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Comparing math fluency and automaticity using explicit timing with students with disabilities

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COMPARING MATH FLUENCY AND AUTOMATICITY USING EXPLICIT TIMING WITH STUDENTS WITH DISABILITIES

by

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Dedication

I would like to dedicate this manuscript to my mother Germaine W. Ehala and my father Richard Ehala.

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I would like to express my gratitude to Professor S. Jay Kuder for his guidance and patience throughout this research. The skills and knowledge that I have learned have been invaluable and I will take them to the next stage of my educational career. I would like to thank Mrs. Carolyn J. McDonald and Mr. James DiDonato for all of their guidance and support throughout my teaching career.

Abstract

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The purpose of this study was to determine the mathematical fluency performance of a group of students with various learning disabilities in an eighth grade classroom by implementing and intervention intensification program that incorporates an explicit timing model. Students demonstrated a wide range of progression with their mathematical fluency with all students showing progress from the start of the study to the conclusion. Analysis of the data determined that student's fluency levels increased at a faster rate when provided with a consistent intensive regime of math computational facts. Implications for teaching students with disabilities mathematical fluency are discussed.

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Table of Contents

Table of Contents (Continued)

List of Tables

Chapter 1

Introduction

When students have reached middle school they are introduced to algebraic principles and concepts. Some schools have even adopted curriculum that integrates algebra into the elementary schools. When taught at a rigorous and steady pace students have shown consistent progress and growth in developing the tools, skills and knowledge for understanding and applying algebraic principles in mathematics. However school districts may become so caught up in being cutting edge with introducing these concepts that often the fluency and basic mathematical skills needed for higher order thinking are not being re-enforced at the rigor they should be. Some special education students are even at a further disadvantage when it comes to mastering math fluency. Some students with learning disabilities haven't attained the necessary prior knowledge needed in order to be proficient at these algebraic concepts. While a general education student will typically make progress in their fact fluency over time, a student with disabilities may struggle with retaining their facts and will not be able to progress as efficiently through normal learning strategies. To address this issue, curriculum has begun to be reformed towards putting a stronger emphasis on fact fluency memorization for special education students by increasing the rigor or memorization in a creative manner. This study will focus on placing an emphasis on developing fact fluency skills through multiple means of repetition and presentation that will actively engage students in a creative learning environment.

In 2009 the National Mathematics Advisory Panel (NMAP) concluded that 40% of fourth graders demonstrated proficiency on standardized assessments, only 32% of eighth graders demonstrated proficiency and only 23% of twelfth graders demonstrated proficiency (Golightly and Rave). These statistics conclude that as students begin more coursework in algebra there is a sharp drop off in their fluency achievement of basic concepts and skills.

Statement of the Problem

In this study I plan to examine the relationship between fluency and automaticity of math skills. “Fluency is generally acquired in a three phase process: simple counting, critical thinking and calculation and automatic retrieval of responses” (Golightly and Rave). My objective is to determine if increasing fluency practice will have an effect on their response time and increase their automatic retrieval of their skills when tested. I implemented an intervention intensification strategy in which students are given a placement test on the computer with a three second response time to answer each multiplication question. As a special education math teacher in a pull out resource room, the one main commonality I have observed over my four years teaching is that these students continually struggle with their automatic retrieval of basic skills which leads to a low frustration level and a negative “domino effect” on the quality and effort of their work.

As it is the same with reading comprehension and literacy, math fluency is a skill that requires daily repetition and practice. Students with learning disabilities struggle with retaining material and require the continuous practice and repetition in order to develop that automatic fluent response to their basic skills. My research question that I will examine in this study is:

1. Will students with disabilities increase their math fluency and proficiency when they are provided with an intervention intensification program that focuses on mathematical fluency and automatic response?

This study will be conducted across two 8th grade special education classrooms. The control will be a baseline assessment that the students will be given without any intervention strategies. This baseline will be used to help tier the students into three categories: Low, medium, and high. Students will be tiered into the three categories based off the initial proficiency score they receive on the baseline. Students will be given twenty minutes each day to focus on the specific skill and difficulty of the problems over the course of a four week trial.

The intervention group will consist of ten 8th grade students who are in the Pull-Out Resource classroom that I instruct. Of the ten students, five are classified with Specific Learning Disabilities (SLD) specifically in math calculation, three are classified as Other Health Impaired (OHI), one is classified as Communication Impaired (CI), and one is classified as Multiply Disabled (MD), with Emotionally Disturbed and Other Health Impaired. All of the students have been classified by the school district and have Individual Education Plans (IEP's) written accordingly to each classification. Each student also has specific goals and objectives that are met in their IEP's as well.

The independent variable in this study will be the math program *XtraMath*. It is a computer software program for developing math fluency for a wide range of basic skills. By using this program, the students will have access to practice their math facts daily in class by logging into the computer or chrome books. Students will work on developing fluency, cutting down their response time for questions, and increasing their automatic fluency. The students will first take a placement quiz on XtraMath based off of the program they are set to. For this study, all students will take the multiplication placement quiz. The quiz gives students a four second response time to answer each question before moving on. Every answer is calculated with either a check for correct, an x for incorrect, and a question mark if left unanswered. This quiz will give the students a proficiency percentage that the teacher will record for the initial benchmark. The students will then continue to practice these facts daily to improve on their proficiency and fluency as the response time is cut down to two seconds. Once a student masters the level that they are on, they will receive a certificate that documents when they are ready to move on to more advanced problems and facts.

The dependent variable in this study will be the response time the computer software program XtraMath. All students will begin the program with a response time of four seconds. Over the course of the study the goal is for these students to go from a four second response time for their facts down to a two second response time. Each student will be on a specific program based off of their initial baseline results with a four second response time. Students will advance to a three second response time once the program recognizes that they have mastered fluency at a four second response, and once they master a three second response the program will then reset to a two second response.

Significance of the Study

In this study a control group of 8th grade students and a tested group of 8th grade special education students in a pull out math resource room will be tested to analyze how a change in instruction will impact their math fluency for special education students. An intervention intensification methodology of teaching will be implemented into the special education classroom that will allow these students to practice math fluency using the software program XtraMath. It will be hypothesized that special education students who receive this extra intervention will be able to retain their math fluency and improve their automatic response from a four second response down to a two second response. If my hypothesis is proved to be correct, this intervention could impact the way special education math is being taught in schools without changing the curriculum. It will provide teachers with a more interactive way of developing automatic response time and fact finding fluency without decreasing the expectations and rigor of the classroom. Teachers will continue to implement the same curriculum as before during instruction, but the students will be able to achieve a higher order of thinking due to an increase in response time of the fact fluency. This could eventually lead to less students being required to be in a Pull-Out Resource program and to be placed in a lesser restrictive learning environment. It will give the students the necessary steps to grow and become more efficient in higher order mathematical calculations.

Chapter 2

Literature Review

Math fluency application is one of the most fundamental goals for math education. However as recent as 2005 only 38% of fourth grade students were considered proficient in their mathematical fluency according to the National Assessment of Educational Progress (NAEP,2005). This number figures to be significant less with the population of students with learning disabilities. In fact when the NAEP surveyed students with learning disabilities it was reported that 64% of 4th graders and 70% of 8th graders did not demonstrate grade level competency skills (Jaspers, Pouncy, Skinner, 2006).

Developing response time is the first step to the mastery of math fluency. In the primary grades students are provided with rigorous repetition of math facts with the hope that the more they see the equation and can solve it the easier it will be for them to recall the answers on an assessment or for more advanced work. In order for math fact rehearsal to be effective, it should include materials that provide an appropriate level of difficulty and utilize brief practice opportunity that incorporate modeling, feedback, timed practice, self-management, and reinforcement (Burns, Kanive, Nelson, Ysseldyke, 2013). Typical math fluency strategies include flash card repetition to memorize facts, minute math worksheets for fluency competency and response time progression and benchmark assessments to track student progression. In most cases, accurately mastering basic math facts requires little effort (Jaspers, Pouncy, Skinner, 2006), however as students advance to the higher grade levels, the curriculum becomes more abstract which requires students to recall their fluency skills and apply them to these concepts. The more proficient the students are at recalling their fluency; the easier they can apply them to these abstract algebraic concepts and are generally more successful in mathematics.

Computational Fluency

The Principles and Standards for Teaching Mathematics of the National Council of Teachers define computational fluency as “having efficient and accurate methods for computing; to be efficient, students must perform calculations at an appropriate rate for a given skill level” (Calhoon, Emerson, Flores, Houchins, pg 292). Students must be able to be computationally fluent at an identified level of difficulty within given time period. The NCTM believes that computational fluency is so important that they have created a standard for kindergarten through eighth grade asserting that by eighth grade students should able to fluently apply mental math to whole and rational number operations and that by the time they enter high school computational fluency is to be assumed and is no longer a standard or practiced in a classroom setting (Calhoon et al., 2007). Computational fluency is the building blocks of mathematics and if students do not develop these skills at an early age they are severely limited to learning and applying higher order thinking as they get older.

Students with learning disabilities in mathematics all display weak recall of basic facts as one of the most common characteristics. Other targeted areas of weakness for these students are: upper level division of whole numbers, basic operations involving factions, decimals and percentages, fraction terminology and multiplication of whole numbers. All of these weaknesses can be attributed with a struggle of computational fluency. Since these students haven’t mastered these fundamental mathematical concepts upper level concepts such as multi-step equations will continue to be an area of weakness for students.

Calhoon, Emerson, Flores and Houchins conducted a study in 2007 that involved two hundred twenty-four high school students. Each student was identified based on standardized assessments by their school district as students with mild to moderate learning disabilities in the area of mathematics. They were all taught in a special education resource room; all had IEP goals for mathematics and met all local, state and federal eligibility requirements for special education. The students were given the Mathematics Operations Test-Revised (MOT-R) for an initial placement/pre-assessment test. The test consisted of fifty questions requiring addition, subtraction, multiplication, and division with whole numbers, decimals and fractions covering grades first-sixth. The test was administered in a pencil and paper format in the student's resource rooms during their math period of the day. Scripted directions were read to each class before the test began. Students had ten minutes to complete as many questions as possible before they were told to stop and the tests were collected (Calhoon, Emerson, Houchins & Flores, 2007).

The test results showed that the percentage correct decreased and the percentage increased across each grade level until fourth grade where the percentages hit a plateau. After the fourth grade, the continuing decline in percentage correct was due to an increase in the number of items that students did not attempt (Calhoon, et al., 2007). This trend also continued in the various skill areas that were covered in the test. The percentage correct decreased as the skill area increased in difficulty. Just as students attempted fewer items above a fourth grade level, they also attempted in fewer problems involving fractions and decimals resulting in a higher percentage of questions incorrect due to unanswered problems. This article displays a decline in computational fluency of the population of special education due to the lack of practice and repetition of facts as they progress to higher education.

Mnemonic Strategies

Mnemonic strategies typically are often referred to words and sentences in order to enhance storage and recall facts. Strategies involving a peg word or some association with a number to remember lists, keywords associating with a similar sound and acronyms have been known to help improve computational fluency for struggling learners because they can rely on cues rather than repetition. While repetition is a very successful intervention when used correctly and appropriately, it can also cause a high frustration level with students who continually struggle with math fact fluency. The peg word is a highly successful mnemonic strategy since students are taught a rhyming sentence to match a math fact. When students were presented with an equation such as 3x3=9, they were presented with a visual showing two trees on a line and the students are taught “tree and tree on a line” (81) as a verbal cue to remember the answer because it rhymes with three times three is nine (Frank, Wacker, Wood 1998). Times Table the Fun Way (TTWF) is an intervention similar to the peg method that incorporates visuals that are designed to help students with disabilities an alternative method to recall their basic math facts. This method teaches students to compare numbers to real life pictures and visuals such as the number 8 looks like a snowman. This strategy cues upon keywords that sound familiar to the number equation and is consistent with common mnemonic strategies (Burns, Kanive, Nelson, Ysseldyke 2013).

In this study, a random sample of ninety third and fourth graders who scored below the 25th percentile on a district administered standardized mathematics assessment. Students went to the computer lab to practice their mnemonic strategy intervention. Each math fact that was presented to them was associated with a story designed to enhance retention (Burns, Kanive, Nelson, Ysseldyke, 2013). Struggling learners are often strong visual learners so providing them with a visual to go along with the equation helps build and enforces the foundation of fluency. Two or three of the facts and associated stories were presented each day for this study.

The mnemonic strategy (TTFW) was selected because it focused on the recalling of specific multiplication facts. More and more school districts have adopted curriculums that introduce algebraic concepts to students at a younger age in which case there is less time in the classroom to emphasize a foundation of their basic skills. Memorization of multiplication facts are the foundation to understanding algebra and if students struggle with fluency and basic skills, they won't develop the higher order abstract skills needed to solve and understand algebraic concepts. TTFW provides teachers with a strategy that they can share with their students about how to relate math facts and fluency with real life objects.

Rocket Math Fluency Program

In order to help teachers and districts improve math fluency for all students, mathematic intervention programs have been developed based off of successful intervention strategies. In 2010 the National Center for Education Statistics (NCES) through math assessments showed that only 40% of fourth graders demonstrated proficiency on standardized assessments, 32% of eighth graders showed proficiency on their grade level assessment and only 23% of twelfth graders showed proficiency (Golightly, Rave 2010). This research continues the trend stated earlier that as students get older, there is less time to work on and develop fluency which causes a gap in educational achievements for more advanced concepts. Golightly and Rave (2010) conducted a survey on student's weaknesses in basic skill fluency by interviewing algebra teachers. The most common response was that students have become over-reliant on calculators for basic calculations. Using a calculator for these basic skills prevents students from becoming more fluent and proficient in fact memorization due to that the students are not actually practicing the skills needed to solve them. In developing fluency, accuracy must be adequately developed before automatic responses become the goal (Golightly, Rave 2010). What Golightly and Rave researched and studied was finding motivation factors to use for students so that the drill aspects of math fluency don't become dull and potentially aversive to students. They found that allowing students to track their own progress in addition to frequent feedback regarding their performance are the best practices to maintain motivation and develop self-regulated learning.

To measure the effects of the Rocket Math Program a study was conducted by Golightly and Rave (2010) from forty four students in three fifth grade classrooms. Students were all between ten and eleven years old. The classrooms began Rocket Math at the multiplication level while other grades doing this same program began with addition and subtraction. Baseline data was gathered using placement probes prior to the implementation of the intervention. All students were leveled and were given an initial problem completion task based on their performance on the probes. The probe consisted of the students being asked to copy as many numbers as possible in one minute. Depending on how many numbers they could write, a corresponding goal was set for the amount of problems they should be able to complete and solve. Based on the number of probes passed, each student was placed at his or her starting fluency level. The students had practice sessions two-to-five times a week for nine weeks for a total of twenty eight sessions.

Each day the students practiced in pairs for two minutes. One student was the "checker" and the other one was the "learner". The problems were practiced out loud and read to each other. The students completed as many problems as possible in the allotted time. After practicing the students a one minute probe that had the problems on a worksheet. If a student met or exceeded their goal they moved onto the next level and if a student's goal was not met they had to continue to practice that probe level. If a student failed to pass a level after five attempts they dropped back a level until that was passed and could move on again. As students passed levels, they filled in corresponding bars on their Rocket Chart to visually track their own progress. Every two weeks a progress monitoring test was given for data collected. Data from these progress tests as well as results from the daily probes were analyzed and graphed to track and monitor student progress upon completion of the study (Golightly, Rave 2010).

The results of this research showed that forty one (93%) of the students made positive strides in their math fluency and improved their automatic response times. Only three students suffered regression in their percentages. Golightly and Rave theorized that because the study did not include a component to measure general accuracy levels before the intervention, some of the students did not have sufficient practice and accuracy with math facts in order to effectively increase fluency. While Rocket Math does not explore the effectiveness of the same strategies for other basic facts and skills such as division it did have an immediate positive impact on students multiplication skills which will naturally improve their division and other basic math skills.

Detect, Practice and Repair Model

Detect, Practice and Repair (DPR) is a three stage test technique that is used to individualize math fact instruction for each student in a whole class setting while targeting a specific basic skill group (Fontenelle, Poncy, Skinner, 2013). The authors targeted ways to increase math fact instruction in a whole class setting without the need to break up special education students into small group settings. While these forms of interventions are very successful, research shows that these math fact weaknesses are displayed across general education classrooms as well. Research has now begun on how to design intervention strategies and models to prevent math fact deficits at the class wide level (Fontenelle et al., 2013).

This study was conducted across eleven fourth grade students. A paced pre-test was used to detect (D) items that each student will use to practice. The assessment differentiates between items that can be completed with automaticity and items that a student accurately but with difficulty. After each student completed this phase each student the first five uncompleted problems in their own pre-test. These uncompleted problems will be the targeted skill that will be used in the practice phase. With each targeted skill there are five questions that students will focus on for a total of twenty-five questions. The practice (P) phase students are instructed to complete the items starting with the first one and ending with the fifth and the repeat the process until they complete all items or if time expires. The last phase is repair (R). In this phase, explicit timing is used to elicit generalized responding with the five targeted items that are integrated into a larger group of facts. This is considered a "math sprint" and students are to graph their performance.

The intervention sessions for this study were conducted once a day for fifteen minutes at the beginning of the participant's math period. The initial assessment was an eighty question math fact assessment in which they had to answer as many questions as they could in two minutes. The detection phase identified two students who needed to work on subtraction, three who needed to work on multiplication, and seven who needed intervention with division facts.

When the students moved onto the practice phase, they used the Cover, Copy and Compare approach to practice their facts. Students would read the printed problem and answer, cover the problem and answer, write the problem and answer and then check the model for accuracy (Fontenelle et al., 2013).

The final phase which was the repair stage required the students to "sprint" and complete as many problems as possible in one minute. The instructor emphasized accuracy during this one minute timed sprint. When students were finished they were told to count the number of problems completed and correct and then document it in a chart.

While this study used a very small sample size, it was still concluded that the DPR model was successful. Nine of the eleven students (82%) showed gains in the mathematical skill they were tasked with working on. This was a study to show that in order for teachers to meet a wide variety of skills in the general education classroom, they need to show differentiation of their instructional methods. The goal was to increase student learning rates by providing an appropriate skill to instruction match. The DPR model was effective in that it was able to simultaneously meet the needs of the students both across and within fact computation skills (Fontenelle, et al., 2013).

Intervention Intensification

The utilization of intervention strategies through an intensive program is crucial in order to be successful with students with disabilities. Recently, the secondary mathematics curriculum has become less concrete driven and more abstract with algebraic principles, the time to work on these fluency skills have decreased as well. When students are given the opportunity to work on basic math facts it is not at the rigor and demand that they require especially if they are functioning below grade level. Less structured approaches to intensification may simply add or remove interventions components until a combination of components may be employed until they result in the desired effect (Duhon, House, Hastings, Poncy, Solomon, 2014). Even though there are many different intervention strategies available for improving fluency responses, little is known about how they interact when they are intensified for an extended period of time.

Data Based Individualization Intervention Intensification

A strategy that has been implemented for a more intensive form of intervention, is Data Based Individualization or DPI. This is used when students require a specific individualized method of instruction to accommodate their learning disability. DPI is an empirically proven method for individually tailoring instruction for students with learning disabilities (Fuchs, Fuchs, and Vaughn, 2014). A study was conducted that was designed to determine if DPI can help teachers provide stronger, more strategic plans and can help accelerate the academic growth of struggling learners. This teacher designed a progress monitoring sheet that had specific, hand-picked goals geared towards increasing the student's math fluency in multiplication. In order to set the goals, the teacher spent three days with the student collecting data by given initial assessments. She used the median score from the three tests to calculate the student's level of performance. The teacher then plotted a baseline score on a graph to begin plotting the student's baseline performance. In order to determine goals, the teacher can use normative information to indicate how much progress is made by general education students performing at grade level without any interventions and compare it to the progress made each week by the student in the research study (Fuchs, et al., 2014). The teacher will then plot a second point on the graph indicating the goal line and draws a line connecting the baseline score to the end of year goal.

Throughout the school year the teacher will collect and graph data each week as the intensified instructional program begins (Fuchs, et al,. 2014). As soon as four consecutive points fall above the created goal line for the student the teacher will increase the goal line and re-draws a new goal line. This way the goals continue to grow and the teacher is able to show precise development for the student in the study. If four consecutive goals fall below the goal line, then the teacher can re-visit and change the goals and revise the instructional program. In order to determine progress or revisions in the program a line of best fit is drawn after every eight points are plotted and graphed. If the line is steeper than the original goal line, the teacher can set new higher achieving goals, and if the line is less steep than the goal line, revisions can be made to the instructional program. The teacher is continually inspecting the progress monitoring sheets that the data is on to identify weaknesses in the student's skills or in the program that can be revised and can also provide additional targets of instruction.

This study on DPI is a very small sample size that took place over the course of one academic school year with one student. The research did show that through an intensified instructional intervention, the student was able to show progress in their multiplication fluency which was the goal that was set by the teacher. The student was able to recall prior math facts learned and apply them in higher order thinking and they should a steady growth throughout the school year. What's important about DPI is that it can be modified specifically to meet the student's individual academic needs. Each DPI program will be unique due to each student and the length of time that the program is used will be different based on how fast the student can progress.

Explicit Timing

Explicit timing has been a successful intensive strategy that has been used for increasing fluency and improving student's responses. Explicit Timing (ET) has seen extensive use due to the ease at which it can be implemented (Duhon, House, Hastings, Poncy, Solomon, 2014). These techniques can be implemented with large groups of students simultaneously and can be easily implemented in a classroom setting. Interventions have been implemented based off of explicit timing in order to decrease the students automated response time. In 2010 Poncy and Duhon reviewed extensively the effects of explicit timing and how the interventionist provides the learners with a set of problems, and times the learner as they complete as many problems as they can in the time frame. Regardless of what strategy was used, it was concluded that in order to enhance the effectiveness of the interventions the frequency or duration can be increased. By increasing the frequency of the intervention strategy allows the instructor to focus on specific skills for the students to concentrate on. Instead of quickly covering a wide range of skills, they can narrow it down on specific weaknesses and increase the rigor of the practice.

Goal and Reward Setting for Explicit Timing

One benefit for utilizing explicit timing is that it can provide immediate resolutions. Duhon, House, Hastings, Poncy, Solomon researched and discovered that by setting goals and rewarding the students immediately conditioned them to focus more on the timer that was set. Students in this group practiced every day for two minutes. The goal was that if the students exceeded the performance from the previous day they could select a prize from the prize box. The students were continually informed of the reward for exceeding their work from the previous day, the current number of rewards earned and the amount of numbers they got correct from the previous day (Duhon et al., 2014).

At the conclusion of this study it was reported that this was the group of students that performed the highest. Students were more motivated because of the rewards and concentrated harder on finishing the facts within the two minute window.

Performance Feedback with Computer Based Technologies for Explicit Timing

In order to provide an immediate feedback on the effects of explicit timing, Duhon, House, Hastings, Poncy & Solomon (2014) conducted a study to systematically the effect and immediate accuracy feedback on math fluency when added to an explicit timing (ET) intervention. The study was also designed to determine whether a specific form of intervention intensification would amplify the effect of ET (2014). The study examined forty-eight second graders in which all activities were conducted in the school's computer laboratory. Students used a web based computer program which displayed math problems one at a time. They consisted of simple subtraction problems randomly generated and presented one at a time. A "no" feedback mode that displayed a randomly generated subtraction problem with a response box below the problem was where the students answered each question. Students were given a 2 minute session and when the session timed out, the program closed automatically. An "explicit timing" mode was also utilized which counted down minutes and seconds from 2 minutes down to zero. A third option that displayed immediate feedback was used to provide feedback based on accuracy. Visual and auditory feedback was both provided. Students visually saw a large green check mark for correct answers and a large red X was used for incorrect responses. Auditory feedback consisted of a ding or buzz following each student response.

Prior to any testing sessions, all participants were given an initial assessment and were instructed to complete as many problems as possible. This was completed over the course of three days and after which the accuracy of completion was examined. Once the pre-test was completed and established the students were tiered to the ET with goal setting. Over the course of twenty consecutive school days, students were brought to the computer lab to practice upon their tier groups.

Upon completion of the study it was concluded that the students in the Explicit Timing with immediate feedback performed significantly higher than the group that did not get immediate feedback. The results provide evidence that validating the addition of immediate feedback was an effective method of intensification when added to an Explicit Timing program (Duhan, Hastings, House, Poncy, Solomon,2014). While the explicit timing itself was not an effective method; when paired with the intensification of repetition and intervention it allowed the students to become more proficient at developing their math fluency skills.

Summary

What this study and research has shown is that, with appropriate instruction, it is possible to achieve an increase in the development of math fluency with students with disabilities. Ongoing intervention is crucial for special education because it allows that additional reinforcement of basic skills that a general education classroom may not spend as much time with rehearsing due to the increased curriculum demands. Activating this prior knowledge helps students with disabilities.

Older students with disabilities have shown that despite taking mathematics courses with algebraic concepts, they continually struggle with the basic fluency and struggle with applying those concrete facts with the abstract. Teaching these students is about making sure that they have and develop a strong mathematical foundation that they can take and apply it as they progress in math. The purpose of my study is to build upon and conduct research which supports that with an intensification of intervention, students with disabilities will develop a better explicit timing and become quicker at their automated response time with fundamental mathematical practices and fluency skills.

Chapter 3

Methodology

This study took place in two eighth grade pull out resource mathematics classroom in a middle school in New Jersey. In eighth grade, students are exposed to algebraic equations, linear functions, slope intercept form, the Pythagorean Theorem and geometric transformations. The curriculum that is taught is Math in Focus by Houghton, Mifflin & Harcourt that is written and published by Pearson that the district has adopted. The pre-requisite for this class is that students must pass seventh grade mathematics following the same curriculum material. All mathematic courses are aligned to follow the New Jersey Common Core.

The study began with eleven students however one student is in the process of undergoing an IEP re-evaluation plan. Another student moved out of district but that number was replaced by a student who returned off of home bound instruction. The first class consists of three female and the second class consists of eight students, four male and four female. Both classes are eighty-four minutes long.

Prior to the intervention phase, the students received a timed assessment of basic skill multiplication questions. The results of this assessment placed the students into three categories: Low, medium, and high. Students were tiered into the three categories based off the initial proficiency score they receive on the baseline. The students who are taking this control assessment will not have any modifications during this assessment. Students took the assessment until it was completed.

The state standard that this project was: CCSS.Math.Content.7.NS.A.2.C which addresses, “Applying properties of operations as strategies to multiply and divide rational numbers”. One of the instructional/interventional objectives is for the students to improve on their response time when answering the questions. Explicit timing provides them with a rigorous intervention intensification program that provides sufficient repetition and practice for the students to review their basic multiplication facts. Constant repetition of these facts allows the students to develop mental math which leads to these basic math facts to become effortless for them to recall. Students achieve automaticity with math facts when they can directly retrieve the correct answer, without any intervening thought process. The explicit timing strategy model is the foundation to developing this higher order thought process of automaticity. The goal is for the students to practice continuously for a short amount of time each day rather than practice once or twice a week for a longer session. Explicit timing allows the students to develop the ability to answer a large amount of math facts in a short amount of time.

To model explicit timing, the students worked each day mastering their multiplication facts. Students were broken up into rotations that will rotate between small group instruction of the lesson and working independently on the computer on these basic skills. When the students log onto the program it will begin right where their placement level is. The program is set to a four second response time for each problem. If a student answers the question correctly it will move on to a different question, if a student answers incorrectly an X will appear and the program won’t let the student move on until they answer it correctly. If a student doesn’t answer the question in the amount of time given, then the answer will appear, the student can type it in and the same question will re-appear.

To show growth and mastery of these skills, students were assessed on their progress with weekly progress quizzes that they will take at the end of each mini lesson. They used the practice portion of the software three days of the week and then on Thursday's took a "Race Against the Teacher" progress quiz that the software generates. The progress quizzes consisted of problems that are similar to the ones that each student practices throughout the week. The difference is that they did not have the opportunity to see what the correct answer is if they miss a question. Each problem was scored immediately and then they were given a percentage when the quiz is complete. Mastery was shown when students complete each level move on to the higher level of questioning. Students were not able to show complete mastery of all of their facts due to the time restraint but the goal was that over the course of the school year by practicing the software on a consistent routine, they would show the mastery skills of facts needed to be successful in higher level mathematics.

Over the course of four weeks (twenty school days) the students were instructed to log into XtraMath on the computers. The students broke up into the two tiers and logged onto the computers in groups. The tiers were created based on how the students did on their fluency placement quiz. One group worked on fluency skills using the software and the other group worked with the instructor in a guided math group working on the lesson. Before the students brake up into the groups and rotations, the class completed a whole class lesson together with the lesson that was planned based off of the curriculum. Students on the computer practiced their fluency independently in a race against the timer on the software. The students that work with the instructor completed guided practice and independent practice of the lesson content. This gave the instructor a lot of opportunities for direct instruction and a chance for quick formative assessments to determine individual student's strengths and weaknesses with the lesson content.

The assessments are a computer generated pre and post assessment through the software program. When the students register for XtraMath they took an initial placement (pre) test to determine their starting point of the program I have set for them. The teacher set the pre assessment on basic multiplication facts using digits 0-9. Each exam was randomly ordered consisting of the same problem. The questions started with simple single digit multiplication facts such as 1x5. If students correctly answered the question it would move on to a harder question such as 2x7. If answered incorrect or left blank it would stay at the same level of difficulty until the student answered enough questions. The more questions the student answered correctly, the harder the degree of difficulty the questions became. The software was then able to generate a fluency percentage based off of how many questions the student answered correctly and their program was set to their ability. Once the students are tiered they worked on practice problems and models each time they log onto the computer. At the end of each week they took a progress quiz in order to assess their development. In order for a student to move onto the next level of questions they must have at least at an 80% proficiency to have the program considered them mastered. The post assessment was the same test as the pre-assessment with the questions randomly ordered and the posttest had a shorter response time to determine if the explicit timing strategy is effective. Both assessments consisted of a variety of questions that go from easy questions to more difficult multiplication questions. The instructor wanted to see growth from answering a question in four seconds down to two seconds in the program but also be able to see acquisition and retention of these skills during small group instruction during the lesson. These skills are needed to be successful in the math curriculum the school district uses and throughout this process, students will be evaluated not only on their skills on this program but how they use them and apply them to algebra in the classroom.

Variables

The independent variable in this study was the math program XtraMath. It is a computer software program for developing math fluency for a wide range of basic skills. By using this program, the students had access to practice their math facts daily in class by logging into the computer or chrome books. Students worked on developing fluency, cutting down their response time for questions, and increasing their automatic fluency. The students first took a placement quiz on XtraMath based off of the program they were assigned to. For this study, all students took the multiplication placement quiz. The quiz gives students a four second response time to answer each question before moving on. Every answer is calculated with either a check for correct, an x for incorrect, and a question mark if left unanswered. This quiz gave the students a proficiency percentage that the teacher recorded for the initial benchmark. The students then continued to practice these facts daily to improve on their proficiency and fluency as the response time is cut down to two seconds. Once a student mastered the level that they are on, they received a certificate that documents when they are ready to move on to more advanced problems and facts.

The dependent variable in this study was the response time the computer software program XtraMath. All students began the program with a response time of four seconds. Over the course of the study the goal was for these students to go from a four second response time for their facts down to a two second response time. Each student was on a specific program based off of their initial baseline results with a four second response time. Students advanced to a three second response time once the program recognized that they mastered fluency at a four second response, and once they master a three second response the program then reset to a two second response.

Chapter 4

Results

This study was designed to measure and examine the effect of increasing math fluency and automaticity in the basic mathematical skills of students in an eighth grade special education resource classroom. Two classes participated in this study. A control assessment was given to the students without any modifications or interventions. The intervention program is a computer software program called XtraMath which is geared for constant repetition on mathematical facts and skills. The research question that was addressed was: Will students with disabilities increase their math fluency and proficiency when they are provided with an intervention intensification program that focuses on mathematical fluency and automatic response?

The study began with a control pre-assessment assessment that all students took on the computer. The assessment consisted of random multiplication questions with a four second response time to answer each question. The test did not have a time limit and ended when students had a certain amount of questions answered incorrectly. All students finished at different times. The pre-assessment was used to classify students into three tiers: low, medium and high. At the conclusion of the study, all students completed a post-assessment that was set at a two second response time covering the same multiplication facts.

Data Results

Table 1 shows the students pre-assessment results, weekly progress quizzes and the post-intervention assessment to document growth. Additionally the mean was calculated for the pre-assessment and post-assessment.

Table 1

Pre-assessment Results, Weekly Progress Quizzes, Post-Assessment Results

Students	**Pre-Assessment**	**Progress Quiz 1**	**Progress Quiz 2**	**Progress Quiz 3**	**Progress Quiz 4**	**Post Assessment**
1	**32%**	**71%**	**47%**	**54%**	**60%**	**59%**
2	**78%**	**80%**	**93%**	**96%**	**88%**	**96%**
3	**27%**	**54%**	**71%**	**60%**	**44%**	**50%**
4	**69%**	**92%**	**53%**	**81%**	**73%**	**90%**
5	**44%**	**36%**	**77%**	**35%**	**40%**	**68%**
6	**18%**	**20%**	**42%**	**46%**	**46%**	**41%**
7	**38%**	**54%**	**52%**	**40%**	**16%**	**45%**
8	**29%**	**44%**	**57%**	**64%**	**48%**	**36%**

Table 1 (Continued)

Students	Pre-Assessment	Progress Quiz 1	Progress Quiz 2	Progress Quiz 3	Progress Quiz 4	Post Assessment
9	**11%**	**18%**	**52%**	**53%**	**58%**	**65%**
10	**18%**	**22%**	**77%**	**N/A**	**N/A**	**29%**
Mean	**36.4%**					**57.9%**

The pre-assessment was a computer generated assessment in which all students had the same exam but in a different order. Students completed the pre assessment and a fluency percentage was calculated based on how many questions a student correctly answered. There was no time limit as the students worked on it until they incorrectly answered or left blank a specific number of questions.

During the intervention stage, all students worked in rotating groups for twenty minutes. One group was completing the study and practicing math fact memorization independently on the computer while the second group was working in a teacher led small group instruction of the daily lesson. At the end of each week, students were given weekly progress quizzes to determine their weekly progress and to measure any improvement on fluency to see if they had improved their explicit timing. All students then took the post assessment that was set at a two second response time. The post assessment was the same test as the pre assessment with the only change being the automated response time to answer each question. A mean was calculated after the pre and post assessment with the difference response times. After the pre-assessment the average fluency was a 36.4% using a four second response time. After the post assessment the mean fluency improved to 57.9%. There was a +21.5% increase in fluency over the four week testing period. All ten students were able to increase their math fact memorization. The average increase in fluency from the pre to post assessment was a 21.5% increase. A t-test was performed on the difference between the pre-test and post-test results. The results yielded a statistically significant score of 2.17 (df=18), $p<.05$. Table 2 shows the change from the pre to post assessment along with the mean that was calculated.

Table 2

Pre-Assessment, Post-Assessment and Percentage of Change.

Student	**Pre-Assessment**	**Post Assessment**	**Percent change**
1	32%	59%	**+29%**
2	78%	96%	**+18%**
3	27%	50%	**+23%**
4	69%	90%	**+21%**
5	44%	68%	**+24%**
6	18%	41%	**+23%**

Table 2 (Continued)

Student	**Pre-Assessment**	**Post Assessment**	**Percent Change**
7	38%	45%	**+7%**
8	29%	36%	**+7%**
9	11%	65%	**+54%**
10	18%	29%	**+11%**
Mean	**36.4%**	**57.9%**	**21.5%**

In further examining fluency from the pre to post assessment the lowest student made the greatest gain in fluency. The student initially tested at an 11% and ended with a 65% which was a gain of 54% in fluency comprehension.   The students that were consistently in class showed the most growth in their fluency over the course of the study due to the consistent repetition they were receiving in class.

Student 1 began in Tier one after week one's progress quiz displayed mastery of the four second response time to move into the three second response time of explicit timing. Week 2 was the first week that the student was moved into the three second automated response time for the quiz and practice and the student stayed on the mid-range tier for the duration of the study.   Student 1's mean for all progress quizzes was a 58%.

Student 2 achieved a fluency pre-assessment score of 78% which placed the student in the mid- range tier for the beginning of the study. Student 2 was able to master the three second automated response time after week one with a score of 80%. Each week student 2 showed close to perfection of mastery of facts with a two second automated response time and scored a 96% of the post assessment.

Student 3 had a 27% fluency on the pre-assessment which placed the student in the lowest tier with a four second response time. After two weeks of the study, Student 3 had mastered the four second automated response time and was moved onto the three second response time. The student spent the final two weeks of the study on the mid-range tier with the three second response time. Student 3 received a fluency percentage of 50 on the post assessment showing a 23% increase over the course of the study.

Student 4 scored 69% on the pre-assessment, which placed the student in the low tier to begin the study. At the conclusion of week 1 Student one had mastered fluency at a four second response time and moved to a three second response time. After week 3 Student 4 had mastered the middle tier of a three second response time and moved to the highest tier of a two second response time. Student 4 scored a 90% on the Post Assessment and showed a growth of 21% from the pre to post assessment.

Student 5 scored a 44% on the pre-assessment, which placed them in the low tier. After week 2, the student had mastered the four second automated response time and moved onto the mid-range tier which was the three second response time. Student 5 scored a 68% on the post assessment which showed a 24% percent increase from the pre to post assessment.

Student 6 scored 18% on the pre-assessment which placed the student in the low tier. Student 6 stayed on the low tier throughout the duration of the study working on the four second automated response time. Student 6 did improve on each progress quiz on scored a 41 on the post assessment. This was a 23% increase from the pre to post assessment.

Student 7 scored a 38% on the pre-assessment, which placed the student in the lowest tier. Student 7 regressed each week due on the progress quizzes and showed the least amount of progress during the course of the study. The last week was due to a four day absence due to behavior infractions. Student 7 scored a 45% on the post assessment which was a 7% increase from the pre-assessment to post assessment.

Student 8 scored a 29% on the pre-assessment, which placed the student in the lowest tier. When present, Student 8 was able to do well on progress quizzes; however attendance was inconsistent throughout the duration of the study. Student 8 showed the least amount of progress during the duration of study along with Student 7 On the post assessment, Student 8 scored a 36% which showed a 7% increase from the pre-assessment to post assessment.

Student 9 received a score of 11% don the pre-assessment, which placed them in the lowest tier. Student 9 remained in the lowest tier throughout the duration of the study but they were able to consistently improve on each progress quiz at the four second response time. On the post assessment, Student 9 scored a 65% which showed a growth of 54%. This was the largest growth from the pre-assessment to post assessment out of all of the subjects in the study.

On the pre-assessment, Student 10 scored 18%, which placed them in the lowest tier. Student 10 was only able to complete half of the study due to extended absences. The student was not able to complete weeks 3 and 4 of the study but did complete the post assessment. If present to complete the study, Student 10 had mastered the low tier and was able to move onto the mid-range tier of a three second response time. On the post assessment, Student 10 scored a 29% which showed an 11% increase from the pre to post assessment.

Chapter 5

Discussion

The purpose of this study was to examine the effect of increasing math fluency and automaticity in the basic mathematical skills of students in an eighth grade special education resource classroom. The study was conducted in a Title 1 grades 6-8 middle school located in South Jersey. Ten students participated in this study and all students are eligible for special services under the categories of: Specific Learning Disabilities, Communication Impairments, Other Health Impairments, Multiple Disabled and Emotional Disturbed. All ten of the students are below grade level for mathematics by at least one full grade level and six of the students are below grade level for language arts literacy by one grade level. Four students are on grade level for literacy.

All ten of the students increased their mathematical fluency accuracy and were able to improve on their automated response time to answer questions. Overall mean scores increased in accuracy as a result of daily consistent repetition of these math facts. Each student met their goal which was to have them all show improvement in their mathematical fluency of basic multiplication facts. The expectation was that if students were given a set amount of time each day to work on multiplication skills they would increase their fluency and decrease the amount of time it took for them to answer each question. Fluency was measured by percentage of number of facts answered correctly during weekly assessments and a pre and post assessment.

One participant (student 9) made the largest gain from the pre to post assessment 54%. Five participants (participants 4, 3, 6 , 5, 1) all showed significant changes in fluency in the post assessment (21%, 23%, 23%, 24% and 29% respectively) over the course of the study.

The Principles and Standards for Teaching Mathematics of the National Council of Teachers define computational fluency as, “having efficient and accurate methods for computing; to be efficient, students must perform calculations at an appropriate rate for a given skill level” (Calhoon, Emerson, Flores, Houchins, pg 292). Students must be able to be computationally fluent at an identified level of difficulty within given time period. Computational fluency is the building blocks of mathematics and if students do not develop these skills at an early age they are severely limited to learning and applying higher order thinking as they get older. As the students basic computational skills improved, so did their performance in the classroom on the curriculum. They were able to apply their computational fluency and skills to the algebraic concepts being taught. My results were very similar to how computational fluency should be reinforced and my students showed the growth that was expected when they are given sufficient time for rehearsal. My four week study was a small sample size of how computational fluency can be reinforced with special education teachers and how that over time their fluency will increase.

Explicit Timing (ET) has seen extensive use due to the ease at which it can be implemented (Duhon, House, Hastings, Poncy, Solomon, 2014). These techniques can be implemented with large groups of students simultaneously and can be easily implemented in a classroom setting. Interventions have been implemented based off of explicit timing in order to decrease the students automated response time. My results were different from explicit timing because there was no countdown and timer on the program. In the previous research explicit timing was not effective but when it was paired with an intensive repetition program such as XtraMath students were able to cut down on their response time. My study focused more on accuracy on the math facts instead of the time aspect of math fluency.

Limitations

While all ten participants showed an increase in their mathematical fluency, several factors limited the growth of some of the participants. The most significant with students was inconsistent attendance to school. Participant 10 was absent from school several days due to behavior infractions and did not take the last two progress quizzes. When these students are not in class on a consistent basis, they have difficulty retaining that math fact memorization which results in lack of progress and higher frustration level. The students lose the ability to practice and receive the repetition to be able to recall in the information at an efficient pace.

In the study, the students were working on these skills and facts independently from the very beginning. Several of the students had difficulty with self- monitoring themselves independently during the time they were working and displayed off task behaviors during the study. A contributing factor to this was the behavior disabilities that the participants have which require additional modifications and interventions. The students were all in one room with one group working with the instructor and another group on the computers in the back of the room. With only one teacher in the classroom, the students working on the computers did not have the direct supervision to always remain on task while working on the progress quizzes and practice. The sample size of this study was limited to ten students. The sample was restricted to students who display significant academic delays in their mathematical abilities and did not include students who are in an inclusion classroom setting with two teachers in the classroom.

Practical Implications

The participants in this study experienced an intervention for math fact memorization and multiplication fluency. While this study was carried out in a special education resource classroom in a small group setting, the effect was carried over into their daily classwork and lessons directed by the teacher. The majority of the curriculum that was taught during the time of the study centered around algebraic principles and solving multi step algebraic equations. Students became more independent during their math work and the teacher could increase the pace of the lessons that led to a gradual release from introduction of the content, to guided practice to independent practice of the lesson content. Students also experienced higher self -esteem and confidence in their own mathematical ability throughout the study. After the study was concluded, students enjoyed to continue working in the rotations between guided and independent instruction and mathematical fluency. They became more motivated to continue to improve on the fluency and during the small group rotations they can be given more direct instruction by the teacher when they are participating in the teacher led group of the lesson. The students are able to learn at a more comfortable pace that allows them to take their time to implement the basic mathematical facts that they are practicing and apply them to the multi-step equations that they are learning from the curriculum.

Teachers should continue to have their students practice and rehearse mathematical fluency. While this study is a very small sample size, the data and results provide the beginning stages of future success for students at the primary grades. If teachers begin to have their students practice these facts at a younger age, then their mathematical sense will continue to grow as they get older into the secondary grades. Struggling learners will be identified earlier and interventions can be applied immediately and can be monitored throughout the school year. The purpose of a special education teacher and classroom is to modify the current curriculum in order for material to be broken down at a simplistic level for the learner. This doesn't mean that teacher's should teach below grade level or teach the basic skills to students. By intervening at an early age, the teachers can develop strategies that will enable the student to continue to receive the basic mathematical fluency rehearsal they require but also continue to teach on grade level and have them keep up and not fall behind other learners. This study provides a clear plan that requires minimal time spent each day for struggling math students to practice basic math facts without losing "teaching" time in a classroom.

Future Studies

Future research should continue to study the effectiveness of math fact memorization and fluency practice of students who are placed in an inclusion math classroom. Students who are in these inclusion settings may only be slightly below grade level and the extra practice and retention can give them the extra intervention needed to be able to perform successfully on grade level. Future research may also want to monitor the student's progress over the course of a longer period of time. A longer time frame of research would give researchers a larger sample size and more time to gather data. It would also enable students to continue to receive the necessary repetition and skill work needed to get closer to mastering basic multiplication math facts.

Conclusion

This study set out to answer the following question: Will students with disabilities increase their math fluency and proficiency when they are provided with an intervention intensification program that focuses on mathematical fluency and automatic response?

It was determined from student data that given the proper time and practice, students with disabilities can increase their math fact memorization skills become more proficient with basic multiplication fluency. Participants in this study, not only showed an increase in their skills but learned to become more independent in grade level algebraic equations and became more motivated to attempt equations on their own. They were motivated to master their facts and demonstrated perseverance throughout the study. Students gained a new sense of confidence in math which they will carry with them as they continue in their education and they have the awareness that with time and effort they are capable of solving these equations. Implementations for this study can be conducted with minimal monetary expenses and proper time management of the class period.

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Appendix A

Definitions of Mathematical Strategies

Computational Fluency: Having efficient and accurate methods for computing; to be efficient, students must perform calculations at an appropriate rate for a given skill level

Mnemonic Strategies: words and sentences in order to enhance storage and recall facts. Strategies involving a peg word or some association with a number to remember lists, keywords associating with a similar sound and acronyms have been known to help improve computational fluency for struggling learners because they can rely on cues rather than repetition

Detect, Practice, Repair (DPR): a three stage test technique that is used to individualize math fact instruction for each student in a whole class setting while targeting a specific basic skill group.

Data Based Individualization Intensification Intervention: when students require a specific individualized method of instruction to accommodate their learning disability. DPI is an empirically proven method for individually tailoring instruction for students with learning disabilities.

Explicit Timing: Increasing and Improving a student’s fluency.

Appendix B

Definition of Mathematical Programs

Rocket Math Program: worksheet based, supplemental, math facts practice curriculum is uniquely structured for the sequential practice and mastery of math facts. Students learn two facts and their reverses on each worksheet in a carefully controlled sequence which enables mastery at an individualized pace.