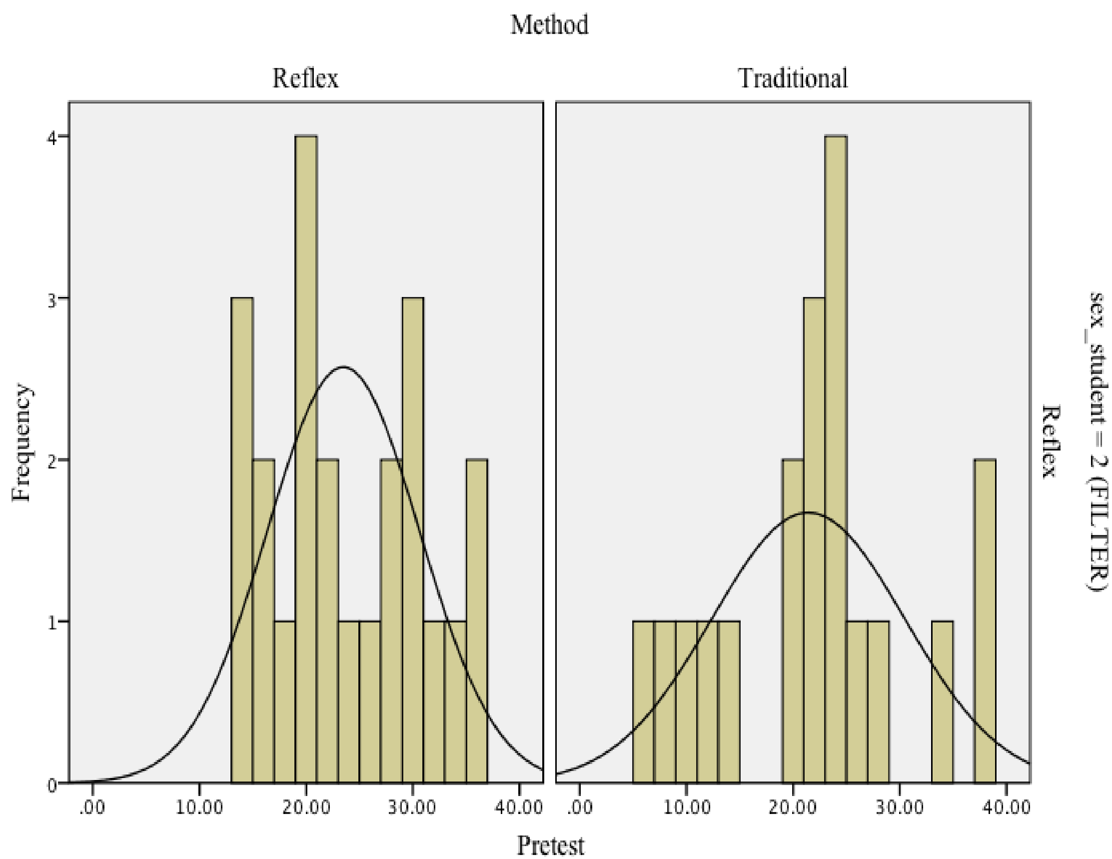

Figure 8. Histogram of pretest scores of females by method.

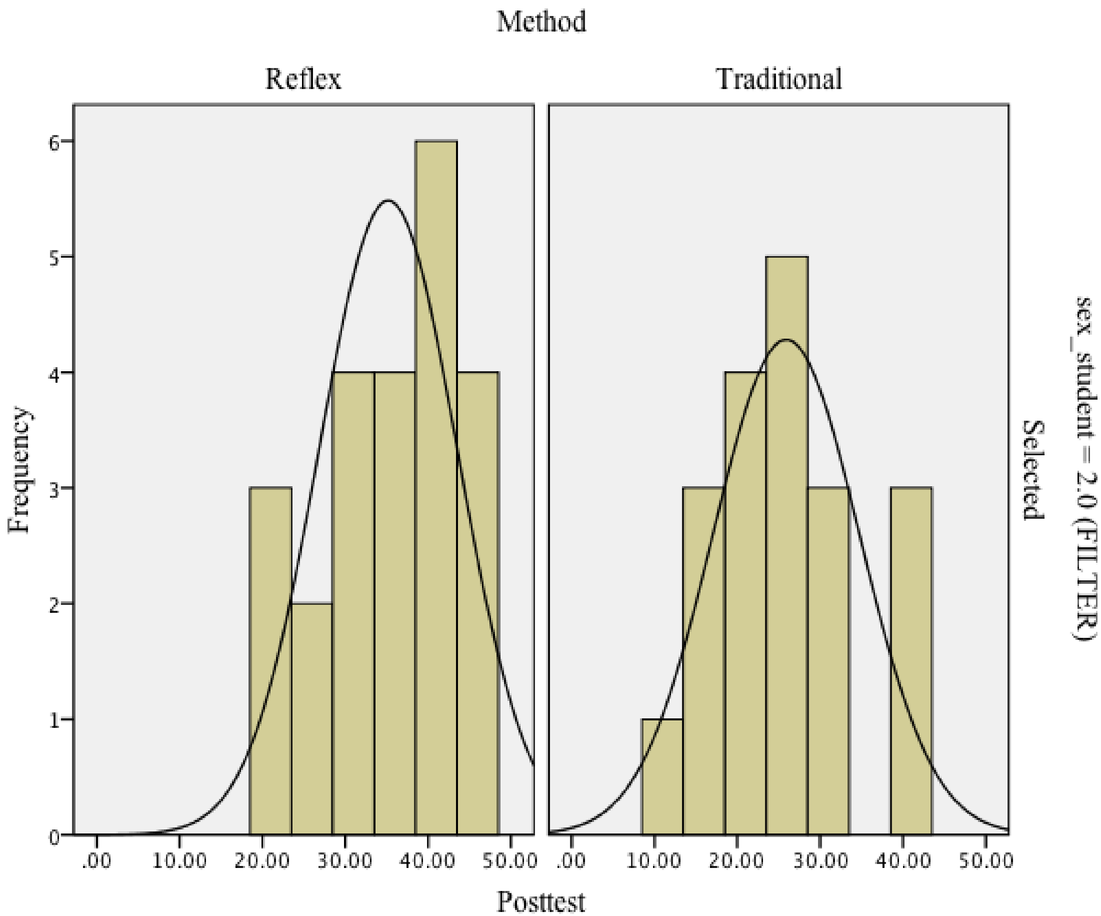

Figure 9. Histogram of posttest scores of females by method.

The results of Levene's test, F(1,42) = 5.87, p = .02 indicates that the variances among the groups were significantly different and that the two populations cannot be assumed to be approximately equal thereby violating the assumption of homogeneity of variances and affecting the interpretation of any associated hypothesis. A scatterplot illustrated in Figure 10 provides a model that supports the assumption of linearity. The linear relationship between the dependent variable and the covariate with the line of best fit traveling in the same general direction indicate there is no interaction between the treatment and the covariate. Statistical support for this lack of interaction is provided with a test of between-subject effects that validates that the assumption of homogeneity of regression slopes was not violated with an interaction that was not significant, $F(1, 42) = 2.3$, $MS = 61.5$, $p = .14$.

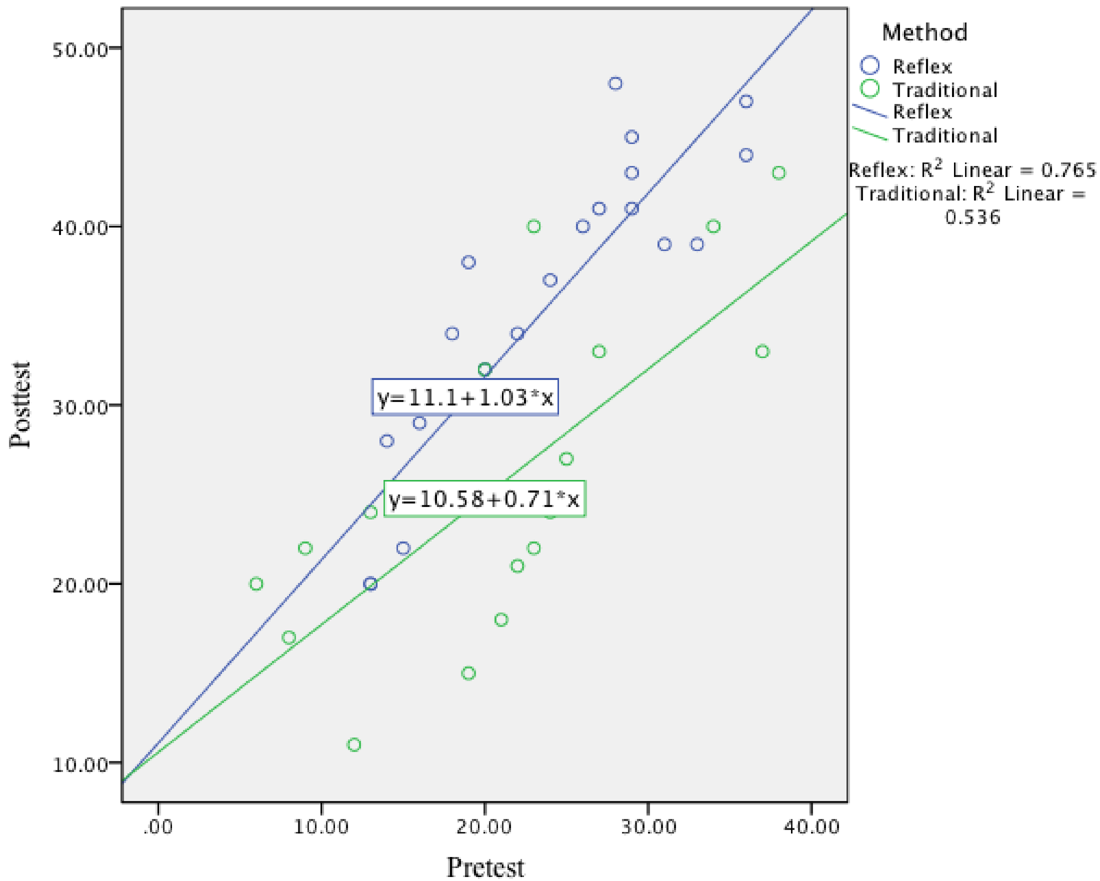

Figure 10. Scatterplot of pretest and posttest scores of females by method.

Table 4.5

Descriptive Statistics of BMOT Pretest Scores by Intervention Method Among Females

Intervention Method	*n*	*M*	*SD*
Reflex Intervention	23	23.48	7.13
Traditional Intervention	19	21.42	9.06

Table 4.6

Descriptive Statistics for BMOT Posttest Scores by Intervention Method Among Females

Intervention Method	*n*	*M*	*SD*
Reflex Intervention	23	35.17	8.36
Traditional Intervention	19	25.89	8.85

Although the assumption of equality of variances among the groups of females was violated, an ANCOVA was conducted to test for the null hypotheses H_{o3}: There is no statistically significant difference in Basic Math Operations Task scores between at-risk females who receive Reflex math computerized intervention as a Response to Intervention strategy and at-risk females who receive traditional Response to Intervention instruction while controlling for previous knowledge.

After adjustments for BMOT pretest scores, the mean score for females receiving the Reflex math computerized intervention was 34.38 facts correct per minute, and for females taking part in the traditional Response to Intervention strategy, the mean score was 26.85 facts correct per minute. There was a statistically significant difference between females by intervention method at an $\alpha = .05$ level, $F(1, 42) = 21.0$, $p = .000$, partial $n^2 = .35$. According to Cohen's interpretation, the effect size of .35 was large and indicates that approximately 35% of any variance in posttest scores can be attributed to participation in the Reflex math computerized intervention group. An observed power of .99 indicates the likelihood of a Type I error is minimal. Therefore, the null hypothesis was rejected.

Summary of Results

The purpose of this study was to evaluate the effectiveness of the Reflex math computerized intervention on the automaticity of math facts among at-risk middle school students. In response to the first null hypothesis, the results of the study indicate that when using BMOT pretest scores as a covariate, there is a significant relationship between at-risk students who participated in the Reflex math computerized intervention and automaticity of math facts. Adjusted posttest BMOT mean scores for those who participated with the Reflex math computerized intervention were 31.83 facts correct per minute versus 25.68 facts correct per minute for those who participated in other traditional Response to Intervention strategies. This study was also intended to examine the differences in automaticity scores among at-risk males who did or did not use the Reflex math computerized intervention as well as at-risk females who did or did not use the computerized intervention. The second hypothesis, which examined at-risk males, established significant differences in automaticity scores for males in regards to intervention method. Adjusted posttest BMOT mean scores for males who participated with the Reflex math computerized intervention were 29.43 facts correct per minute versus 24.54 facts correct per minute for those who participated in other traditional Response to Intervention strategies. At-risk females were examined in the third hypothesis and statistically significant differences were found to exist between females in regards to intervention method. Adjusted posttest BMOT mean scores for females who participated with the Reflex math computerized intervention were 34.38 facts correct per minute versus 26.85 facts correct per minute for those who participated in other traditional Response to Intervention strategies. All three null hypotheses were rejected thus supporting the benefit of Reflex math computerized intervention as an effective intervention strategy to use for middle school students who at-risk for academic achievement in mathematics related to the automaticity of basic math facts.

CHAPTER FIVE: DISCUSSION

The intent of this chapter is to review and discuss the results of the study, and it is divided into several sections. Initially, a general overview of the study is provided that explores pertinent background information for the study and evolves into the problem statement and purpose of the study. Next, a summary and discussion of the findings according to each research question and its corresponding null hypothesis is provided. Finally, implications for and limitations of the study are posed and are followed by suggestions for future research. A conclusion provides a brief culmination of the rationale, results, and recommendations for the study.

Overview

Background of the Study

Since recent shifts in math reform consider automaticity to be old-fashioned, monotonous, and pointless, the focus on math fact mastery has dwindled. As a result, student math scores have declined (Institute of Education Sciences, 2009). In an attempt to address the dire state of mathematics performance that indicates most American students failing to meet minimal mathematics proficiency by the end of their formal school years, President George W. Bush created the National Math Advisory Panel (NMAP). This panel charged educators to adhere to the "best available scientific evidence to foster greater knowledge and improved performance" and also addressed the postulated achievement gap (NMAP, 2008, p. xiii). For many students, this gap begins in middle school and continues to widen (Southern Regional Education Board, 2012, p.10). In response to legislation placing emphasis on closing this gap and assisting students in attaining grade level performance, the implementation of a tiered Response to Intervention model was suggested. This intervention model seeks to implement evidence-based interventions to meet the academic needs of students who are primarily at-risk in the hopes that they may achieve parity with their peers. Unfortunately, “best practice” instructional models for mathematics support in general are limited, and those that specifically address automaticity of math facts are even fewer. Advantages for students who possess automaticity of basic math facts include enhanced engagement with more difficult math problems, better test scores, improved retention, lower levels of anxiety, and an overall improvement in math engagement (Skinner, Pappas, & Davis, 2005). One evidence-based intervention that is reported as effective at enhancing automaticity of math facts is Reflex math (Cholmsky, 2011). This computerized intervention progresses from initial acquisition to automaticity while adapting and differentiating instruction through games (Cholmsky, 2011).

A literature review of the cognitive sciences supports the notion that math automaticity is a fundamental necessity in order for students to succeed at higher levels of cognitive functioning and attempt more complex math problems (Baroody, Bajwa, & Eiland, 2009; Gagne, 1983; Poncy, Skinner, & Jaspers, 2006; Verschaffel, Luwel, Torbeyns, & VanDooren, 2009; Woodward, 2006). The cognitive learning theory, information processing theory, and cognitive load theory all provide meaningful support for the need of automatic recall of math facts. In addition, operant conditioning and a reward token economy corroborate the importance of rewards when the repetition of desired behaviors is sought.

In addition to the importance of math achievement and proficiency for all students, of particular interest are the achievement differences in regards to gender. The notion that boys outperform girls in mathematics is commonly touted and researched especially amid the underrepresentation of females in authority positions in STEM positions (Ceci & Williams, 2010; Halpern et al., 2007; National Science Foundation, 2011; Wand, Eccles, & Kenny, 2013).

Though the gap between achievement in regards to gender fluctuates, males continue to outperform females in most mathematic domains, with one of the most often researched reasons being a lack of computational fluency and automaticity (Carr, Steiner, Kyser, & Biddlecomb, 2008: Geary et al., 2000; OECD 2010). It is important to know which interventions are effective for all and if the intervention might specifically benefit one gender over another.

Problem Statement

While ample research supports that academically at-risk students need interventions in regards to the automaticity of math facts (Woodward, 2006), there is limited research that addresses the effectiveness of specific interventions on math achievement for at-risk middle school students (Esch, 2009; Foegen, 2008; Gersten et al., 2009). Specific interventions and strategies need to be unearthed and tested to determine their effectiveness so they can be utilized to support the academic needs of at-risk students. The effectiveness of specific interventions when looking at males and females separately is also of concern when designing and implementing a tiered support system aimed at addressing particular deficits.

Purpose of Study

The primary purpose of this quasi-experimental pretest-posttest nonequivalent control group study was to determine if math automaticity could be improved when at-risk students in a north Georgia middle school participated in the Reflex math computerized intervention. It was also the intent to examine potential differences in automaticity that might exist between males who do and do not participate in the Reflex math computerized intervention as well as females who do the same.

Summary of the Results

Research Question One

The main intent for this quasi-experimental study was to determine if differences exist in automaticity scores for students who participated in the Reflex math computerized intervention and those who participated in traditional interventions. The 89 participants were middle school students from a north Georgia school who had previously been identified as being at-risk for academic achievement in mathematics according to Criterion Referenced Competency Test (CRCT) scores on the previous year's administration as well as the results of a computerized program that determined approximate grade level performance at the beginning of the current 2013-2014 school year.

An analysis of covariance (ANCOVA) test established that Basic Math Operations Task (BMOT) posttest scores among students who participated in the Reflex math computerized intervention group were significantly higher than the scores of those who participated in the traditional interventions. After the covariate was considered, at-risk students who participated in the Reflex math computerized intervention group had a BMOT mean score of 31.83 problems correct per minute, and those students who participated in the traditional interventions group had a BMOT mean score of 25.68 facts correct per minute. This supports the notion that participating in the Reflex math computerized intervention group did help to improve the automaticity of math facts among at-risk middle school students.

Research Question Two

The second question addressed in this study examined differences in BMOT posttest scores for males who did and did not participate in the Reflex math computerized intervention group to improve math fact automaticity. The BMOT posttest scores reported in problems correct per minute served as the dependent variable, the male gender served as the independent variable, and the BMOT pretest scores acted as the covariate for data analysis. An ANCOVA test established that BMOT posttest scores among males who participated in the Reflex math computerized intervention group were higher than the scores of those who participated in traditional intervention groups. After the covariate was taken into account, at-risk males who participated in Reflex math computerized intervention group had a BMOT mean score of 29.43 problems correct per minute, and those males who participated in the traditional interventions group had a BMOT mean score of 24.54 problems correct per minute. This supports the notion that participating in the Reflex math computerized intervention group helps to improve the automaticity of math facts among at-risk middle school males.

Research Question Three

The third question examined differences in BMOT posttest scores for females who did and did not participate in the Reflex math computerized intervention group to improve math fact automaticity scores. The BMOT posttest scores reported in problems correct per minute served as the dependent variable, the female gender served as the independent variable, and the BMOT pretest scores acted as the covariate for data analysis. An ANCOVA test established that BMOT posttest scores among females who participated in the Reflex math computerized intervention group were significantly higher than the scores of those who participated in the traditional interventions. After the covariate was taken into account, at-risk females who participated in Reflex math had a BMOT mean score of 34.38 problems correct per minute, and those females who participated in the traditional interventions group had a BMOT mean score of 26.85 problems correct per minute. This supports the idea that participating in the Reflex math computerized intervention group does significantly help to improve the automaticity of math facts among at-risk middle school females.

Discussion of the Results

The shift towards accountability for outcomes, as well as progress monitoring, has transpired from the early 1960s with the passage of the Elementary and Secondary Education Act (ESEA), then with the Improving America's Schools Act (IASA), next the 2004 reauthorization of the Individuals with Disabilities Act (IDEA), and finally the monumental enactment of Public Law 107-110, better known as No Child Left Behind (NCLB). This shift placed a burden upon schools to narrow the achievement gap with the intent of ensuring academic proficiency for all students. Hence, there is an emphasis placed on the identification of effective methods, interventions, and practices that would promote achievement. As an answer to this push, Response to Intervention (RtI) evolved as a recommended multi-tiered delivery model for identifying, assisting, and monitoring at-risk students who need additional academic support. The focus is on targeted and systematic research-based interventions applied when the need becomes evident rather than relying on the "wait to fail" approach (Buffman, Mattos, & Weber, 2010; Fletcher et al., 2002).

Research Question One

Based upon a current literature review, there is limited research on effective math interventions that may help the most at-risk students to attain and maintain mathematical proficiency. There is even less research evaluating interventions for middle school students who lack automaticity of basic math facts. According to Gersten, et al (2009), "Many children in the United States never achieve proficiency with basic math facts, and those who do typically achieve it later than their peers in nations with higher mathematics achievement" (p. 34). As the

National Math Advisory Council (2008), National Council of Teachers of Mathematics (2006), and the Common Core State Standards Initiative (2010) agree that the automaticity of math facts is a basic skill needed to progress academically, additional research is needed to identify which interventions, methods, and strategies may improve automaticity. Current trends support the benefits of computer-assisted instruction on learning for students at-risk for academic achievement in mathematics, though proof is limited. It is thought that the interventions must target specific deficiencies to be effective (Burns, VanDerHeyden, & Boice, 2008). Therein provides the basis for further investigation for specific interventions that prove beneficial.

Interventions that address automaticity through repetition are crucial for at-risk students since they tend to struggle with math fact recall and fluency (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007). The ability to rapidly recall math facts has been shown to be an indicator of mathematics achievement, and since the rapid decline in math achievement begins as students near the end of middle school, it is paramount to address it during this transitional time (NMAP, 2008). Reflex, a recently developed math computerized intervention, has shown positive results among elementary school students. It assesses and monitors math fluency, tracks response speed, and constantly modifies facts introduced to align with progress (Cholmsky, 2012).

While the findings in regards to automaticity for the at-risk students in the study are generally consistent with other math fact recall research, this study provides information that has been limited up to this point regarding the use of such an intervention at the middle school level with at-risk students. Not only did this study assist the students with their automaticity of math facts, it may also improve math classroom performance and enhance future academic achievement testing as well. With the requirements associated with NCLB and importance of a school's adequate yearly progress (AYP status), school personnel need to determine which interventions and strategies are most beneficial in supporting the mathematical endeavors of students and better prepare them for subsequent math instruction and a competitive job market.

Research Question Two

The purpose of question two was to determine whether the Reflex intervention made a difference in automaticity of math facts for at-risk males when compared to males who did not receive the Reflex intervention and instead received traditional mathematics interventions. Research confirms that the majority of computer games are bought for males and that this enhances motivation and attitudes of males toward Computer Assisted Instruction (CAI) (Roblyer & Doering, 2009). It is postulated that this pattern widens the achievement gap among gender and bolsters performance levels of males. In addition, postulated gender bias among games, educational software, and CAI continues (Hartmann & Klimmt, 2006). The results of the study revealed that there was a difference between the males who did and did not receive the Reflex math computerized intervention. The findings were also consistent with the suggestion that males tend to be more motivated when engaged in computer-assisted learning (Bontempi & Warden-Hazelwood, 2003).

Research Question Three

Question three was aimed at determining the impact on math fact automaticity between at-risk females who participated in the Reflex math intervention and females who did not participate in Reflex math intervention and instead received traditional mathematics interventions. Results indicate that Reflex math computerized intervention significantly improved the math fact automaticity level of at-risk females who utilized the intervention when compared to at-risk females who did not use the intervention. The results are consistent with research that Computer Assisted Instruction (CAI) tends to be beneficial when aimed at improving the automaticity of math facts yet inconsistent with the notion that is does not make as great an impact on females as it does males (Spradlin & Ackerman, 2010).

Implications

Study findings support utilization of Reflex math in the form of CAI as an effective research-based intervention to aid in improving the automaticity of math facts for at-risk middle school students. Evidence was also unearthed that suggests female students who are at-risk academically experience greater benefits than males from the same at-risk population. As a result, the use of technology-based interventions could become more integral in assisting at-risk students in achieving equity in mathematics if included into the middle school curriculum on a regular basis (Hasselbring et al., 2006). These findings provide valuable information that may guide decisions regarding the implementation of best practices to benefit those with mathematical deficits and allow at-risk students to approach more complex mathematical problems that are inherent to the middle school Common Core curriculum. This evidence may also help many school districts advance math achievement in the classroom as well as on CRCT scores in an attempt to attain AYP because if schools fail to make AYP, they are identified as needing improvement and suffer the sanctions associated with this occurrence. Also, as a component for the highly encouraged tiered RtI pyramid, by addressing the deficits of students in the first two tiers of the pyramids with successful research-based interventions, fewer students will require a transition to the third tier of the pyramid and possibly avoid referral for special education testing. Decreasing these referrals keeps the majority of students in the least restrictive environment for academic instruction, thereby adhering to legislative mandates that require such placement among students with disabilities. As a result, remediation for those with the greatest academic needs should decrease retention rates and increase graduation rates, further diminishing the achievement gap between males and females and thus advancing mathematical literacy.

In addition to the academic impact that the Reflex math computerized intervention can make, it may well prove to increase motivation and engagement among some students. Altering the belief that mathematics ability is not purely based upon natural ability but heavily dependent upon effort may enhance engagement and, in turn, achievement (NMAP, 2008, p. xxi). In order to get students enthusiastically involved in learning, motivation is a fundamental requirement (Jovanovic et al., 2008). The degree of success that a student expects to have when performing mathematical operations and the amount of importance they assign to this success drives future motivation towards education in general (Gersten et al., 2009). Therefore, students who exhibit automaticity of math facts may anticipate greater success not only in mathematics but other academic areas and are more likely to be engaged (Gersten et al., 2009; Poncy, Skinner, & O'Mara, 2006; McCallum et al., 2006).

Amid the ongoing debate concerning the math achievement gap between males and females, the current data available for this study that indicates a greater benefit for females as opposed to males can be postulated in several ways. It is possible that this particular computerized intervention was not very engaging for at-risk middle grade males, and therefore, they did not take it seriously. It is also possible that the Reflex math computerized intervention did not include age appropriate games and avatar selections or that middle school males are accustomed to more complicated, action-packed gaming scenarios. On the other hand, the enhanced benefits attributed to the females could be explained by the notion that girls are more comfortable with technology and computer gaming than they had previously been, they enjoyed changing the styles of their avatars, they flourished in a noncompetitive gaming situation, took the practice opportunity more seriously, or had the opportunity to progress quietly and at their own pace.

Limitations

Limitations of the study exist in terms of design, selection, environment, participants, and instrumentation. Design limitations are attributed to the fact that random assignment was not possible since at-risk students for math achievement had been identified prior to the study, and therefore, each student in the middle school did not have the same opportunity to be included in the study (Gall, Gall, & Borg, 2007). A selection threat was also present because the non-equivalent groups of participants did not have balanced characteristics. To help control for this situation, participants were chosen from the same population and deemed as similar as possible (Cohen, 2007) and a covariate, BMOT pretest scores, was used. The participants as a group and the environment in which the study transpired were additional limitations because the participants all attended the same rural school and were primarily Caucasian, thereby limiting the generalizability of the results to schools that are similar both ethnically and geographically. When all participants attend the same school, this is a significant limitation and indicates that the results are only generalizable to a similar situation. Another limitation was attributed to the use of the BMOT to measure automaticity scores. This instrument is similar to other timed instruments that most likely have been used in the past.

Recommendations for Future Research

As a result of limited research among middle school students who have used Reflex math, research findings, implications, and limitations, supplementary research is needed. In an attempt to extend the current body of literature related to automaticity, the results of this study combined with additional research can help clarify the role of specific computer-assisted interventions used to help at-risk students who struggle with math achievement. Studies that include younger students, multiple schools, a more diverse population, or a variety of geographical regions would help in generalizing the results to a larger populace of students. This research could also be continued with follow-up studies to test for the maintenance of automaticity levels among participants. With the emphasis placed on NCLB and AYP, further research could examine the CRCT scores of students who participated in the study and look for any correlation between the two.

In an attempt to continue the search for specific interventions to assist at-risk students and delve into the motivation and engagement that computer-assisted instruction may evoke, attitudinal surveys in conjunction with Reflex math computerized intervention could offer insight into which elements of the intervention appeal most to the students, and this same survey could also further explore some of the reasons that females performed better overall than males when they participated in Reflex math computerized intervention. Specific components of the intervention that appear to engage and motivate could spur additional technological innovations aimed at improving mathematical performance.

Conclusion

The automatic recall of basic math facts is the foundation upon which subsequent mathematics education builds. Its presence or lack thereof is a precursor to future academic achievement and needs considerable attention. With the mandates of NCLB, the reauthorization of IDEA, and the NMAP's call for the enhancement of computational fluency, educators continue to search for effective interventions to meet the specific needs of those who need them the most. The results of this study support Reflex math as such an intervention for middle school at-risk students overall, with females reporting larger differences than males when studied separately.

The researcher believes that drill and practice embedded within a game based learning environment is driving the results. Opinion is supported by the instructional hierarchy theory that details the stages of learning beginning with acquisition, focusing on drill and practice and then moving towards automaticity. For students who are at-risk for academic performance in mathematics, computer assisted instruction and interventions must target specific deficiencies to be effective (Burns, VanDerHeyden, & Boice, 2008), and when focusing on automaticity of math facts it should be done so through interventions that address fluency through repeated practice (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007). Game-assisted learning improves rates of retention and enhances learning (Jovanovic et al., 2008) and when embedded into an action format, learning, performance and motivation can be enhanced. Reflex math includes all of these aspects by introducing students to small sets of facts, providing extended practice to obtain proficiency, including game-based practice, and providing students with guided support on their quest for automaticity.

Further research is suggested to corroborate the results and increase the population of students to which the results can be generalized as well as shed additional light on the impact of automaticity on the academic success and future aspirations of at-risk students. It will also help to clarify some of the disparity that continues to exist in regards to gender and mathematics achievement.

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APPENDIX A

Permission to Conduct Research

Research Study
Consent to Participate

August 14, 2013

Study Title: The Effects of Reflex Math as a Response to Intervention Strategy to Improve Math Automaticity Among Male and Female at-risk Middle School Students.

Researcher: Daphne M. Sarrell

Introduction: As part of a research study conducted by Daphne Sarrell and supervised by Dr. Gina Grogan at Liberty University in Lynchburg, Virginia, [redacted] Middle School has been asked to participate in an effort to ascertain the effectiveness of a computerized math intervention and assist Mrs. Sarrell in her dissertation process.

Purpose: The purpose of the study is to determine whether or not the use of Reflex math computerized intervention will significantly increase the automaticity of basic math facts among at-risk male and female middle school students. The data will be used to help determine the benefit of Reflex math for at-risk middle school students when used as prescribed in the study.

Procedures: Participants will take a one-minute pretest that is composed of 80 random basic math facts of whole numbers. Participants will then be assigned to either an experimental group that uses Reflex math computerized intervention as a response to intervention strategy or a control group that does not use Reflex math but utilizes other means of responding to the academic needs of students in math. The experimental group will use Reflex math computerized intervention four days a week for 20 minutes and the control group will receive other math interventions that do not include Reflex math. After six weeks, all participants will then take a posttest that is similar to the pretest.

Potential Risks: There are no foreseeable risks or potential harm to participants.

Confidentiality: All records as well as the identity of participants will remain confidential and be kept in a locked file cabinet. Upon completion of the research study and after the results have been reported and confirmed, all identifying information and documents will be destroyed.

Participation: Participation in the study will be voluntary and participants may withdraw at any time without penalty. Participants and their parents or guardians will be provided with informed consent information prior to participating.

Dissemination: The results of the study will be reported in a doctoral dissertation written by Mrs. Sarrell and be included in a doctoral database assessable to university students.

Contacts and/or Questions: All inquiries concerning this study may be directed to Daphne Sarrell at dsarrell@ucschools.org.

Statement of Consent: The signatures below indicate the willingness of the [redacted] Board of Education as well as the principal of [redacted] Middle School to allow Mrs. Sarrell to conduct research as part of her educational requirements as a doctoral candidate at Liberty University School of Education.

[redacted]
Superintendent – [redacted] Schools

8-14-2013
Date

[redacted]
Assistant Superintendent – [redacted] Schools

8/14/13
Date

[redacted]
Principal – [redacted] Middle School

8-14-13
Date

APPENDIX B

Teacher Introduction to Study

"Colleagues, in a effort to serve the needs of our at-risk students who struggle with math achievement due to a lack of automaticity of math facts, I will conduct a study on the benefits of Reflex math as a successful response to intervention strategy. In conducting this study, I will need the assistance of some of you to implement and monitor students who will participate in either the treatment group or the experimental group. Students who have been identified as in need of math response to intervention strategies will be asked to participate in the study. Of those who agree to participate and have parental permission, they will be randomly assigned to either the treatment group or the control group. The treatment group will receive Reflex math computerized intervention sessions that last approximately 20 minutes for four days a week for six weeks. This treatment will take place during your regularly scheduled RtI time segment. There will be nothing to grade or any planning that will have to be done on your part. You will simply have to practice fidelity to the study and ensure that these students participate as scheduled. For those of you who are willing to monitor a control group, you will simply employ the variety of response to intervention strategies that you would normally utilize to help these struggling math learners. All I ask and what is expected is that the strategies or interventions that you use are not related to the automaticity of math facts. The intent of the study is to determine if Reflex math is a beneficial intervention that can be applied during the response to intervention time segment and whether or not the gender of the participants plays a role in the automatic acquisition of basic math facts."

APPENDIX C

Parental Consent

Dear Parents,

Your child is invited to be in a research study trying to determine if Reflex math is an effective tool to use for improving their knowledge of math facts.

This study is being conducted by Mrs. Sarrell, a teacher at Union County Middle School, and a student at Liberty University.

Background Information:

The purpose of this study is to determine if Reflex math is effective at improving the knowledge of math facts for students who struggle with math. It will take 20 minutes per day for four days a week, for six weeks. It will take place during regular class times and require no homework.

Procedures:

If you agree for your child to take part in this study, I would ask them to do the following things: a) take a one-minute pretest of basic math facts, b) be part of a group using Reflex math or another group that helps with math in other ways, and c) take a one-minute posttest over basic math facts.

Risks and Benefits of Being in the Study:

The risks are no more than your child might have in any school day. The benefits to taking part are that your child might improve their knowledge of basic math facts.

Compensation:

All students who complete the study will be entered into a drawing to receive one of several $25 Walmart gift cards.

Confidentiality:

All information from the study will be kept private and remain in a locked file cabinet with only the researcher having access. Your child's name will not be used in any reports.

Voluntary Nature of the Study:

Participating in the study is voluntary. Your decision as to whether or not to allow your child to participate will not affect your current or future relations with Union County Schools or Liberty University. They may withdraw at any time.

Contacts and Questions:

The researcher conducting this study is Mrs. Sarrell. If you have questions, you can contact her at Union County Middle School by calling 706-745-2483 or emailing her at dsarrell@ucschools.org. You may also contact her advisor, Dr. Gina Grogan at gldildine@liberty.edu or by calling her at 615-243-1399.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, you are encouraged to contact the Institutional Review Board, 1971 University Blvd, Suite 1837, Lynchburg , VA 24502 or email at irb@liberty.edu.

You will be given a copy of this information to keep for your records.

I have read and understood the above information. I consent to have my child take part in the study.

Signature of parent or guardian: ______________________________ Date: ___________

Signature of Investigator: ___________________________________ Date: ___________

IRB Code Numbers: 1653.082013

IRB Expiration Date: 8/13/2014

APPENDIX D

Student Assent

Mrs. Sarrell has asked me to take part in a research study that will help determine if Reflex math is an effective intervention strategy to improve the automaticity of basic math facts. She has explained the study and I understand that it may help provide information on how Reflex math might help improve math achievement for students.

I understand that I will be doing the following things:

1. I will take a pretest and posttest over basic math facts.
2. I may or may not receive the Reflex math computerized intervention.

There will be no risks by being part of the study and I can change my mind and drop out at any time without getting in trouble. Only students in my RtI group will know I am taking part in the study because they will have the same opportunity as I did to participate.

Mrs. Sarrell will be conducting the research and I will be able to ask her any questions I have. I have her email, school phone number, and know where her room is located and understand that I can contact her anytime I need to. All information that Mrs. Sarrell obtains will be confidential and will not include any names when reported

I will take part in the study. ______

I agree to have my pre/posttest scores analyzed for study purposes. _______

____

Signature Date

APPENDIX E

Teacher Training Guidelines for Reflex Math

General Information

1. Classes will be created and managed for you by the researcher.

2. All computers in the lab will have a bookmark for Reflex Math on the home page.

3. Four 20 minute sessions per week for 6 weeks for a total of 24 sessions.

4. Tips and tricks webinar be provided via Explorelearning if needed for additional help.

5. Each student will be provided with headphones for use since Reflex makes noise.

Session Information

1. First time students log in they will meet Crabby, a crustacean guide who will help the students create personalized Avatars.

2. Each session begins with a Speed Cube Challenge that determines a student's level of fluency with facts and their families and how fast they can physically respond since the computerized intervention factors in response speed.

3. After the Speed Cube Challenge, student's avatars travel to Reflex Island where they choose a game to play by clicking on the game's tree house. Game choices are limited at first but the choices increase as Reflex is used and they may choose and change games at any time without any additional benefits or drawbacks.

4. When a game is chosen, Coach Penny appears and teaches new facts and families that the results of the Speed Cube Challenge have determined lacking in automaticity.

5. Students will then have an additional opportunity to practice memorized math facts through Coach Penny's Picture Puzzle.

6. Students will earn tokens for practice in each portion of the session as well as for

fluency with a new math fact. When sufficient fluency has been achieved for a session, the Reflex Store unlocks and tokens can be exchanged for items to individualize the student's avatar. The daily usage requirement must be fulfilled and the green light must light up before the store unlocks.

Progress Monitoring

1. The Progress Tree lets students know how many facts they have mastered.

2. Teachers can also access many additional reports via the teacher dashboard that includes a fluency meter, percentage of facts that have been assessed for a group of students, and various alerts for progress and well as mastery (Reflex Teacher Guide, 2011).

APPENDIX F

Pretest/Posttest Administration Guidelines

The FIRST time you administer Basic Facts Task that will serve as a Pretest, say:

"As you know, this RtI group and others within the school class are working with Mrs. Sarrell and Liberty University on a research study to learn more about improving math teaching and learning. Today we are going to learn about a math task that you will be doing this year. It is called a Basic Math Facts Task. You will complete this task at the beginning of the research study and again at the end. Remember that all students participating in the study will be completing the BMOT, and Mrs. Sarrell and her committee will see the scores for all students. Your score will only be used for the research project if both you and your parent/guardian have given permission.

This is what the task looks like (hold up a test). The task is composed of basic math facts. There are a few things you should know about the task.

First, you will be given a limited amount of time to determine the answer to the fact. You will be given 1 minute to complete as many problems as you can. These math tasks are different from classroom tests or quizzes and are not meant to be completely finished. What's important is that as you learn more math facts, your scores will improve.

Second, keep in mind that the object of the task is to correctly answer as many questions as you can in the amount of time given. Please begin in the upper left corner and move across the rows or down the columns (demonstrate). There may be problems on the task that are difficult or unfamiliar. Please look at each problem. If you do not know how the answer to it, skip it, and go on to the next problem. Do not spend a great deal of time on any one problem. If you get to the end of the probe and still have time to work, go back to the problems you skipped and try to solve them.

Third, your scores on these tasks will be used to see your progress in the automaticity of math facts. Because of this, it's important that you try your best.

Do you have any questions at this point?"

Basic Math Facts Task

1. Hand out Basic Facts Skills probes (with the sample page), keeping the probes face down.
2. Ask students to keep the probes face down and write their name and the date on the back of the probe.
3. Set the timer for 1 minute.

Give these standard directions:

“Please turn your paper over. This sample page shows some examples of the types of problems on the Basic Facts probes. Now we’ll take a minute so you can practice doing a Basic Facts probe. If you finish before I say ‘Stop’, please do not turn to the next page. Any questions?

Ready, begin. Time for 1 minute.
Stop, pencils down.

Now that you’ve had a chance to try out this type of probe, do you have any questions? Only answer procedural questions, do not suggest ways to solve the problems.

Now we’ll do the first Basic Facts probe. You will have 1 minute to work on this probe. Remember, your job is to answer as many problems correctly as you can in 1 minute. Please look at each problem, but if you do not know how to do it, skip it and move on. If you get to the end of the probe before the time is up, go back and work on the more difficult problems.

When I say begin, please turn past the sample page and start working. You will have 1 minute. Do your best work.

Ready. (Pause)

Begin.” Start timer.

Time for 1 minute.

When the timer goes off, say, “Stop. Please put your pencils down and turn your probe over.” Collect papers.

For the second administration that will serve as the posttest, say:

“It’s time to do the second Basic Facts probe. Please write your name and the date on the back of the probe; then put your pencil down, so I will know you’re ready. I’d like you to do as many problems as you can. You will have 1 minute; please do your best work.

Ready? Pause

Begin.” Start timer

Time for 1 minute.

When timer goes off, say: “Stop. Put your pencil down and turn your probe face down.”

Collect papers.

APPENDIX G

Basic Math Facts Probe Sample

Examples:

A) 13 – 9 =

B) 7 x 9 =

C) 6 + 3 =

D) 32 ÷ 8 =

Try these:

8 – 7 =	7 + 3 =	27 ÷ 9 =	4 x 0 =
5 ÷ 5 =	11 – 3 =	12 – 8 =	0 x 9 =
2 + 5 =	1 – 0 =	9 x 1 =	3 + 0 =

APPENDIX H

Basic Math Facts Probe for Pretest

1-1=	8 x 1 =	5 x 5 =	1 x 7 =
4 x 7 =	5 x 7 =	4 + 6 =	9 x 5 =
3 + 0 =	12 ÷ 3 =	14 ÷ 2 =	6 ÷ 6 =
12 – 9 =	7 + 4 =	0 x 7 =	7 – 4 =
10 ÷ 5 =	48 ÷ 8 =	11 – 7 =	12 ÷ 4 =
8 – 2 =	9 + 6 =	6 + 6 =	1 x 2 =
8 + 7 =	0 x 0 =	11 – 2 =	8 – 5 =
6 – 2 =	7 + 0 =	3 + 3 =	17 – 9 =
10 – 4 =	9 x 9 =	4 ÷ 4 =	5 ÷ 1 =
1 ÷ 1 =	2 – 2 =	5 + 9 =	7 x 8 =
54 ÷ 6 =	9 – 3 =	32 ÷ 4 =	16 – 7 =
4 + 5 =	14 – 9 =	7 + 6 =	2 x 6 =
8 + 8 =	13 – 6 =	2 x 4 =	0 ÷ 5 =
1 + 0 =	6 x 2 =	2 + 8 =	1 + 8 =
63 ÷ 9 =	27 ÷ 3 =	15 ÷ 3 =	36 ÷ 6 =
0 + 0 =	8 x 3 =	8 + 5 =	42 ÷ 7 =
13 – 8 =	24 ÷ 6 =	2 x 2 =	2 – 0 =
9 + 1 =	6 – 3 =	0 + 7 =	3 x 5 =
8 ÷ 8 =	4 x 9 =	9 – 7 =	40 ÷ 5 =
5 + 2 =	7 – 0 =	1 x 6 =	8 + 0 =

APPENDIX I

Basic Math Facts Probe for Posttest

6 ÷ 2 =	56 ÷ 8 =	5 – 1 =	35 ÷ 7 =
11 – 6 =	9 – 2 =	20 ÷ 4 =	5 × 6 =
8 – 0 =	0 ÷ 8 =	9 – 5 =	21 ÷ 7 =
1 × 8 =	6 × 9 =	5 -3 =	0 × 2 =
8 × 8 =	12-3 =	6 + 2 =	9 +8 =
8 × 6 =	3 ÷ 1 =	12 ÷ 3 =	72 ÷ 8 =
6 + 6 =	9 – 1 =	7 × 7 =	4 × 1 =
7 – 7 =	10 ÷ 2 =	2 × 1 =	5 + 5 =
0 + 9 =	2 × 5 =	45 ÷ 9 =	4 + 7 =
17 – 8 =	3 × 9 =	6 ÷ 1 =	6 + 4 =
9 + 0 =	5 ÷ 5 =	0 + 6 =	3 – 0 =
7 – 6 =	0 × 5 =	12 – 4 =	8 × 5 =
6 × 3 =	8 + 1 =	7 + 9=	0 ÷ 6 =
0 + 4 =	9 × 4 =	8 ÷ 1 =	45 ÷ 5 =
6 × 8 =	6 ÷ 3 =	3 + 4 =	8 – 8 =
8 ÷ 4 =	10 – 9 =	2 + 9 =	15 – 9 =
4 – 2 =	9 + 6 =	4 + 3 =	14 – 7 =
18 – 9 =	8 – 4 =	4 × 6 =	15 ÷ 5 =
30 ÷ 6 =	3 × 1 =	16 ÷ 8 =	1 × 5 =
3 + 8 =	7 + 6 =	1 + 2 =	9 + 4 =

APPENDIX J

Institutional Review Board Approval

LIBERTY UNIVERSITY
INSTITUTIONAL REVIEW BOARD

August 20, 2013

Daphne M. Sarrell
IRB Exemption 1653.082013: The Effects of Reflex Math as a Response to Intervention Strategy to Improve Math Automaticity among Male and Female At-Risk Middle School Students

Dear Daphne,

The Liberty University Institutional Review Board has reviewed your application in accordance with the Office for Human Research Protections (OHRP) and Food and Drug Administration (FDA) regulations and finds your study to be exempt from further IRB review. This means you may begin your research with the data safeguarding methods mentioned in your approved application, and that no further IRB oversight is required.

Your study falls under exemption category 46.101 (b)(2,), which identifies specific situations in which human participants research is exempt from the policy set forth in 45 CFR 46:

> (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless:
> (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation

Please note that this exemption only applies to your current research application, and that any changes to your protocol must be reported to the Liberty IRB for verification of continued exemption status. You may report these changes by submitting a change in protocol form or a new application to the IRB and referencing the above IRB Exemption number.

If you have any questions about this exemption, or need assistance in determining whether possible changes to your protocol would change your exemption status, please email us at irb@liberty.edu.

Sincerely,

Fernando Garzon, Psy.D.
Professor, IRB Chair
Counseling

(434) 592-4054

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APPENDIX K

Georgia RtI Graphic Permission

Ms. Sarrell,

My name is Dr. Paula Freer and I serve as the RTI Contact for the Georgia Department of Education. I was forwarded your request and checked with our legal department at GaDOE and was given the following information for you:

The Georgia Department of Education (GaDOE) is happy to grant limited permission to you to utilize GaDOE's *Georgia Pyramid of Intervention Graphic* as a reference figure in your dissertation.

Any use of the material and reproductions must expressly state that all rights in and to the material belong to the Georgia Department of Education. Please note that this permission is a revocable non-exclusive license granted by GaDOE. The license is limited to the non-commercial use by you only as described above and cannot be assigned to or assumed by another party. No other permission is granted or implied.

Paula

Paula Freer, Ph.D.
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APPENDIX L

Permission to use BMOT

Basic Math Operations Test

Daphne Sarrell Fri, Jul 6, 2012 at 12:04 PM

Ms. Foegan,

As a doctoral student at Liberty University in Lynchburg, Va. I am interested in determining the impact of fluency in regards to basic math facts. I am interested in using the BMOT outcome based measure that was developed and cited in your article, *Identifying Growth Indicators for Low-Achieving Students in Middle School Mathematics.* Do I have permission to use the test as part of my dissertation research, and if so, would you be willing to send me a copy?

Thank-you,

Sincerely,

Daphne Sarrell
Union County Middle School
Special Education Teacher

Foegen, Anne M [C I] Tue, Jul 10, 2012 at 10:30 AM

Hi Daphne,
Thank you for your interest in my work. The BMOT was a simple math fact fluency task. I've attached a copy of two forms that I've used in research studies more recently (see the article in Remedial and Special Education, 2008 on middle school progress indicators, which also included facts). I have additional forms if you might need them. I've also included keys and the administration materials (directions and a sample page) that we used in the 2008 study.
Best of luck with your doctoral studies! We need more folks doing research related to mathematics and students with disabilities.
Take care,
Anne Foegen, Ph.D.
Associate Professor, Special Education
Director of Graduate Education
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N162D Lagomarcino Hall
Iowa State University
Ames, IA 50011
515.294.8373
afoegen@iastate.edu

From: Daphne Sarrell
Date: Friday, July 6, 2012 11:04 AM
To: Anne Foegen
Subject: Basic Math Operations Test