THE EFFECTS OF TOUCHMATH ON STUDENTS WITH MILD INTELLECTUAL DISABILITIES

by

Hugh E. Waters

(Under the Direction of Richard T. Boon)

ABSTRACT

Though there are a small number of studies that have examined the effectiveness of the kinesthetic strategy TouchMath in teaching elementary school students mathematics, none have analyzed the use of this strategy to instruct high school students with intellectual disabilities. This dissertation sought to provide evidence to support the implementation of TouchMath to teach secondary school students with intellectual disabilities how to subtract 3-digit money value problems with regrouping. Employing a multiple probe across students design, information was gathered from three ninth and tenth grade students. Participants were able to successfully met the criteria set forth by the study though maintenance was not demonstrated by all the participants.

INDEX WORDS: TouchMath, Kinesthetic strategy, Multisensory strategy, Mild intellectual disabilities, Mathematics, Subtraction, Money, High school

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A Dissertation Submitted to the Graduate Faculty of the University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2010

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DEDICATION

I would like to dedicate my dissertation to my family.

ACKNOWLEDGEMENTS

First, my mother and father who never stopped believing in my abilities and supported me every chance given to them. Second, my wife who has put up with all the late nights and watching our daughter while I pursued my dreams. My brother, David, who talked me into the doing this in the first place. I would also like to thank the professors who guided me along my path.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Mathematics affects many facets of any person's life, but none as important as money and finances. New government regulations are beginning to require students with intellectual disabilities to take a more active role in regular education settings and academics. While admirable, certain functional academic areas should not be over looked. Functional mathematics skills are important to real world survival of any student particularly students with disabilities. Andrew and Williamson (1994) through a qualitative study determined that 57% of the stakeholders in the education of students with disabilities felt that life and prevocational skills should occupy the entire educational day. The stakeholders strongly favored life skills preparation over traditional academic curriculum domains.

Beginning with the *Education of All Handicapped Children Act* (1975), now codified as IDEA (*Individuals with Disabilities Education Act* (IDEA, 1997; 2004), mandating that students with special needs be placed in the least restrictive environment, *No Child Left Behind* (NCLB, 2001) and *Individuals with Disabilities Education Improvement Act* (IDEA, 2004) has now mandated that all students should have equal access to the general education curriculum. Students with intellectual disabilities are moving into the regular education classroom and are expected to succeed not only in class but also on high stakes testing such as the Georgia End of Course test (EOCT) and Georgia High School Graduation Test (GHSGT). The new classroom rigors include moving away from functional academics and replacing them with traditional academics. While this is a positive move toward allowing any student regardless of disability the opportunity to graduate with a high school diploma and ready to attend further educational and occupational prospects, this does not allow students with intellectual disabilities the chance to learn life skills that are important for survival in the community as an independent member of society.

The educational change for students with intellectual disabilities began with the *Brown v. Board of Education* (1954) case that outlawed segregation in public schools. This legal victory over denial of educational opportunities for minorities in the United States sparked a movement to accomplish the same for students with disabilities. Students in special education were taught in separate schools or in the home. *Brown* dictated that education must be provided to all on equal terms. Prior to this landmark decision, rights were guaranteed in the documents that began this country. Phrases like, “created equal,” “unalienable rights,” and “life, liberty, and the pursuit of happiness” are found in the Declaration of Independence and then guaranteed by the Constitution of the United States. Amendment V states that, “nor be deprived of life, liberty, or property, without due process of law” and in Amendment XIV: Section 1 prevents states from denying equal protection under state law.

After *Brown v. Board of Education*, cases considering special education were brought before the courts. *The Pennsylvania Association for Retarded Children (PARC) v. Pennsylvania* (1972) case established that any student, six to twenty-one, was entitled to a free and appropriate public education. This lead to legislation which laid the foundation for the “least restrictive environment” by allowing students with disabilities placement in the regular education classroom when possible and in special education setting with necessary. *Mills v. Board of Education of the District of Columbia* (1972) established due process with respect to inclusion in or exclusion from special education services (La Morte, 2008).

The federal government instituted laws permitting students with disabilities placement in a regular education setting to the maximum extent possible by passing the *Rehabilitation Act* (1973) later mandated by the *Individuals with Disabilities Education Improvement Act* (IDEA, 2004). The *Education for All Handicapped Children Act* (PL 94-142, 1975) amended and reauthorized as IDEA (1990), strove to improve public education for all students. The act was reauthorized and changed again in 2004. With *No Child Left Behind* (2001) and the reauthorization of IDEA mandating scientifically research-based strategies, how students are taught and determined eligible for services have changed.

No Child Left Behind (NCLB, 2001) legislation addresses school reform and provisions to be made in education. Part F: Section 1601 of NCLB specifically offers funds to schools for reform along scientifically research-based approaches. NCLB defines what constitutes scientifically research-based in section 901 as, “research that involves the application of rigorous, systematic, and objective procedures to obtain reliable and valid knowledge relevant to education activities and programs.” These ideals along with IDEA 2004 prompted Response-to-Intervention (RTI) as an approach to “catch” students before they fail or evaluated for special education services, and attend to their educational needs with approaches that are research-based.

Response-to-Intervention (RTI) is the new method for determining eligibility for special education services for learning disabilities (Deschler, 2009). RTI is based on how the student responds to various strategies. The strategies are to be research-based and the strategy intrusiveness is directly related to positive student response. The National Research Council Study (Heller, Holtzman, & Messick, 1982) stated that students’ eligibility should be based on three criteria: a) instructional quality, b) special education program value to the students, and c) student evaluation validity (Bender & Shores, 2007). Student academic functioning level goals and research-based interventions were recommendation also found in the report. RTI has been the key eligibility criteria for students with learning disabilities and is just one aspect of the new legislation pushing for instruction to be research-based for the entire system and not just for eligibility purposes. School accountability for student progress and graduation has led to more effort placed into research-based interventions for curriculum and instruction.

The National Mathematics Advisory Panel was created in 2006 to advise the president on scientifically research-based instructional methods and learning. The panel issued its recommendation, Foundations for Success: The Final Report of the National Mathematics Advisory Panel, to the President in 2008 on how math curriculum and instruction should be designed. The panel clearly states that math curriculum should make use of "what is clearly known from rigorous research." The report supports the use of "real world context" to teach mathematic skills and concepts. If the student demonstrates ineptitude for the current instruction then explicit methods should be implemented on a regular basis to improve problem solving and computational behaviors and the instruction should be on the student's functioning level. The panel declared that "few curricula in the United States provide sufficient practice to ensure fast and efficient solving of basic fact combinations and execution of standard algorithms" which it deems necessary for mathematical learning process.

Research policies and mechanisms were addressed by the panel on how the country and school systems should continue the search for new scientifically research-based methods. Meticulous and stringent efforts should be put forth to discover research-based strategies that address critical elements of instructional and learning processes. Educators should join with researchers to offer significant contributions, "effective instructional practices, materials, and principals of instructional design." Researchers need an arena to test theories and applications to determine if interventions are appropriate and valid. With cooperation from classroom instructors, educational practices and policy will be built upon solid research-based methodology. The panel states, “The nation must continue to build capacity for more rigorous research in education so that it can inform policy and practice more effectively.”

Codding, Hilt-Panahon, Panahon, and Benson (2009) stated that mastery of computational skills is vital to establish a jumping point for further skill development and independent living. Money and time management applications depend upon basic computational skill mastery. Codding et al (2009) implied that computational skills permits higher order thinking such as problem solving and abstract thought. Since students with intellectual disabilities are expected to enter the regular education setting, calculation automaticity would allow for comprehension of underlying math skills and “access to curriculum that emphasizes a problem solving approach” (Codding et al, 2009).

The learning characteristics of students with intellectual disabilities vary from other students but various researchers hypothesize that students with disabilities develop intellectually through the same stages as other nondisabled students. These researchers determined that students should be taught the same material but on a level the student can understand (Smith, Patton, & Kim, 2006). Other researchers believe that students with intellectual disabilities learn and process information differently than other students and should be taught implementing distinctive strategies specifically designed to lessen the effects of the disability (Smith et al, 2006). Andrew and Williamson (1994) indicated that students with intellectual disabilities demonstrate slow learning rates, short term memory problems, poor generalization and transfer skills, and require continual specific reinforcement.

Smith et al (2006) and Andrew and Williamson (1994) stated that students with intellectual disabilities understand material presented in a concrete format and may not develop beyond Piaget's concrete or preoperational stage of learning and comprehension dependent upon IQ level, furthermore, it was the instructor's job to provide the strategy and material that is appropriate to the student's developmental level. When compared to students with learning disabilities and low achiever on various academic skills such as IQ (verbal, performance, and full), arithmetic, vocabulary, comprehension, reading, and spelling, students with intellectual disabilities scored considerably lower on all aspects (Gresham, MacMillian, & Bocian, 1996).

Attention deficits plague students with intellectual disabilities. Student attention can be affected by information processing, concentration, or memory. Researchers (Zeaman & House, 1963) formulated that many students do not have enough attention capacity to devote to information processing. Based on deficits in the areas mentioned, students with intellectual disabilities would need more time and strategies to process information properly and attend to pertinent details. Possible ways to combat attention deficits is to offer concrete stimuli with few or no extraneous details, increase difficulty over time, and model decision-making (Smith et al, 2006).

Memory deficits are caused by a range of issues according to Smith et al (2006) such as selective attention difficulties, a lack of rehearsal strategies, and delayed learning sets. Sternberg (1997) sited in Smith (2006) that students did not effectively implement executive control or meta-cognition though the student could be instructed to do so. Speech and Language disorders are common among students with intellectual disabilities. With delayed language development and narrow vocabulary base, speech and language disorders have become the most common secondary disability. Regardless, speech and language is the most difficult academic area for these students (Smith et al, 2006). Another major academic deficit area is mathematics and money skills.

Managing money, banking, and purchasing are skills that should be targeted to ensure students with intellectual disabilities are competent in the areas before leaving school (Gardill & Browder, 1995, Van Luit & Naglieri, 1999). Schloss, Kobza, & Alper (1997) offered the statement that, "ability to function as an independent consumer all hinge on the ability to use money correctly." Too often students complete their school tenure and do not attain or master basic math operations. Stith & Fishbein (1996) stated that this might be due to a lack of understanding of complex and abstract symbols. Horton, Lovitt, & White (1992) cited early studies and found that students with intellectual disabilities scored 2.5 grade levels below average on the Key Math and scored lower on the Stanford Achievement test than regular education students in mathematical reasoning. Addition and subtraction with regrouping was the area of greatest difficult.

Students with intellectual disabilities goals for becoming independent in the community should have at least one for purchasing skills. Students may find themselves in a restaurant and need to add menu items to check for a total and determine if he or she has enough money to pay for the charges. Several approaches have been successful in teaching students to add or pay for purchases in the community. The next dollar strategy has been proven by researchers to be an effective method to teach students to make a purchase and expect change (Test, Howell, Burkhart, & Beroth, 1993, Denny & Test 1995 Colyer & Collins 1996, Ayers, Langone, Boon, & Norman, 2006). Horton, Lovitt, & White (1992) found that calculators are an effective and efficient manner for students to total bills and purchases and calculators offer less negative stigma. These strategies, though proper, have possible shortcomings. The one-more-than strategy is optimal for paying but totaling the bill could be a problem. The TouchMath method for adding money can be an appropriate strategy combined with one-more-than to be confident and accurate with community purchases.

Van Luit & Naglieri (1999) proposed that the best manner to overcome severe math difficulties is, “one-to-one or small group remedial teaching.” Berry (n.d.) is a proponent of solid direct instructional methods, which can include modeling coupled with positive feedback and prompts. When attempting to teach money skills with two studies, McDonnell (1987) & McDonnell & Ferguson (1989) determined that an effective method for instruction was decreasing prompt hierarchy over time delay or increasing prompt hierarchy. The debate over which environment, classroom or *in vivo*, is the better for teaching students with intellectual disabilities application and generalization has come to no clear consensus. McDonnell & Ferguson (1988) argues that instruction was best applied in the natural community setting as well as the classroom and not exclusively one or the other.

Whether learning in the classroom or the community, students with intellectual disabilities require special attention to be paid to their individual learning style and to the construction and use of the strategy needed to ensure their comprehension and retention. Students should be taught skills and information necessary for them to become an independent consumer and productive citizen to the greatest extent possible. Independent community living skills should be taught form an early age to promote repetition and practice. Becoming independent and productive citizens will allow for greater self-esteem and competency in the students when they enter a post secondary environment.

Rationale

TouchMath offers several products beyond what has been studied thus far. One such product deals with subtraction problems with decimals. The student is taught how to subtract money through this program. This skill can be essential to students when managing banking accounts. Research has not been undertaken to prove if this strategy is effective with any population of students with disabilities. Students leaving high school can only benefit from learning how to add and subtract money values before leaving secondary school. The study was implemented to provide further evidence that the TouchMath program is able to facilitate mathematical learning for students with intellectual disabilities at the middle and secondary levels.

Purpose

The purpose of this study was to examine the efficacy of using a multi-sensory strategy via the use of the TouchMath program to facilitate the learning of three digit subtraction problems containing decimals for students with intellectual disabilities at the secondary grade level. To date, there are a limited number of studies that demonstrate the effectiveness of TouchMath for students with and without disabilities. At the high school level, teachers ever desire better or more efficient methods for teaching student with disabilities mathematics problem-solving skills. One strategy, TouchMath demonstrates promising multi-sensory methods to assist students with and without disabilities in mathematics applications; however, much of the research has focused on students with specific learning disabilities (SLD) at the elementary grade levels. Therefore,

Research Questions

This research study is intended to investigate:

1. Does the use of a multi-sensory mathematics program (e.g., TouchMath) with students with intellectual disabilities have a positive effect on three digit subtraction problems with decimals at the high school level?

2. What are the students' or teachers' attitudes and perceptions toward the use of the TouchMath program as an effective instructional strategy in mathematics classes for students with intellectual disabilities?

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

This section provides an extensive review of the published mathematics intervention research and instructional strategies for individuals classified with intellectual disabilities. In this review, 32 studies were obtained, reviewed, and synthesized. Research has been conducted in two major areas money applications and touch point activities. Results and limitations are discussed in relation to instructional practice and future research issues to extend and replicate current research findings. This literature review will focus specifically on money applications and the TouchMath program.

As transition and supported employment programs increase for individuals classified as intellectually disabled, the percentage of individuals competitively employed and the importance of utilizing and managing money becomes an increasingly important issue. Previous studies have focused on teaching basic skills, problem solving or rule-learning activities, and applications consisting of interventions teaching the use of money and measurement skills. More recently, Browder and Grasso (1999) reviewed the literature of mathematics interventions for individuals classified as mentally retarded from 1975 to 1997 and identified 43 studies relating to mathematics interventions that met their established criteria for inclusion.

Therefore, the purpose of this paper is to extend the previous literature reviews conducted concerning money applications and the TouchMath program. This paper provides a thorough analysis of the research literature from 1980-2009 of research interventions in mathematics with individuals characterized as intellectually disabled. Such a research analysis can provide educators an extensive review of the types of interventions conducted with individuals that are intellectually disabled as well as descriptions of the populations investigated in the studies. Moreover, this analysis provides efficacy data regarding mathematics intervention research for populations with mild-to-severe mental retardation. Finally, through such a review researchers can gain greater insight into future efforts to extend and replicate research in mathematics interventions for students with intellectual disabilities.

Money Applications

Literature Search Procedures

The following literature search procedures were employed to retrieve relevant articles. First, a computer-assisted search of five major databases was conducted including ERIC, PsyInfo, ArticleFirst, Dissertation Abstracts, and Education Abstracts from 1980-2009. The descriptors used in the search were "mathematics, mathematics instruction, arithmetic cognitive strategies, problem-solving, computation, mentally retarded, retardation, retarded children, disabilities, mild-moderate-severe mental retardation, developmental disabilities, mildly handicapped, intellectual disabilities, money applications, and learning problems. Second, a hand search of relevant articles was completed. Finally, a hand search of reference lists and table of contents of relevant journals was conducted. This revealed 23 studies, which met the criteria for inclusion in this review.

Criteria for Inclusion

The three main criteria for inclusion in this review include: (a) articles published between 1980 to 2009 to extend previous review conducted by Browder and Grasso, (1999); (b) studies that examined the effects of an intervention on students' mathematics money performance; and

(c) individuals included in the study are classified as intellectually disabled by the authors and meet IQ (intelligence quotient) as defined by the state. For the purposes of this review, studies were excluded when no clear mathematical intervention was employed or subjects were not classified as mentally retarded in the article by the authors and met current intelligence quotients.

Overall Study Characteristics

There were 23 studies that ranged in publication date 1980-2006, and appeared in refereed journals such as the *Journal of Applied Behavior Analysis, American Journal on Mental Retardation, Education and Training in Mental Retardation, Association for Persons with Severe handicaps, Research in Developmental Disabilities, Journal of Learning Disabilities, Journal of Applied Behavior, Education and Training in Developmental Disabilities, Education and Training of the Mentally Retarded, Journal of Special Education, Education and Treatment of Children, American Journal of Mental Deficiency, Education and Training in Mental Retardation and Developmental Disabilities, Remedial and Special Education, European Journal of Special Needs Education, Elementary School Journal* and *Association for Persons with Severe Handicaps*. A total of 555 participants (range 1 to 265) who were in elementary, middle, and high school participated in these studies. The median number of subjects per study was four (range 1 to 265). The majority of studies included in this review were (N=19) single subject designs (82%), while the remaining studies employed (N=4) group designs. The typical interventions targeted included basic skills and concepts, money applications, and problem-solving activities.

The final sample of studies included in this review consisted of eight One-More-Than and various incarnation strategies (Schloss, Kobza, and Alper, 1997; Ayers, Langone, Boon, and Norman, 2006; Test, Howell, Burkhart, and Beroth, 1993; Denny and Test, 1995; Westling, Floyd, and Carr, 1990; McDonnell and Ferguson, 1988; Colyer and Collins, 1996; McDonnell, Horner, & Williams, 1984), seven chaining or task analysis applications (Bourbeau, Sowers, and Close, 1986; Cuvo, Davis, and Gluck, 1991; Wheeler, Ford, Nietupski, Loomis, & Brown, 1980; Fredrick-Dugan, Test, and Varn, 1991; Sandknop, Schuster, Wolery, and Cross, 1992; McDonnell and Ferguson, 1989; Schleien, Certo, and Muccino, 1984), two MASTER program studies (Van Luit and Naglieri, 1999; Kroesbergen, Van Luit, and Maas, 2004), two role playing and modeling studies (Van Den Pol, Iwata, Ivancic, Page, Neef, and F. Paul Whitley, 1981; Gardill and Browder, 1995), two prompting application (McDonnell, 1987; Stith and Fishbein, 1996), one Personalized System of Instruction (Zencius, Davis, and Cuvo, 1990), one calculator application (Horton, Lovitt, and White, 1992). In the ensuing paragraphs, each of these areas will be synthesized and discussed separately.

Money Applications

Van Luit and Naglieri (1999) implemented the MASTER (Mathematics Strategy Training for Educational Remediation) program to guide 84 students with mild intellectual and learning disabilities to generate strategies and goals for simple multiplication and division problem-solving. With ages ranging from 9 to 14, participants' mean IQ scores for students with mental disabilities were 70 and for students with learning disabilities were 100. The dependent variables were the students' ability use proper strategies to solve and accuracy on a 40 multiplication and division problems pre and posttest. Utilizing small group instruction, training took place over a 17-week period three times per week in 45-minute sessions. Teachers employed discussion, logical arguments, and reflection to direct students to create alternative computation methods. Measurements were administered for three months following training. While each group demonstrated improved methods, the group with mild intellectual disabilities exhibited greater strategy development and implementation. Top-down processing can be an effective method to teach basic math skills and to employ several problem-solving strategies.

Using an experimental group design, Kroesbergen, Van Luit, and Maas (2004) implemented the MASTER program and also examined which approach was more effective for the program, constructivist or explicit. Ranging from second through sixth grade, 265 students participated of which 129 were classified with emotional behavior disorder, learning, and mild intellectual disabilities. The dependent variables were automaticity and accuracy of solving 20 numerical and story multiplication problems. Instruction was in small groups twice weekly for 30 minutes over 30 sessions lasting 5 months. Four measures were given of which two covered automaticity and two tested problem solving. The constructivist treatment group demonstrated greater improvement over the explicit and control groups. Within the constructivist treatment group, students with learning disabilities exhibited a higher performance than students with mild intellectual disabilities on the multiplication measures.

Horton, Lovitt, and White (1992) examined which option: a) paper and pencil, b) calculators, or c) a strategy with visual cues used concurrently with a calculator was more efficient and computationally accurate when computing subtraction problems with regrouping by junior high students with intellectual disabilities. With a multiple probe ABCD single-case experimental design, forty-four eighth grade nondisabled students and seven students with mild intellectual disabilities participated in the study. The mean IQ was 60 for those labeled educable mentally handicapped. The dependent variable was subtraction accuracy on a worksheet during a two-minute drill with results recorded on record sheets and standard behavioral charts. Four assessments were conducted the regular education students to obtain comparative data for the three interventions and an input organization into the calculator. Phase A, paper and pencil, was two sessions, one for instruction while the other was used for measurement. Phase B gathered calculator baseline data and Phase C was for calculator instruction. Phase D introduced a rehearsal strategy with visual cues and calculators over seven to ten days and two maintenance sessions were held. A regular education group that performed equally proficient with both calculator and pen and paper skills was used for comparisons. Results found that paper and pencil could be an overwhelming task when computing subtraction problems. Accuracy improved with calculators but computed slowly. The students did not prefer the visual cues coupled with the calculator instruction.

McDonnell, Horner, & Williams (1984) examined which strategy a) flashcards, b) slides, or c) slides with in vivo instruction coupled with next dollar strategy was the better strategy to teach students with moderate and severe intellectual disabilities to purchase items. Four high school students with moderate and severe intellectual disabilities partook in the study. The students' IQs were from 36 to 50 and ages from 16 to 19. The dependent variable was the number of response errors made during the chained events or delayed response in trained and untrained arenas. With a multiple baseline with probes across subjects design, four phases were used with the first phase collecting baseline data. The second phase was flashcard training consisting of 20 trials with sessions lasting from 20 to 30 minutes. Chaining, cues, and correction were implemented to teach the next dollar strategy coupled with flashcards representing an item for purchasing having numerical values written upon them. Slide training phase was identical to the second excluding the stimuli and physical positioning. Slides were presented with pictures while standing to better simulate the grocery store. Slide plus In Vivo utilized ten slide training sessions and five trials in a grocery store for the concluding phase. The results indicated that in vivo instruction was the only strategy that allowed for skill generalization.

With a two level multiple baseline across subjects design, McDonnell and Ferguson (1988) compared general case in vivo and general case simulation plus in vivo paired with the next dollar strategy to teach students with moderate and severe students to purchase items from community restaurants. Participants were six junior high students with intellectual disabilities having a mean IQ's of 44 and average age of 12 years old. The dependent variables were a) percent correct steps taken, b) error frequency and topography, c) quantity of trials needed and, d) training condition fees to measure effectiveness of general case in vivo and general case with simulation with in vivo. Four phases were utilized to construct the study: baseline, pretraining for the next dollar strategy, general case training, and general case training with simulation. Receiving 20 minute daily instructional sessions, students were trained and evaluated in both a classroom setting and various community fast food restaurants. Results showed that classroom simulation instruction did not generalize to in vivo circumstances. Skills mastery was performed only after training occurred coupled with general case in vivo and general case simulation plus in vivo.

Westling, Floyd, and Carr (1990) evaluated two equal student groups with intellectual disabilities capability to generalize shopping skills in department stores. Fifteen middle and high school students with moderate, severe, and profound intellectual disabilities partook in a study. The dependent variable was to determine if multiple settings were necessary to generalize department store shopping skills as evaluated by pre and posttest task analysis checklists. Both groups were taught through simulations, role-playing, discussion, and modeling to find particular priced items, store section, money skills with next dollar strategy, and appropriate social interactions. Both groups were taught by simulation in the classroom after school. The difference stems from the how many settings were exploited to complete the community training. One group was educated in one chain department store while the other was trained in three major chain department stores. The results showed that both groups reached criterion within the same time span. While part of the training did take place in the community, the research demonstrated that mastery could be reached with training held in one setting. This can be beneficial information if community training must occur without a variety of setting available

With a multiple baseline across behaviors design, Test, Howell, Burkhart, and Beroth (1993) modified the one-more-than technique to include a cent pile to teach purchasing skills to students with intellectual disabilities. Five high school participants with moderate intellectual disabilities participated with a mean IQ of 40 and age range of 16 to 24. To determine accuracy, a 15-item money probe was used to gather dependent variable data. Students were instructed to count the exact amount needed in dollars and then place one dollar aside to represent the cents. The two piles are combined then handed to the cashier. One participant was unable to improve upon their performance utilizing the one-more-than strategy. To counter score stagnation, Test et al. (1993) created a coinciding cents pile to the existing dollar pile. Two experiments composed the study. The first was able to establish the method’s efficacy and the second verified generalization to community settings. Results indicated that all participants achieved gains or mastered the technique and more so when the cent pile was added.

Denny and Test (1995) attempted to systematically replicate a previous study performed by Test et. al. (1993) to advance previous results that increased payment accuracy using the One-More-Than strategy with the cent pile modification for students with intellectual disabilities. Three high school students with moderate intellectual disabilities and IQ mean of 51 took part in the investigation. The dependent variable was the students’ ability to accurately pay for items within a dollar over payment as collected by a 12-item probe daily. Utilizing a multiple baseline across students design with 5-20 minute sessions, instruction and probe phase was implemented for four weeks in a separate room. Baseline was gathered until stability was gained then the second phase began with strategy intervention and continued until mastery. A third phase started with a mixed practice application and one student had to enter an extended phase to master this phase. Maintenance and generalization data was collected with a four and ten week probe. All three participants were able to acquire, master, and maintain the target skills for ten weeks and generalize to untrained stimuli and community settings.

With a multiple probe across participants design, Colyer and Collins (1996) investigated whether natural cues and a prompt hierarchy strategy to teach the next dollar strategy so middle school students with mild and moderate intellectual disabilities to purchase item in a classroom and then generalize the skill to a community setting. Participants were four students with mild and moderate students with a mean age of 14 and IQ scores ranging from <40 to 60. The dependent variables were the number of prompts to achieve the correct response and the students' ability to general the behavior in a community setting. Instruction occurred in a separate room and on a one-to-one basis. The students were pulled for 15 trials per day during the school week. Three of the four participants reached criterion and able to maintain the skills. One participant was unable to reach criterion before the termination of the school year.

Schloss, Kobza, and Alper (1997) utilized a multiple baseline across subject pairs with changing criteria to test the efficacy of the next-dollar strategy coupled with peer tutoring to secondary students with moderate intellectual disabilities. Six students participated in the study with IQ's ranging from 32 to 57 and ages from 14 to 17 years old. The dependent variable was accurate next dollar strategy application within one dollar over pay after the introduction of peer tutoring. The instructor utilized modeling, task analysis, and social prompts to direct the tutor's role. Instruction took place in the classroom. Baseline data was collected before the next dollar strategy was introduced through a task analysis. One week after the classroom training ended, the participants were taken into the community to assess for generalization and maintenance. All three dyads responded to the intervention immediately and offered higher response accuracy with peer tutoring. Two of the three dyads were able to generalize and maintain the target skills.

Ayers, Langone, Boon, and Norman (2006) examined a computer-based instructional approach to teach dollar plus with a multiple probe across participants design employed to determine if middle school students with mild and moderate intellectual disabilities could be trained to make community purchases. The participants were four 14 year old students with IQ’s varying from 38 to 58. Response correctness using the dollar plus technique to purchase items was the dependent variable. Baseline data was taken to establish response accuracy in the community and classroom with the computer. Classroom instruction employed computer-based instruction with imbedded video to train the participants to make purchases. For generalization, participants were taken to a major grocery chain to make purchases followed by maintenance probes. Of the four participants, the technique was effective for two students. With the other two participants, one participant demonstrated gains though not with convincing magnitude, while another illustrated variable gains with a descending trend toward the end of the study.

Zencius, Davis, and Cuvo (1990) developed a Personalized System of Instruction (PSI) to teach money management skills to students with mild intellectual disabilities. Participants were eight students placed in two groups to procure banking skills. Participant ages were from 18 to 23 with IQ’s varied from 70-84. The dependent variable for group one was correct responses to an 11-question probe and eight random probes with 12 questions for group two. With a multiple probe across instructional units, three units were developed: 1) writing checks, 2) making deposits into a checking account, and 3) reconciling a checking account. The training basis was task analysis set upon a pace determined by the student. Group one receives their training within the classroom, but the other group received assessments in stores and utility companies where natural transactions could be completed. Both groups acquired the skill sets promptly. Generalization and maintenance were attained for both groups though not equivocal. Both groups retained the skill sets with the four and eight week follow-up measures. For week ten, group one began to score lower, but was able to recoup the skills with some remedial training.

Wheeler, Ford, Nietupski, Loomis, & Brown, (1980) determined that students with moderate and severe intellectual disabilities could be taught to make a list, purchase, and bring home ten items from the grocery store in the community. Seven middle and high school students with moderate and severe intellectually disabled participated in the study. The average age was 15.2 and the mean IQ score was 45. The dependent variable was the amount of time the participant could correctly create a list, purchase ten independent items from a community school and bring them home. With a test-teach design, instruction was divided into three strands and strands one and two were subdivided into two parts. Strands one and two were taught in a concurrent manner, meaning that the skill was taught concurrently in both settings. Picture, gesture, verbal and modeled cues and corrections were employed to assist the student in reaching the correct response. Measurement and data collection probes were given twice a week for the year of instruction. Three students reached criterion by the end of the school year while three others required instruction to continued until December of the following school year. The last student transferred before the study was terminated and the student reached criterion.

Schleien, Certo, and Muccino (1984) examined whether task analysis with error correction could teach a nonverbal adolescent student with severe intellectual disabilities to learn leisure skills in a local bowling alley using printed cards for communication. One 16-year-old student with intellectual disabilities and an IQ of 32 participated in the study. The dependent variables were completing task analysis steps accurately for three activities: a) initiating conversation with attendant and bowling a game, b) purchasing from a vending machine, and c) purchasing from the snack bar. With a multiple baseline design, three or four phases were implemented depending on which skill was being taught. Phase one was for collecting baseline data. Phase two utilized a task analysis to teach the student the skill set. Three skills sets were taught: a) initiating, purchasing, and bowl a game, b) purchasing an item from the counter, and c) purchasing an item from a vending machine. Training sessions were twice a week extending for one and a half to two hours. Phases three and four were used for maintenance and generalization data collection. The results indicated that the participant was able to attain, generalize, and maintain the skills necessary to perform an independent leisure activity based on a task analysis.

Bourbeau, Sowers, and Close (1986) investigated the effectiveness of a banking curriculum taught to secondary students classified as mildly mentally retarded in a classroom setting to produce generalization of performance in a local community bank. The sample consisted of four female secondary level students with a mean age of 19 (range 17 to 21) and a mean IQ of 59.5 (range 53 to 66). Employing a multiple baseline with probes across subjects design, student performance of the same banking procedures in a novel bank that was significantly different from the bank employed as the focus in the curriculum was measured for the dependent variable. Once baseline was established, the first subject was trained in the simulation setting at school for one 40-minute period each day. Upon completion of the target bank in vivo training, the students were escorted to a local community bank to perform withdrawals and make deposits. The authors indicated training conducted at the school for one

40-minute session daily until each student reached criteria of two correct deposit and withdrawal operations in a row for two consecutive training days. The total training time for all students was 16 hours and 40 minutes, or 25 sessions (approximately six forty-minute class periods). Sixty to eighty percent of the steps were generalized to the community bank. Concentrated *in vivo* training was not necessary for the remaining skills to be attained. This study provided evidence that with accurate bank simulation format and stimuli students could generalize techniques learned in the classroom.

In another investigation, McDonnell and Ferguson (1989) compared a decreasing prompt hierarchy procedure to a constant time delay procedure in teaching four students with moderate handicaps to write and cash checks in a bank and to utilize an automated teller machine. Participants included four students from two high schools with a mean age of 17 and a mean IQ score of 40. All students were classified as moderately mentally retarded. Three dependent variables were performance of task analysis, student error topography, and the number of time, trials, and errors to reach criterion. Students received an average of 2.5 hours of training per day on a variety of community activities using money such as shopping, using the transit system, and eating at restaurants. Through 7 to 10 step task analysis and decreasing prompt hierarchy, students were taught to make cash withdrawals of $10 and $20 from an automated teller machine or were instructed to write and cash checks in the bank. Students 1, 2, and 3 were trained a one branch, while student 4 was trained at another bank. Duration of the training sessions lasted 20 minutes and students received two to six training trials per session and received one trial on each of the target amounts (i.e., $10 and $20). Maintenance of performance was conducted 4 and 8 weeks after the termination of the training sessions. The results indicated that both the decreasing prompt hierarchy and time delay procedures in teaching students with moderate mental retardation to use an automated teller machine and to write checks led to the acquisition of both tasks. However, the results indicated the decreasing prompt hierarchy was more efficient in establishing performance.

Cuvo, Davis, and Gluck (1991) assessed which strategy, cumulative or interspersal task sequencing in self-paced formats could teach individuals with mild disabilities banking skills. Twenty individuals located in high schools, sheltered workshops, and residential rehabilitation facilities with ages ranging from 17 to 35 and IQ’s from 60 to 80 participated. Students and adults were classified as mild intellectual and learning disabilities. Percent correct on four 35-item probes was the dependent variable with each item was evaluated as correct steps achieved of the task analysis. Participants were trained during 50-minute sessions four to five days a week at their respective cites. With a two-factor mixed design, two groups were taught using forward chaining with self-paced workbooks that followed the desired task sequencing strategy.
The results indicated that both sequencing techniques demonstrated equally significant gains from pretest to posttest and continued to on the one week and month follow up probes.

In another study, Sandknop, Schuster, Wolery, and Cross, (1992) assessed the effectiveness of the adapted number line recommended by Kleinert (1988) to teach students classified as moderately intellectually disabled to select lower priced grocery items using a task analysis approach. The sample consisted of four male students with a mean age of 16 (range 14 to 18) and a mean IQ of 42.5 (range 40 to 45). The mean developmental age of all four male students was 5.7 (range 5.4 to 6.0). The dependent variable was the ability for the students to properly follow the steps for selection and purchasing correctly. With a single subject design across all individual, students were trained to select the lower priced items when presented with seven different pairs of two and three digit prices. The participants were trained to select the lower priced item. In terms of procedures, one total task (Bellamy, Horner, & Inman, 1979) experimental session was conducted daily and consisted of 14 trials and each of the seven comparisons trained were presented two times each. Results indicated positive effects of the use of a number line and task analysis to selecting lower priced goods in a community grocery store. The results revealed that all students reached criteria and maintained the skill with 90% accuracy up to 14-weeks after training. Moreover, the individuals were able to generalize the skill from the classroom setting to a community-based grocery store with a least 97% accuracy.

Using a single subject design, Fredrick-Dugan, Test, and Varn (1991) proposed to present a replication of the Nietupski (1983) study by teaching students with moderate intellectual disabilities to use a pocket calculator to make purchases in the community. Participants included two individuals with moderate intellectual disabilities with mean age of 19 years and a mean IQ of 38 as measured by the WISC-R. The Task Analysis steps entailed a) turn on the calculator, b) enter the amount indicated on the card for the bill denomination, c) press the minus key, d) enter the cost of the first item, e) press the minus key, and f) continue steps 5 and 6 until all items are purchased or a minus sign appears. Skill maintenance was measured over four weeks once instruction was terminated. Calculator training sessions were conducted twice a week and lasted 20-30 minutes. Furthermore, training involved a progressive time delay, which began at 0 seconds in the first two sessions and then increased each consecutive day. Results indicated that a functional relationship between an instructional strategy involving time delay and general case programming and the use of calculators in decision making of purchasing skills. Moreover, the results revealed purchasing behaviors were generalized to untrained items and both trained and untrained environments for four weeks after training was terminated.

Van Den Pol, Iwata, Ivancic, Page, Neef, and F. Paul Whitley (1981) furthered researched by examining the effectiveness of role playing and simulation to teach restaurant skills to students with mild and moderate intellectual disabilities. The participants were three male students with mild and moderate intellectual disabilities. The students' ages range from 17 to 22 years and have IQ scores of 46 to 75. The dependent variables were the number of error and the length of time to mastery. Using a multiple baseline across subjects design, modeling, role-play and photo slides were employed to teach students social etiquette, ordering, and paying in a classroom setting. The first phase gathered baseline data and the second phase skills training began with ten trials per skills each lasting five to ten minutes. Generalization probes were scored in a local restaurant and compared to a normative sample gained at the same facility. The results showed that the average number of sessions to reach mastery was 77 through ten hours of training in the classroom to generalize to real life settings.

Gardill and Browder (1995) examined whether students with severe intellectual disabilities could be taught to make purchases from three item stimulus classes using multiple exemplars. Participants were three students with severe intellectual disabilities having ages of 12 to 13 and IQs from 45 to 57. The dependent variable was the correct number of monetary selections in training as well as in generalization settings as measured by a company generated assessment called Money Test over ten trials with ten questions per trial. Executing a multiple baseline across subjects design with four phases, training was carried out in the student's regular classroom for individual training. Phase one was for gathering baseline data while phase two involved match to sample training with time delay implemented to teach the students to match a dollar amount to the product presented. Phase three was discrimination training with photographs to teach the difference between the items with no money stimuli. Phase four was to teach the students through modeling the skills necessary to purchase the items with the monetary stimuli. The results indicated that two students mastered the desired skills but the third student was only allowed to show improvement because the end of the school year terminated the study.

McDonnell (1987) compared time delay training and increasing prompt hierarchy to teach high school students with severe intellectual disabilities to purchase snack items from two different settings. With an average age of 16.75 years and IQ mean of 21.8, four high school students severe intellectual disabilities participated in the study. The dependent variables were the steps accurately completed independently, error topography, how long it took, and number of errors to reach criterion. Error data collection and identification was based on a specific list of behaviors. Implementing a multielement alternating treatment within subject design, two phases were executed with the first phase gathering baseline data and phase two introduced both time delay training and increasing prompt hierarchy in both settings. Twenty-minute training sessions were implemented for both procedures and the students received exposure to both items during each session. The students were taught to purchase snack items for a dollar or less in a convenience store and a fast food restaurant. Results found that both prompt hierarchy and time delay were demonstrated as effective strategies but time delay proved to be the better.

Using a group study, Stith and Fishbein (1996) evaluated money counting and comparison capability differences between students with and without disabilities. Forty-nine students with autism and intellectual disabilities as well as regular education students in elementary, middle, and high school participated in the study. The average student age range was 6 to 18 years of age and was instructed in a separate classroom. The dependent variable was the mean proportions of errors over 14 opportunities. The students were given three tasks to accomplish using two stuffed dogs: a) state the value of two coin piles, b) state the value of card piles with coin values written on them, and c) comparing verbally stated values given to each stuffed dog. Three sessions with 14 trials occurred over one to four weeks for 20 minutes were used to gather data. The students without disabilities had made fewer mistakes than those with disabilities with counting and comparisons. No significant differences were discerned when comparing difficulties and errors for the students with autism and intellectual disabilities.

Synthesis of Studies

Table 1 provides a synthesis of the six areas of mathematical interventions included in this review. These areas include: One-More-Than and various incarnation, chaining or task analysis, MASTER program, role playing and modeling, prompting, Personalized System of Instruction, and calculator. The majority of the mathematical interventions are based upon a set of task analysis steps presented in tandem with systematic instructional interventions such as direct feedback, prompting, modeling, or reinforcement to a target skill. As can been seen, Table 1 illustrates that all studies included in this review report positive finding after implementation of their mathematical intervention. Moreover, it is interesting to note that few of the studies are employing computer-assisted instruction. Furthermore, there appears to be trend in the more recent articles to examine more functional mathematics skills such as money management, check cashing, withdrawals, and use of ATM (automated teller machines). Overwhelming, the methodology of the vast majority of the studies included in this review are single subject designs (82%). In order to examine these studies as whole several key sample issues need to be addressed. These sample issues include age levels, disability categories, and methodology.

Sample Issues

Three issues arise out of the sample studies obtained and synthesized included in this review. These issues pertained to age levels, disability category, and methodology. Following are data obtained and synthesized from the summary of data on the 23 sample studies.

A total of 555 subjects (range 1 to 265) who in middle and high school and eligible for mild, moderate, and severe intellectual disabilities participated in these studies. The median number of subjects per study was four (range 1 to 265). The majority of studies included in this review were some types of single subject multiple probe design (82%), while the reaming studies employed group design. There was some variability in the studies concerning age, ranging from 11 to 21. The studies revealed that interventions were conducted from middle school age students through high school. As a result, generalization across age level suggests limitations in the validity of the intervention.

In terms of disability category, all students participating in the study were eligible as mild to severe intellectually disabled. However, most of the studies indicate that interventions were successful for students with mild and moderate intellectual disabilities. In fact, of the 23 studies obtained and synthesized, three studies specifically addressed students with severe disabilities and two studies included a combination of two students with an eligibility of moderate and severe disabilities. This indicates much research is warranted in mathematics interventions for students classified with severe intellectual disabilities and questions whether such effective strategies employed in the studies reviewed potentially can be replicated to meet students and adults with more severe academic deficits.

It appears after an extensive synthesis of the literature the vast majority of the studies (82%) use a single subject. Other studies have employed group designs. With few study design styles, there is a need to replicate and extend current studies on larger scales and sample sizes covering all grade levels and increased maintenance periods. Wider arrays of rigorous methodological research designs are necessary to corroborate current study results as well as offer new directions. Particular consideration is necessary regarding internal and external validity by examining extended maintenance in the community and application.

Limitations

The research studies reviewed in this synthesis indicate positive results in teaching students with intellectual disabilities mathematics. The majority of the studies revealed students were able to generalize mathematics skills in trained and untrained areas across settings as well as maintained those skills over time. However, there is a variety of limitations concerning the review of research results. Corroborating and replicating these studies is deserved. The following limitations are listed in which future research should be guided toward developing instruction for mathematics to individuals classified as intellectually disabled.

· Sample size of all studies suggests validity limitations

· Findings cannot be generalized across grade levels, setting, or ability

· Strategies effectiveness on differing levels of students eligible as intellectually disabled

· Examination of extended maintenance probes

· Determining independent use of strategy over extended periods of time

· Effect of strategy when students have prior knowledge skills (i.e., calculator)

· Additional skills with higher difficulty concerning money management like checkbook management and balancing

· Strategies to address new technologies like electronic checking and ATM machine usage

· Variety with in methods used for instruction (group vs. individual)

· Generalization from trained to nontrained environments

Conclusions

Before students with intellectual disabilities leave secondary education, certain skills should be acquired in order to become independent through self-determination. Basic money and math skills are part of those areas. To make purchases, know how much to give, and expect in return become much easier if the person has knowledge of monetary values and practices. First step is to teach basic math concepts. Fundamental addition, subtraction, multiplication, and division comprehension is a solid building block to teach money purchases. Research by Baroody (2006) presented self-inventive strategies, which informs educators that students with disabilities cannot only comprehend strategies but cognate what can streamline or better the strategy for quicker calculation. This relays that students can manipulate concrete skills and monitor their behavior (Baroody, 1996).

After basic math and counting monetary values is attained, training students to purchase items in naturalistic environments is the next logical step. The research tendered visual prompts and task analysis to teach students monetary transactions. In this modern world, people are quickly no longer using money or checks and are using more electronic forms of payment. While the methods may be valid, the skill set may need to be changed. Instead of currency transaction, the students should be taught how to make purchases with debit cards. A task analysis can be a valid method, but gear it to teach working the machines, remembering the codes, and deducting that amount from a checking account. These new payment methods do not end with purchases in stores.

The internet can be a viable option for those that do not have transportation or limited movement. Personalized System of Instruction (PSI) coupled with a task analysis (Zencius et al.,

1990) would be an effective manner to teach which websites are proper and how to add items to the cart and then pay for them. Visual prompts, printed visuals of the various screens, may also be helpful to guide instruction. The internet can affect how a person controls their banking as well. Electronic banking has become popular to help the environment and control costs of postage and envelops. Students entering the modern world may be able to learn how to pay bills and control their checking and savings accounts online and control not only postage costs but also trips needed to the bank.

Task analysis coupled with video prompting may be an effective manner to teach electronic banking. Develop a slide show program with video prompting (Ayers et al., 2006) that teaches how to enter the website and how to transfer money or cut checks for utilities or other bills. With the modern world creating new forms of monetary exchange and opportunities, school programs should change along with the technology available to students. These new technologies could save someone time and money as well as increasing proficiency. Methods presented within this literature review presented methods to teach students skill sets necessary for them to become a successful and productive citizen within today's society. There are also foundations for which to build upon in order to educate students on future technology and applications. Teachers can modify proven strategies presented to prepare tomorrow's citizens.

Table 1: *Review of Money Applications*

Citation	Participants	Intervention	Procedures	Results
Ayers, Langone, Boon, & Norman (2006)	N= 4 N= 2 MID, 2 MOID Grades: Middle School Math	The study used computer-based instruction and video to teach money skills (dollar plus) to generalize to the community.	A stable baseline was established before training began using computers and video strategy to train for generalization to the community	The strategy worked for 3 of the 4 participants. The visual analysis was highly variable for 1 of the participant claimed to have

			setting.	been successful.
Bourbeau, Sowers, & Close (1986)	N= 4 N= 4 EMR Grades: High School Math	Researcher developed instruction utilizing component training with chaining to teach students banking skills in the classroom for generalization to the community and across banks.	After baseline was established, the students were trained in a simulation setting for 40 minutes each day. After criterion was reached, training was moved to the target bank and then other banks to check for further generalization. Maintenance was established with once a week trips to the bank.	The participants did generalize from simulation to the target bank and did not require intensive *in vivo* training to acquire the skills.
Colyer & Collins (1996)	N= 4 N= 1 MID, 3 MOID Grades: Middle School Math	Natural cues and a prompt hierarchy were used to teach the next dollar strategy and purchase items from a store.	Every school day the students were pulled for 15 trials with one-to-one instruction. Students were then taken into the community to check for generalization	3 of the 4 participants were able to acquire and generalize the skills to the community and able to maintain them. One participants' school year ended before criterion was reached.
Cuvo, Davis, & Gluck (1991)	N= 20 N= 12 MID, 8 LD Grades: High School & Post Secondary Math	Self-paced workbooks were used to teach savings account management, bill paying, and money order skills	Participants were trained during 50-minute sessions four to five days a week	results indicated both sequencing techniques were equally in gains from pretest to posttest and showed maintenance at one week and one month

Denny & Test (1995)	N= 3 N= 3 MOID Grades: High School Math	The study used the one-more-than technique with cent pile modification to teach non-trained money amounts community purchases.	Trainers used 1 on 1 instruction for 20 minutes to teach the skills 4 times a week and probed daily.	All 3 participants mastered and maintained the skills for 10 weeks. They were able to use the technique for non-trained stimulus and community purchases.
Frank & Wacker (1986)	N= 4 N= 4 MID Grades: Elementary Math	Using visual prompting, the study utilized a number line with money increments.	Baseline was collected then trained with visual prompts, evaluated, then faded the prompts and evaluated the students' purchasing skills at the school store.	All four participants responded to the training and were able to use various coin combinations to purchase trained and untrained items. Skills were maintained over a 4-week period.
Fredrick-Dugan, Test, and Varn (1991)	N= 2 N= 2 MOID Grades: High School Math	General case programming with time delay to teach calculator skills for purchasing items.	A task analysis was developed a followed to teach calculator skills for 20-30 minute sessions twice a week.	There was a functional relationship between the strategy implemented and calculator use to purchase. The behavior was maintained and generalized across settings.

Gardill & Browder (1995)	N= 3 N= 3 MOID Grades: Middle School Math	A multiple exemplar strategy to teach three stimulus types to purchase inexpensive independent purchases.	Baseline was gathered then time delay procedure was used to teach monetary identification. Discrimination training follow and then the next phase used modeling to teach monetary skills.	two students mastered the desired skills but the third student was only allowed to show improvement
Horton, Lovitt, & White (1992)	N= 51 N= 7 EMH Grades: 8th Math	The study wanted to determine if pencil and paper, calculator, or calculator with rehearsal and visual prompts were more efficient for computing subtraction problems with regrouping.	Over a 35-day period and a follow session, 50-minute sessions were used to teach the strategy and then measure gains. The study was broken up into 4 phases and 2 maintenance phases.	Regular education students were equally efficient with paper, pencil, and calculators. For students with EMH, subtraction with regrouping can be an overwhelming task, but the calculator results were not consistent for all subjects and did not provide overwhelming support for the necessity calculators.

Kroesbergen & Van Luit (2005)	N= 69 N= 69 MID Grades: Elementary Math	Using two different approaches, the study compared constructivist versus direct instructional methods	The groups received 30 half hour sessions over 4 months of multiplication instruction. Pre and posttest were administered. Lessons were twice a week in small groups.	The DI group scored higher in multiplication ability and strategy adequacy. Automaticity and strategy diversity were the same for both groups.
Kroesbergen, Van Luit, & Maas (2004)	N= 265 N= 129 LD, EBD, and MID Grades: 2-6 Math	Using two different approaches, the study compared constructivist versus explicit instructional methods.	Experimental: The MASTER Training Program was used for both groups but the style of presentation varied one group with a constructivist approach and the other with explicit Control: district's mandated curriculum	All groups showed improvement with boys out performing girls. CI instruction did better with automaticity. Explicit instruction students performed better with both automaticity and problem solving than those taught with regular instruction.
McDonnell, J. (1987)	N= 4 N= 4 SID, PID Grades: High School Math	Compared time delay training and increasing prompt hierarchy to teach purchasing snack items from two different settings.	With 20-minute sessions, both were implemented and students were exposed to both items during each training session.	Results found that both prompt hierarchy and time delay were demonstrated as effective strategies but time delay proved to be the better.

McDonnell and Ferguson (1988)	N= 6 N= 6 MOID Grades: Junior High School Math	Compared general case in vivo and general case simulation plus in vivo paired with the next dollar strategy to teach purchasing items from community restaurants.	4 phases with the first for baseline, then next dollar training, then general case training and the last for simulation training. Daily sessions for 20 minutes in the classroom and the community.	Classroom simulation instruction did not generalize to in vivo circumstances. Skills mastery was performed only after training occurred coupled with general case in vivo and general case simulation plus in vivo.
McDonnell and Ferguson (1989)	N= 4 N= 4 SID, PID Grades: High School Math	Compared a decreasing prompt hierarchy procedure to a constant time delay procedure to teach writing and cashing checks in a bank and to utilize an automated teller machine.	With task analysis and an average of 2.5 hours of training in a variety community settings.	Results indicated that both the decreasing prompt hierarchy and time delay procedures led to the acquisition of both tasks. However, the decreasing prompt hierarchy was more efficient in establishing performance.
McDonnell, Horner, & Williams (1984)	N= 3 N= 2 MOID, 2 SID Grades: Post Secondary Math	3 strategies: flashcards, slides, and slides with in vivo paired chaining, cues, corrections, and the next dollar strategy to teach students purchasing items.	4 phases were implemented using 20-30 minute sessions across 5-20 trials.	Found that in vivo was the only strategy to teach the students to purchase the items.
Sandknop, Schuster, Wolery, and Cross, (1992)	N= 4 N= 4 MOID Grades: High School Math	Using an adapted number line and task analysis to teach grocery selection and purchasing	One session daily with 14 trails to make seven comparisons.	results revealed that all students reached criteria and maintained the skill with 90% accuracy

Schleien, Certo, & Muccino (1984)	N= 1 N= 1 SID Grades: High School Math	A task analysis with error correction to teach skills needed to bowl a game and purchase a snack at a local alley using printed cards to communicate.	3 or 4 phases were used to teach three skills. 2 training sessions per week lasting for 1.5 to 2 hours.	The participant was able to attain, generalize, and maintain the skills to bowl and purchase the items.
Schloss, Kobza, & Alper (1997)	N= 6 N= 6 MOID Grades: High School Math	Peer tutoring paired with next-dollar strategy was used to teach functional money skills. Generalization to actual purchases in the community was also observed.	After 4 baseline sessions, 1 on 2 modeling with verbal prompts was used to teach methods for tutoring and money skills. Community assessments were conducted 1 week after the final classroom session. They visited 3-5 sites in 3 days. All took place over a 6-week period.	Participants demonstrated immediate increase in skill development with supported peer tutoring and next-dollar strategy. Two of the 3 generalized the target skills to the community setting.
Stith & Fishbein (1996)	N= 49 N= 17 MR, 17 Downs Grades: Elementary, Middle & Secondary Math	3 tasks expecting students to count and compare coin money and values across 3 sessions with 14 trials.	3 sessions 20 minute each was divided into 14 trials over a 1 to 4 week period. A pretest was given to establish math ability and then mean proportions of errors was used over the 14 trials.	Regular education student were found to have less difficulties than students with disabilities did. There were no significant differences between students with downs and students with intellectual disabilities.

Test, Howell, Burkhart, & Beroth (1993)	N= 5 N= 5 MOID Grades: Secondary & Post Secondary Math	Using the One-More-Than approach with a cents pile modification, the study wanted to determine if the strategy could be generalized to the community.	Two studies were in the article. The first trained participants over 20 sessions to determine the efficacy of the strategy. The second followed the first's format but was able to establish a functional relationship and generalization.	The first study was cut short by 1 of the parents ending the experiment early, but the other participant showed generalization. The second repeated the first and demonstrated generalization also with all participants.
Van Den Pol, Iwata, Ivancic, Page, Neef, and F. Paul Whitley (1981)	N= 3 N= 3 MID and MOID Grades: Secondary & Post Secondary Math	Using role-playing and simulation to teach 5 restaurant skills and check for generalization in the public arena.	A 3 phase multiple baseline across subject design was used with 10 trials per skill for 5 to 10 minute sessions per trial.	All participants reached mastery over an average of 77 trials and showed generalization to public settings.
Van Luit & Naglieri (1999)	N= 84 N= 42 LD, 42 MMR Grades: Elementary & Middle School Math	Using a self-instructional method, the study compared the MASTER program against standard district instruction using students with LD and MID.	Experimental: The MASTER Training Program was used for both groups. Control: district's general instruction method	Both groups outperformed the general instruction group, but the MMR group demonstrated greater progress over the LD group. Maintenance was established with 3-month follow-up tests
Westling, Floyd, & Carr (1990)	N= 15 N= 8 MOID, 5 SID, 2 PID Grades: Middle & High School Math	To compare 2 settings, the study compared single to multiple setting to train students with MR to shop in department stores and	Each group was trained community skills by role playing, discussion, or modeling to before placement in the community. 2	Both groups demonstrated similar time to reach criterion and amount of performance on generalization measures. Shows that multiple

		generalize to untrained settings.	days a week for 20 days over 3 months in either 1 setting or multiple settings was implemented.	settings may not be necessary.
Wheeler, Ford, Nietupski, Loomis, & Brown (1980)	N= 7 N= 7 MOID, 1 SID Grades: Middle & High School Math	Used a cues and corrections to teach skills concurrently in the classroom and in vivo.	Instruction was broken down into 3 strands and instructed with cues and corrections to learn the skills concurrently In both settings.	6 students were able to meet criterion either within a year to year and a half. 1 student left the study before criterion could be reached.
Zencius, Davis, & Cuvo (1990)	N= 8 N= 8 MID Grades: High School & Post Secondary Math	Using Personalized System of Instruction, the study determined the effectiveness of teaching students complex money management skills and check for maintenance and generalization.	Using Personalized System of Instruction, the study determined the effectiveness of teaching students complex money management skills and check for maintenance and generalization.	All participants demonstrated an increased or mastered the banking skills. 7 of the 8 maintained at the 4 week follow-up and 4 of the 8 maintained at the 10-week follow-up. The participants were able to generalize their skills.

TouchMath Applications

Introduction

A dot-notation system is not a new strategy to teach students math skills. Kramer and Krug (1973) devised an addition and subtraction mathematical dot notation system with counting comparable to TouchMath. Kokaska (1975) investigated the system using four female participants (ranging in age from 9-13 years) with mental disabilities. The participants demonstrated improved skills with addition. Bullock, Pierce, & McClelland (1989) developed a modification and refinement of the previous systems and dubbed it TouchMath. The TouchMath program has been amended a few times and the current version was published in 2005.

Research to support TouchMath procedures began within four years of its creation. Scott (1993) implemented a multiple probe design across skills, replicated across participants, to evaluate the efficacy of TouchMath. Three 4th grade students with learning and intellectual (mild and moderate) disabilities from Georgia participated in the study. Scott (1993) wanted to determine the efficacy of TouchMath to teach addition and subtraction skills. The dependent variable was the percent correct of problems on a paper and pencil worksheet. The worksheet consisted of column addition, double-digit and triple-digit subtraction problems with regrouping. The participant with learning disabilities was able to master all skills while the other two exhibited score improvement.

Literature Search Procedures

The following literature search procedures were employed to retrieve relevant articles. First, a computer-assisted search of seven major databases was conducted including Google, WilsonWeb, ERIC, PsyInfo, ArticleFirst, Dissertation Abstracts, and Education Abstracts from 1980-2009. The descriptors used in the search were "mathematics, mathematics instruction, mentally retarded, retardation, intellectual disabilities, disabilities, mild-moderate-severe mental retardation, developmental disabilities, TouchMath, touch points, kinesthetic strategy, and multisensory strategy. Second, a hand search of relevant articles was completed. Finally, a hand search of reference lists and table of contents of relevant journals was conducted. This revealed nine studies, which met the criteria for inclusion in this review.

Criteria for Inclusion

The three main criteria for inclusion in this review include: (a) articles published from 1980 to 2009 to establish a literature review for TouchMath and similar techniques; (b) individuals included in the study are eligible for any special education classification as defined by the state (c) studies that implemented a touch point strategy. For the purposes of this review, studies were excluded when no clear mathematical intervention was employed or subjects were not classified as mentally retarded in the article by the authors and met current intelligence quotients.

Overall Study Characteristics

There were nine studies that ranged in publication date from 1993-2008, and appeared in refereed journals such as the *Focus on Autism and Other Developmental Disabilities, Exceptionality, Exceptionality, Education and Training of the Mentally Retarded, European Journal of Special Needs Education*. A total of 279 participants (range 3 to 120) who were all of elementary school age and had an array of classification for special education participated in these studies. The median number of subjects per study was six (range 3 to 120). The majority of studies included in this review were (N= 6) single subject designs (75%), while the remaining studies employed (N=3) group designs. The typical interventions targeted basic mathematical skills and concepts.

As stated in Mastropieri et al. (1991), the average intervention length is difficult to calculate since some studies report such figures in trials, sessions, days, and weeks. The final sample of studies included in this review consisted of five dealing solely with addition skills and concepts studies (Bedard, 2002; Cihak & Foust, 2008; Littlefield, 2003; Simon & Hanrahan, 2004; Wisniewski & Smith, 2002) and four addition and subtraction applications (Berry, n.d.;

Dulgarian, n.d.; Scott, 1993; Stand, n.d.). In the following paragraphs, each of these skills are analyzed and synthesized separately.

TouchMath Applications

Implementing a multiple probe across math skills replicated across participants study, Scott (1993) determined the effectiveness of TouchMath to teaching three skills (a) single and double column addition with regrouping, (b) two-digit subtraction with regrouping and (c) three-digit subtraction with regrouping for students with moderate intellectual disabilities. Three fourth grade students with learning and intellectual (mild and moderate) disabilities and IQ are from 44-92 participated in the study. The dependent variable was the percent correct of problems on a paper and pencil worksheet. The worksheet consisted of column addition, double-digit and triple-digit subtraction problems with regrouping. There were four probe periods with four intervention training sessions lasting fifteen to thirty minutes the special education in the resource room. Results indicated that all three participants were able to master all skills at 85% or higher quickly after training sessions were complete.

Utilizing a group study, Bedard (2002) investigated a dot notation system's effect on addition facts achievement with elementary regular and special education students. Six first grade classrooms containing 110 students participated in the quasi-experimental non-equivalent group pretest-posttest design. Four self-contained classrooms and two inclusion classrooms were utilized. The control group (52) and treatment group (58) were described as low-income white students ranging from 6-7 years old. The independent variable was the dot notation system TouchMath and the dependent variable mathematic achievement in addition facts. The control group was instructed with the Harcourt Brace (2000) workbook and objectives. Both pre and post measures contained 49 addition problems with sums between two through ten. Instruction took place in the regular education classroom for 45-minute sessions over a week. The results showed a significant difference between pretests and posttests with the TouchMath group based on t-test statistic despite the brevity of the study (1 week). The control group did not demonstrate a significant difference though actual raw data demonstrated minimal changes between groups.

Wisniewski and Smith (2002) explored a touch point system implementation into a math curriculum to increase student achievement scores for students with intellectual and learning disabilities. Four participants in 3rd and 4th grade were categorized as other health impaired, mild intellectual disabilities, or learning disabilities. A decrease in time to complete the worksheets was the desire result of the TouchMath application. Participants were only tested once and then determined that the students had mastered the TouchMath procedure without visual notation system displayed. The multisensory method was applied to boost percent correct and decrease the number of minutes required to complete the assessment. Mad Minute addition tests were employed as the pre and posttest measures consisting of addition facts and 30-40 double digit addition problem with and without regrouping. Instruction took place in the special education resource room during 20-minute sessions. Student four significantly increased percent correct and decreased completion rate by half. Student one was the only participant that did not decrease completion rate but increase percent correct. Student two scored lower on posttest but required less time to complete the measure.

Dulgarian (n.d.) utilized a pretest-posttest experimental group design with 20 participants to compare district instruction to dot notation strategy to increase addition and subtraction achievement for students with learning disabilities. The participants (9-12 years old) were in 4th and 5th grade and classified as specific learning disabled. The dependent variable was improvement in basic addition and subtraction math skills. The control group’s curriculum was

Math Steps compared to the dot notation system provided by TouchMath. Both groups received instruction over a ten-week period for 45-minute session three days week. A worksheet with 17 single and double-digit addition and subtraction problems with and without regrouping were graded and scored as percent correct for both pre and posttests. The TouchMath group (Group I) was more proficient and accurate completing the paper and pencil assessment than the traditional textbook instruction group. The treatment group completed the post measure both more accurately and needing less time. Group I also felt more confident in the classroom.

With a quasi-experimental pretest-posttest group design study, Strand (n.d.) compare a standard school district instruction (Addison Wesley textbook) to TouchMath with elementary students with regular education students. The participants were 120 regular education 1st grade students in a regular education classroom setting across three elementary schools. The dependent variable was percent correct on a paper and pencil worksheet with sixteen single and double-digit addition and subtraction problems with and without regrouping scored as percent correct. A pretest was given at the beginning of the school year and then a posttest at the year’s conclusion. Both groups were instructed during their regularly scheduled math curricular time. According to the results, both groups improved although the TouchMath group demonstrated better accuracy on all types of computational problems. Simple single addition for both groups was found not to have a significant difference on the posttest while the rest of the Chi comparisons offered significance.

Littlefield (2003) examined two strategies, TouchMath and The Path to Success to determine which was more efficient and effective the concrete (manipulative) or semi-concrete (dot notation) system on first grade student addition achievement. With IQ ranging from 61-98, six first grade six year old students categorized as developmentally delayed, other health impaired, mild intellectually disabled, or learning disabled were recruited to participate. An adapted alternating treatment design was employed with single digit addition achievement as the dependent variable. Instruction took place in small groups within a resource room for 15-20 minute sessions. Three different worksheets containing 49 single digit addition problems were implemented as performance measures. Though not stable and displaying overlap, TouchMath data indicated a greater increase in correct responses and decrease in minutes necessary to complete the probe. The researcher did remark that the TouchMath system took longer to teach. Five participants endorsed dot notation over manipulatives, while only one supported the use of manipulatives.

Implementing a multiple probe design for students with learning disabilities, Simon and Hanrahan (2004) evaluated the percent of problems solved correctly using the method chosen by the participant. Three ten year old elementary students with learning disabilities in the Montreal area participated in the study. All students were determined to have average IQ according to Wechsler Intelligence Scale for Children (WISC III) and have a large discrepancy in math skills. The dependent variables were a) be able to learn a dot notation method, b) once learned, if that would be the preferred method to solve addition problems, c) if the students could apply the method to unpracticed situation and d) if the participants could generalize the dot notation method to non-taught addition problems. The participants were allowed to employ any strategy known to them at the beginning of each probe. The probe was graded as percent of problem solved with dot notation and correct. Eight single and double-digit addition problems were used as probes to determine method and accuracy. All participant IQ falling within the average range according to Wechsler Intelligence Scale for Children (WISC III). A separate quiet room was utilized to instruct and probe the students. All three participants chose the dot notation as the preferred method and were able to master addition skills with multiple difficulty levels.

Utilizing students with autism and an AB design replicated across four groups, Berry (n.d.) tested the effectiveness of TouchMath inserted into a current math curriculum over a two-year period. Ten students with autism from California participated. The ten students were broken into four groups for one-on-one training in a classroom setting. Fluency and math skills gained were the dependent variables measured by math paper and pencil fact sheets. Single digit addition was taught first followed by single digit subtraction problems. Probes contained both addition and subtraction beginning with simple digit arithmetic to more complicated problems containing carrying and borrowing. By the end of the study, eight remained to collect data. Six of the eight participants increased fluency rates and achieved an average three-year skill level improvement. Two of the participants were able to learn the touch points but still depended upon calculators and counters to efficiently add and subtract. However, the article posed a vague systematic description of the study.

Cihak and Foust (2008) used an alternating treatments design with students classified with autism to investigate the use of *TouchMath* to teach single digit addition problem-solving skills versus a number line approach. Three seven and eight year old elementary students with IQ ranging from 40-50 and diagnosed to have severe (2) and average (1) levels of autism participated during the regularly scheduled resource class time. The dependent variable was if there was a functional difference between the two methods to solve addition problems. The percentage of single-digit addition math problems was assessed. Two different probe worksheets with ten single digit addition problems were used to assess math skills. Instruction was based on a least to most prompt hierarchy to guide students to the correct answer as well as an adapted model-lead-test procedure to teach both methods across seventy-four sessions. Testing sessions last from 5-20 minutes. Touch points were found to be more effective and preferred by the participants. There was enough evidence to support a functional difference between the two methods. For two participants the touch point system demonstrate much higher gains but one student showed similar increases in percent problems correct for both methods employed.

Synthesis of Studies

Table 2 provides a synthesis of the mathematical intervention TochMath. Several mathematical operations were examined such as addition and subtract both with and without regrouping. Table 2 illustrates that all studies included in this review reported positive results after instructing students in TouchMath strategies. Some studies are unpublished. Few studies have been published concerning TouchMath. Interestingly, all studies contained in this review dealt with elementary school populations.

Limitations

The research studies reviewed in this synthesis indicate positive results in teaching students and adults classified as mentally retarded mathematics instruction. Moreover, many of the studies revealed students and adults classified as mild to severely retarded were able to generalize mathematics skills in trained and untrained areas across settings as well as maintained proficiency over time. However, there are a vast array of limitations where research to extend and replicate these studies is warranted. The following limitations are listed in which further research is warranted in instruction of mathematics to individuals classified as mentally retarded.

· A lack of diversity in the majority of the studies suggests validity issues

· Findings cannot be generalized across grade levels, setting, or ability

· Strategies' effectiveness for differing levels of student intellectual levels and capabilities

· Examination of extended maintenance probes

· Determining independent use of strategy over extended periods of time

· Effect of strategy when students have prior knowledge skills (i.e., calculator)

· Additional skills with higher difficulty

· Diversity with methods implemented for instruction (group vs. individual)

· Generalization from trained to nontrained environments

· Lack of experimental studies

· Limited number of studies enacted

· Need for additional studies including other grade levels and disabilities

· Replication of studies and results

Conclusions

The nine studies synthesized in the review concentrated on two areas: addition and subtraction. Throughout the literature, it has been evident that much research is warranted in instructing students to gain greater independence and the area of managing money and banking skills. The results in the studies indicate that the strategies being employed have positive effects on the students but more rigorous research designs are needed to generalize and replicate on a larger scale. Interestingly, throughout this review not a single study utilized computers to facilitating mathematics instruction.

Visual prompts with coins present a concrete strategy to teach monetary quantities and coin denominations. For example, the TouchMath system can be implemented in the same manner as the number line. With TouchMath, each number has points corresponding to their value, which one touches as they count. Instead of points, dollar bills of various denominations or coins could be used to teach students how to count money. This method combine with the dollar plus or other incarnations could teach students who need concrete manipulatives to learn money counting or possible facilitation at the least.

With very few experimental studies conducted applying the TouchMath program that further research is necessary to prove its effectiveness. TouchMath offers several other strategies to teach other mathematical operations and functions. No studies to date have examined the money addition problems with decimals. All of the studies have been on elementary age students with disabilities but none has been administered on the middle and high school level. Moreover, the majority of the populations utilized were students classified as learning disabled. Finally, further investigations are warranted in transferring mastered skills in diverse simulated setting environments across grade, age, and disability level.

Table 2: *Review of TouchMath Applications*

Citation	Participants	Intervention	Procedures	Results
Bedard (2002)	N= 110 N= 110 Special Education Grades: Elementary Math	*TouchMath* was compared to the district's adopted curriculum, Harcourt Brace (2000) workbook and objectives, to teach basic addition.	For 45 minutes over a week, the groups were taught either the district's method or *TouchMath*. Both groups were pretested before the instruction began and then after instruction ended at the end of the week.	control group demonstrated significant difference between pretests and posttests based on t-test statistic, control no significant change, minimal change showed between groups
Berry (n.d.)	N= 10 N= 10 Autism Grades: Elementary Math	Using *TouchMath*, the researcher attempted to teach addition and subtraction over a 2-year period in groups of 2 to 4	Group instruction with drill and practice method to teach the math strategy over a 2-year period.	increased math fluency and an average of three year gain on math skills

		participants.		
Cihak & Foust (2008)	N= 3 N= 3 Autism Grades: Elementary Math	Researcher compared *TouchMath* to number lines to teach simple addition	Alternating design was use over 74 sessions to teach addition. Testing session lasted from 5-20 minutes. Adapted model-lead-test procedure was used to teach both methods.	touch points were effective and preferred method and functionally more effective
Dulgarian (n.d.)	N= 20 N= 20 LD Grades: Elementary Math	Researchers compared *TouchMath* to district's curriculum Math Steps to teach addition and subtraction with and without regrouping	Group instruction was for 45 minutes over 10 weeks. Instruction took place in the regular education classroom. Drill and practice was the dominate method to teach both strategies.	The *TouchMath* group was able to solve math problems faster and more accurately than their counterparts were. And Group I felt more confident in the classroom
Littlefield (2003)	N= 6 N= 2 MID, 2 LD, 1 DD, 1 OHI Grades: Elementary Math	*TouchMath* vs. The Path to Math Success (district adopted curriculum) to teach simple single digit addition problems.	Using 15-20 minute sessions over 3 months in a resource room to determine the effectiveness of district curriculum (concrete manipulatives) vs. *TouchMath* (semi-concrete) to teach addition	effective to increase correct responses and increase per minute but had overlapping data and not very stable data, touch point more efficient to work problems but took longer to teach how to use, 5 like touch points and 1 liked manipulatives
Simon & Hanrahan (2004)	N= 3 N= 3 LD Grades: Elementary Math	Using eight addition problem probes to determine which strategy students	For 40-minute sessions, three times a week for 45 sessions to teach the dot	All three participants were able to master the dot patterns in one session and

		were more apt to use and the accuracy of their attempts	notation and probe the individuals.	nine progressively more difficult instructional levels in ten sessions, all subjects choose dot notation as preferred method for solving problems even when allowed to use any method
Scott (1993)	N= 3 N= 1 MID, 1 MOID, 1 LD Grades: Elementary Math	Using *TouchMath* to teach single and double column addition and subtraction	Over 34 sessions with feedback and reinforcement, 15-30 min sessions were used to probe, train, and check for maintenance and generalization of the students.	subjects 1 and 2 improved scores on all three target skills and subject 3 mastered all skills
Strand (n.d.)	N= 120 N= 120 Grades: Elementary Math	Used *TouchMath* to teach students addition and subtraction. Percent correct was used to determine effectiveness.	Both groups were given a pretest at the beginning of the school year and then taught with the *TouchMath* method and given a posttest at the end of the school year.	both groups showed improvement but *TouchMath* group responded more accurately to all types of computational problems on worksheet
Wisniewski & Smith (2002)	N= 4 N= 4 MID Grades: Elementary Math	*TouchMath* was used to determine if the dot notation could increase the students' accuracy and fluency on basic addition math problems.	During 20-minute sessions over 14 weeks, students were taught *TouchMath* and tested every Friday to check for math competency.	two students showed increase in percentage and three took less time to complete the tests

CHAPTER 3

METHODS

This chapter delineates the methodology developed for this investigation.

Experimental Design

This study employed a multiple-probe across participants design (Tawney & Gast, 1984). The design examined the effectiveness of a concrete multisensory approach to teach students to subtract monetary values. Multiple probe designs demonstrate experimental control by replicating effect across no less than three participants at three points in time. This design also allowed for intervention institution while it did not necessitate that behaviors return to baseline conditions. A stable baseline is required before implementing intervention. Data was collected across all subjects, conditions, and tiers to evaluate functional relationships while scrutinizing level and trend changes.

Considering the dependent and independent variable, the design will permit the researcher to control for internal threats to validity and institute an effective experimental study. History was controlled by stable baselines and abrupt changes in levels between phases. Multiple tiers manage maturation and history effects. Maturation was also controlled by continuous measurement right before intervention implementation. Testing was a concern for this design and item differentiation on multiple probes accounts for this effect. Proper interobserver agreement collection by two people scoring each probe controlled for instrumentation effects. Four participants were included in this study. One treatment was applied therefore multitreatment interference was not an issue. The criterion for mastery was set before the study began. The intervention was only applied after a stable baseline condition was established. Both actions controlled for data variability.

Intersubject replication accounted for external validity issues. The intervention was applied to four participants to gain intersubject replication. The participants were similar across IQ, age, grade, and achievement characteristics, which created minimal differences for the entire sample establishing reliability. Baseline and intervention conditions should demonstrate minimal differences to manage procedural fidelity. Generalization measures conducted on similar math skills facilitated tracking of a second behavior.

Participants

Three students with mild and moderate intellectual disabilities from the same self-contained community-based instruction classroom partook in the study. The ages ranged from 14 to 16 with a mean of 14.75. Participant Intellectual Quotients varied from 61 to 64 with a mean of 63. All participants were classified based on county, state, and federal criteria, having below average intellectual ability, deficits in adaptive behavior scores, and both severely negatively affect academic performance. Two participants were dually diagnosed with emotional behavior disorder and another with autism. Demographic and educational information is depicted in Table 3.

All participants have received special education services since entering high school where they were in self-contained special education classroom settings three blocks a day and took part in one regular education elective. The participants are taught all academic subjects including mathematics in the same self-contained classroom from the same teacher for all three blocks during the 2009-2010 school year. Participants scored well below grade level in mathematics based the Woodcock-McGrew-Werder Mini-Battery of Achievement (MBA) (1994) test results.

Table 3: *Participant Information*

	Student 1 "Michael"	Student 2 "Trent"	Student 3 "Alex"
Chronological Age	14-11	15-0	16-1
Grade	9th	9th	10th
Sex	Male	Male	Male
IQ*	61	64	64
Adaptive Behavior Score Composite**	54	83	71
Math Composite*** (Grade Equivalent)	4.2	5.1	2.8
Primary Eligibility	MID	Autism	MID

*WISC III COG = Wechsler Intelligence Scale for Children (3rd ed.) by D. Wechsler. Copyright 1991 by Psychological Corp, San Antonio, TX.
** ABAS II = Adaptive Behavior Assessment System – Second Edition by P. Harrison & T. Oakland. Copyright 2003 by Psychological Corp, San Antonio, TX.
***MBA = Mini-Battery of Achievement by R. Woodcock, K. McGrew, & J. Werder. Copyright 1994 by Riverside Publishing, Chicago, IL.
Note: Pseudonyms are used for participants here and elsewhere in this dissertation.

Michael

Michael entered his first year of high school during the study at 14 years, 11 months old and turned 15 within the study's span. He does struggle with all academic subjects as evident by his instructors' observations during daily education sessions and receives one to four instructions daily for his academics. Michael has received special education services since his entrance into the school system in self-contained classrooms for students with mild intellectual disabilities. According to the WISC III (Wechsler, 1991) Michael had a Full Scale IQ score of 61. With a 53 conceptual score, 70 social score, 53 practical score, and general adaptive composite score of 54, the results from the ABAS II (Harrison & Oakland, 2003) instrument determined Michael lack adaptive behavior skills. Michael met criterion for classification as mild intellectually disabled based on these testing information. Increasing basic math skills was one of his academic IEP goals. His teacher states that he is cooperative during instruction and puts forth effort towards his class work.

Trent

Trent was a 9th grader in the same class as Michael. He is 15 years, 10 months old at the outset of the study. Trent had received special education services for ten years for autism and moderate intellectual disabilities. Placement was supported with a Full Scale IQ of 64 from the WISC III (Wechsler, 1991) and the ABAS II (Harrison & Oakland, 2003) scores of 72 on conceptual, 75 on social, 91 on practical, and a general adaptive composite score of 83. Trent's IEP goals covered several academic and life skill areas. He had a math academic goal of becoming more proficient in basic math skills. He teacher said that he is consistently willing to work hard to complete tasks and comply with directions from the classroom teacher and paraprofessionals.

Alex

Alex was a 10th grade student being served in the same self-contained class as the other two participants. He was 16 years, 1 month at the commencement of the study. He has received special education services for thirteen years with an eligibility of mild intellectually disabled and aspergers. Alex's placement was determined by a WISC III (Wechsler, 1991) Full Scale IQ score of 64. The ABAS II (Harrison & Oakland, 2003) scores of 70 on conceptual, 77 on social, 75 practical, and general adaptive composite score of 71. He has two money math skill goals on his IEP. Adding and subtracting two and three digit math problems without a calculator was the first and writing checks, making deposits, balancing checkbooks, etc. correctly was the second. He has demonstrated a lack of restraint and cooperation with teachers in the past but has not shown these behaviors since entering high school last year. His teachers had stated that he had been very obliging and receptive to instruction.

The participant composition is not indicative of the school population based on racial demographics. Participants were selected based on their grade level, special education classification and mathematical ability. All the participants were unable to properly and accurately subtract numerical or monetary values without a calculator. The classroom instructor taught the students to use calculators to determine purchase price in order to facilitate accuracy and fluency in the classroom and community settings. Research approval was ascertained from the school system, principal, instructor, and university's Institutional Review Board before the study was implemented. Student and parent or guardian permission were obtained. Data was gathered in the fall of 2009.

Setting & Arrangements

The school where the study occurred was a 1,500-student public high school with grades 9-12. The high school was located in a southeastern suburban county in the US. The county school system population was considered low income with manufacturing as the major employer. All phases utilized one self-contained special education math classroom for this study. Data collection, training, and instruction was collected and instituted in that same classroom. Each participant had their own scheduled block. The classroom dimensions were 3 m x 6.5 m. The room consisted of 12 student desks and two teacher desks. The teacher desks faced the student desks located to the side of the student desks. Immediately in front of one teacher desk, was a podium. There is one main dry erase board and each student was issued a small personal dry erase board. There is one large bulletin board behind the student desks. A two-door cabinet and bookshelf are next to the door.

A filing cabinet was between the teacher desks against the wall. A television hung from the wall. Two student computers and one teacher computer are in the room. The students were instructed at a distance of 1 meter, facing the teacher, in two student desks directly in front of the teacher. The TouchMath poster displaying touch points for numbers 1 to 9 were placed on the wall between the student and teacher desks for reminder visual cues during the instruction and intervention phases. No other students were in the classroom during the block and phases of the study. The participants were pulled from their classroom into a private room with little to no distractions.

Materials

The TouchMath system (Bullock, 2005) was the intervention utilized during the treatment phase. The researcher was the sole instructor and data collector during all phases of the study. The researcher and observer were trained with the TouchMath teacher training DVD sent by the publisher in the free materials packet. The TouchMath system (Bullock, 2005) was based on the placement of dots on numbers (1-9). The student was asked to state the number aloud. The student was expected to count aloud as they make contact on the points. For subtraction, the students must be able to count backwards from 20. When regrouping, the student was expected to be able to mark
through the number borrowed from and then place a 1 next to the previous number and subtract the numbers. TouchMath made a point of ensuring the number barrowed was the same size as the other digits.

Worksheets provided by the publisher and researcher were utilized to introduce, instruct, practice, and assess the participants. The worksheets were built based on the said steps previously mentioned. Publisher worksheets consisted of methods and examples on how to count forward and add with and without regrouping. A poster with the touch points for each number was posted on the wall. Miniposters were given to students to reference while learning the touch points.

Assessment Materials

Publisher and researcher developed worksheets with the same font and size as the publisher's were employed as the probe during the maintenance and intervention phase. The measures served as permanent products to collect data. These worksheets contained 10 subtraction problems. All probes consisted of different math problems so the participants cannot memorize the answers.

Procedures

General Procedures

All instruction, training, observations and probes occurred during the regular school day during the first block. There were five sessions per week for ten weeks with one week student vacation. Each participant was pulled from class at the beginning of the instructional day and brought into a separate room. Instruction and probes were issued during this time in the isolated room. Incentive (computer access) for cooperation in the sessions will be given daily following the sessions. During intervention, skills will be introduced from simplest to more difficult.

Participants must take the screener and satisfy the requirements for selection. The training and instructional sessions lasted 10-15 minutes on TouchMath techniques and procedures for subtraction. Probes were designed to take no longer than 10-15 minutes. Maintenance sessions extended long enough to complete the probe (10-15 minutes). These sessions were held concurrently with the last three intervention sessions of subsequent participant's sessions. Intervention was instituted to subsequent participants based on the participant reaching criterion. Criterion was established as the participant's average score increase is 40% above the average baseline score for 80% of the sessions. Baseline stability will follow the 80/30 guideline to establish trend before intervention is implemented.

Instruction began with identifying each number (1-9) and where the touch points were located. Next, the student was taught how to count those points in a certain order. TouchMath procedures recommended that counting be done aloud during instruction while learning touch points. Counting backward was taught and practiced while utilizing the touch points. Only after these skills had been mastered was the student expected to move on to actual subtraction with regrouping problems. With subtraction, the student was taught to (a) state the problem aloud, (b) state the first number aloud, (c) count backwards using the touch points on the second number (if participant reaches 0 before finishing counting bottom number, then regroup), (d) mark out number borrowed from, write lowered number above, (e) place a 1 next to number on right making sure it is the same size, (f) count backwards using the touch points on the second number, (g) place the difference in the answer blank, and (h) repeat the problem aloud with the answer. The current research was to establish if the participants could implement and retain the strategy and an inevitable goal would be to gradually fade the touch points and expected the student to complete the problems without the benefit of the visual stimulus.

Experimental Procedures

Baseline. A baseline condition was employed to determine the participants' natural skill level. Experimental control was established through stable baseline conditions and significant level change demonstration with intervention application. This was to account for history and maturation threats to internal validity. Before baseline probes were delivered, prerequisite skills were taught until 100% participant mastery was achieved. The participant must learn to count backward, place the touch points on numbers 1-9, and count those touch points in a proper pattern. The first participant was administered a minimum of three probes to establish trend stability. Once stability was established, intervention was applied.

Subsequent participants were probed concurrently with the last three intervention sessions of the previous participant. The first participant was probed a minimum of three times before intervention deliverance. Reinforcement (computer time) was employed after each session to continue involvement compliance and moral. Verbal cues and praise were offered for incorrect or correct behaviors. Baseline probes follow the same format as intervention probes. Probes were designed to take no longer than 10-15 minutes. Sessions commenced at the beginning of each participant's block.

Instructional Procedures

Session 1: The TouchMath strategy was introduced to the student. The instructor modeled the proper methods necessary to solve a subtraction problem utilizing the touch points and verbalizations. The students were then given an opportunity to practice one problem along with the instructor.

Session 2: The instructor modeled the proper steps and verbal cues to solve a subtraction problem. The student was then asked to perform the task as modeled. During the problem solving procedures, the instructor gave positive verbal corrective feedback to redirect any operational errors performed by the student. The student practiced the steps a minimum of five times.

Session 3: The instructor modeled the proper steps and verbal cues to solve a subtraction problem. The student was then asked to perform the task as modeled. During the problem solving procedures, the instructor gave positive verbal corrective feedback to redirect any operational errors performed by the student for the first two practice problems and then asked to solve a minimum of five problems independently.

Session 4: The instructor modeled the proper steps and verbal cues to solve a subtraction problem. The student was then expected to solve all practice problems independently.

Table 4: *Task Analysis for Subtraction Problems with Regrouping*

1. State the problem aloud
2. State the first number aloud
3. Count backwards using the touch points on the second number (if reach 0 before done counting bottom number, then regroup)
4. Mark out number borrowed from, write lowered number above
5. Place a 1 next to number on right making sure it is the same size
6. Count backwards using the touch points on the second number
7. Place the difference in the answer blank
8. Repeat the problem aloud with the answer

Data Collection

Data collection began on the fifth session. The student was given the probes upon entering the room. Verbal prompting and corrective feedback was offered when necessary but modeling and instruction was no longer presented.

Maintenance

During maintenance, the participants were given no instruction or visual cues from the TouchMath materials. After the participant had reached criteria for three consecutive days, a minimum of two sessions without instruction lapsed before a maintenance probe was given. These probes consisted of 10 subtraction problems with the same format as intervention probes. Concurrent with subsequent participants being presented their last two intervention probes, each previous participant was given a minimum of one maintenance probe every five days until the conclusion of the study with the last participant. These probes indicated if the touch point system could be retained across future problem sets.

Generalization was monitored throughout the study with subtraction problems at the end of each probe. These problems also accompanied maintenance sessions. These three problems, consisting of same skills addressed during intervention, were presented to participants from different stimuli, workbooks and instructor made worksheets. This measure determined if the participants could generalize TouchMath techniques and procedures to the same math behaviors from different stimuli. Touch point examples and instruction were not offered.

Reliability

The researcher's paraprofessional was the second observer asked to independently grade the probes and evaluate the procedural fidelity. The paraprofessional viewed the training material in conjunction with the researcher and was present during a minimum of 20% of the sessions. Interobserver agreement was calculated based on the point-by-point method (number of agreements/number of agreements + disagreements). Agreement between the graders should be 90% for correct and error causation. Procedural fidelity data was collected on a minimum of 20% of the sessions. The researcher instructed the paraprofessional on how to grade the probes and fill out the fidelity checklist. Both graders were expected to grade each probe with the same method to determine interobserver agreement.

Table 4 states the steps necessary to complete the problems was followed and checked as each step was completed to assess procedural fidelity. A section was devoted to whether prompting and feedback was offered and consistent. If each process was followed then a check was placed next to the corresponding step. Procedure fidelity between the observer and researcher was set for a minimum of 90%.

Scoring

Correct responses were defined as whether the participants were able to accurately calculate the problem and place that answer beneath the problem. Participants were not given visual reminders for the touch points. Probes were collected after the student completed the problems and announced completion and was finished working on the probe. Both the researcher and his paraprofessional scored the percent correct independently and compared the results to determine interrater reliability. The percent correct was calculated by dividing the number of correct responses by the total number of problems and multiplied by 100. The same technique for scoring and accuracy was implemented throughout the all phases.

Data Analyses

Percent correct will be the focal behavior for measurement and recorded for visual analysis. Baseline and treatment phases will be analyzed by various procedures to determine TouchMath effectiveness. Four graphs displayed participants' results. The intensity of change between phases will dictate the experimental control and effectiveness of TouchMath. Descriptive statistics such as mean and range of scores were scrutinized for further analysis.

Session length during intervention depended on the effectiveness of the treatment. The time needed for the student to comprehend and apply the technique successfully dictated the intervention session length. Once the participant reached criteria for four out of five probes, the intervention sessions are concluded. Baseline lasted long enough to establish data and trend stability. For the first participant, a minimum of four sessions was implemented. Stability was established based on the 80/30 guideline. If an abrupt level change was not immediate after intervention application then a level change should have been detectable within the next 1-3 sessions. A level trend line should be shown in baseline. After treatment institution, an effective treatment should show a detectable upward trend. Ideal percent of nonoverlapping (PND) data will be 100%. Changes from baseline to intervention should illustrate adequate amplification to secure no data reoccurring in the same position next phase.

Table 3 illustrates the participant descriptive data. A task analysis of what steps were to be followed when completing a problem with the TouchMath system is contained in Table 4. Tables 5 and 6 delineated the number of sessions and average score for participants across each phase. Figures 1demonstrated the results from the participants during the study. TouchMath was expected to be an effective instructional strategy once the student comprehended and was able to apply it correctly to subtraction problems.

The percent correct was the measure of success to carry TouchMath over to other math skills. Once the participants understood the dot notation procedures, some carryover was expected for basic math skills but may not be demonstrated on problems that are more complex. Social validity data should demonstrate the need for different approaches to teaching math. Participants should find the TouchMath procedures facilitate math skill acquisition. The table culminated the data in average Likert score response per question from each group.

CHAPTER 4

RESULTS

The purpose of this chapter is to convey the results of the study concerning intervention effectiveness for the participants, study reliability, and social validity surveys from students, parents, and instructors. The study proposed to examine the effectiveness of teaching students to subtract money amounts while incorporating regrouping skills in the problems through the use of TouchMath. Reliability data are relayed regarding the independent and dependent variable. The social survey sought to determine the participants', parents', and instructors' view of the strategy and its relevance to the student and his or her needs. Within this chapter, raw data and its' direct interpretation are provided. The next chapter presents discussions, limitations, and implications.

Reliability

Independent and dependent reliability data were gathered. Dependent data was collected on 100% of the student responses and probes. Both the researcher and observer independently graded the responses and the point by point agreement was 96%. Of the 49 probes graded, two were found to have different scores between the graders. On the two probes, each had one response in conflict between the graders due to disagreement over identifying a particular digit in the response. Procedural reliability data was collected on 20% of the sessions. 56% of the observed sessions were during training and 44% during probe sessions. The interobserver agreement was 100%. The script was followed each time to ensure consistency between the participants.

Sessions

Clarifying the differing numbers of sessions during phases, single-subject methodology stipulates that participants have differing session numbers during each condition depending upon the order in which the participant would enter the phases. The first participant would have the shortest baseline period and longest maintenance, while the last participant would have the opposite with the longest baseline phase and shortest maintenance. The study was terminated with the last participant have one maintenance session due to study design and an impending student holiday making that time a logical ending date.

Table 5: *Number of Sessions Participants Spent in Each Condition*

Participant	Baseline	Intervention	Maintenance	Total Sessions
Trent	3	5	6	14
Michael	6	5	4	15
Alex	9	10	1	20

Table 5 delineates the number of sessions for each participant during each phase. The study was concluded based on a pending student holiday extending for one week and the study design. Participants spent a minimum of nine sessions in intervention, four for instructional purposes and five sessions to reach criteria. The last participant spent a longer period during intervention due to requiring more sessions needed to reach criteria. Alex had an extended intervention phase due to him not reaching criteria until five additional sessions were completed.

Effectiveness of the Intervention

Figure 1 illustrates the percentage scores the participants received for correct responses to subtraction problems with regrouping during each study phase. The visual kinesthetic TouchMath strategy imposed dramatic and significant change in aptitude for solving subtraction problems. During the maintenance phase, correct responses continued though with slightly lower scores. Replication across subjects was attained demonstrating effectiveness of the intervention for the participants. Table 6 presents the data for cumulative study results across all participants. The mean score for all participants during the baseline phase compared to intervention phase demonstrates patently observable change between the two phases illustrating the effectiveness of the intervention strategy. During the maintenance phase, scores continued to be dramatically higher than during baseline.

Table 6: *Average Probe Scores across Participants during Each Phase*

Students Scores (Percentages)	Baseline	Intervention	Maintenance
Mean	.39	77.5	70.9
Median	0	85	80
Range	1	80	80

Trent. Trent’s baseline score mean was 6.66% across all 3 sessions which demonstrates a stable trend in the data. A substantial immediate positive score increase was observed when the intervention probes were issued. This showed an effective intervention for subtraction skills with problems containing regrouping. The average score across all intervention sessions was 75.55% demonstrating a continual, stable, and maintained acquisition of the skills set needed to calculate the correct answers, which was a 68.88% increase from the baseline phase. Trent reached criteria within the preset number of sessions, which was established when 80% of the probe scores were 40% higher than the baseline scores. There was no data point overlap observed from the baseline to the intervention phases signifying an immediate positive increase that was maintained throughout intervention. The trend from the intervention through the maintenance phase was positive and the data points within the trend were reasonably stable. Trent's mean score during intervention was 75.55% and increased to 83% during maintenance indicating a continual improvement in skill level with additional opportunities to utilize the strategy. There was an 83% overlap between the intervention and maintenance phase though Trent was able to increase his mean scores during maintenance. This indicates that Trent was able to prolong his ability to solve subtraction problems with regrouping and, based on his scores during the maintenance phase, improve his scores over time. The intervention strategy was successful initially and in sustaining Trent's ability to solve subtraction problems with regrouping.

Michael. His mean score during the baseline phase was 5% indicating that Michael had established a flat and stable baseline measure. However, Michael's mean score during the intervention phase increased to 88%, which was an 83% increase from the baseline phase. This abrupt level change and 0% overlapping data points from baseline to intervention identified that the intervention strategy was effective for Michael in acquiring the subtraction skills via the use of the TouchMath program. Michael met criteria after only four sessions. There was a level trend after the abrupt level change from the baseline to the intervention phase indicating a consistent calculation skill aptitude. The mean maintenance score for Michael was 45% with a median score of 35%. There was 100% data point overlap from intervention to the maintenance phase. A continual decreasing trend occurred during the maintenance phase ending in a 20% score on the final probe session. Michael did not revert to his previous baseline scores but further probes would be needed to determine sustained skill retention. The intervention strategy was confirmed to be effective over a relatively short period, as further strategy instruction may prove beneficial for Michael's continued success.

Alex. The baseline phase extended for 9 sessions for Alex while maintaining a flat and stable trend with a mean score of 2.22%. However, during the intervention phase, Alex demonstrated a positive level change with the first intervention probe session. The second probe score increased significantly from 20% to 70% then faltering back to 30% causing an unstable level change with the first four sessions. The fifth session established the start of an observable stable level change. Due to beginning unstable scores, Alex required the greatest time to meet criteria. Criteria were met after ten sessions with an average score of 76% and a 90% median score, which was a 73.77% increase from the baseline measures. The intervention strategy was effective for Alex to subtract three-digit money problems with regrouping. Between the baseline and intervention phases there was 0% data point overlap, demonstrating a positive level change though five additional sessions were required until stability and criteria were met. There was 100% overlap from intervention to maintenance phase. The mean maintenance score for Michael was 100%. From beginning of baseline to the end of the maintenance phase, there was a steady increasing data score trend. The intervention strategy proved to be effective for Alex.

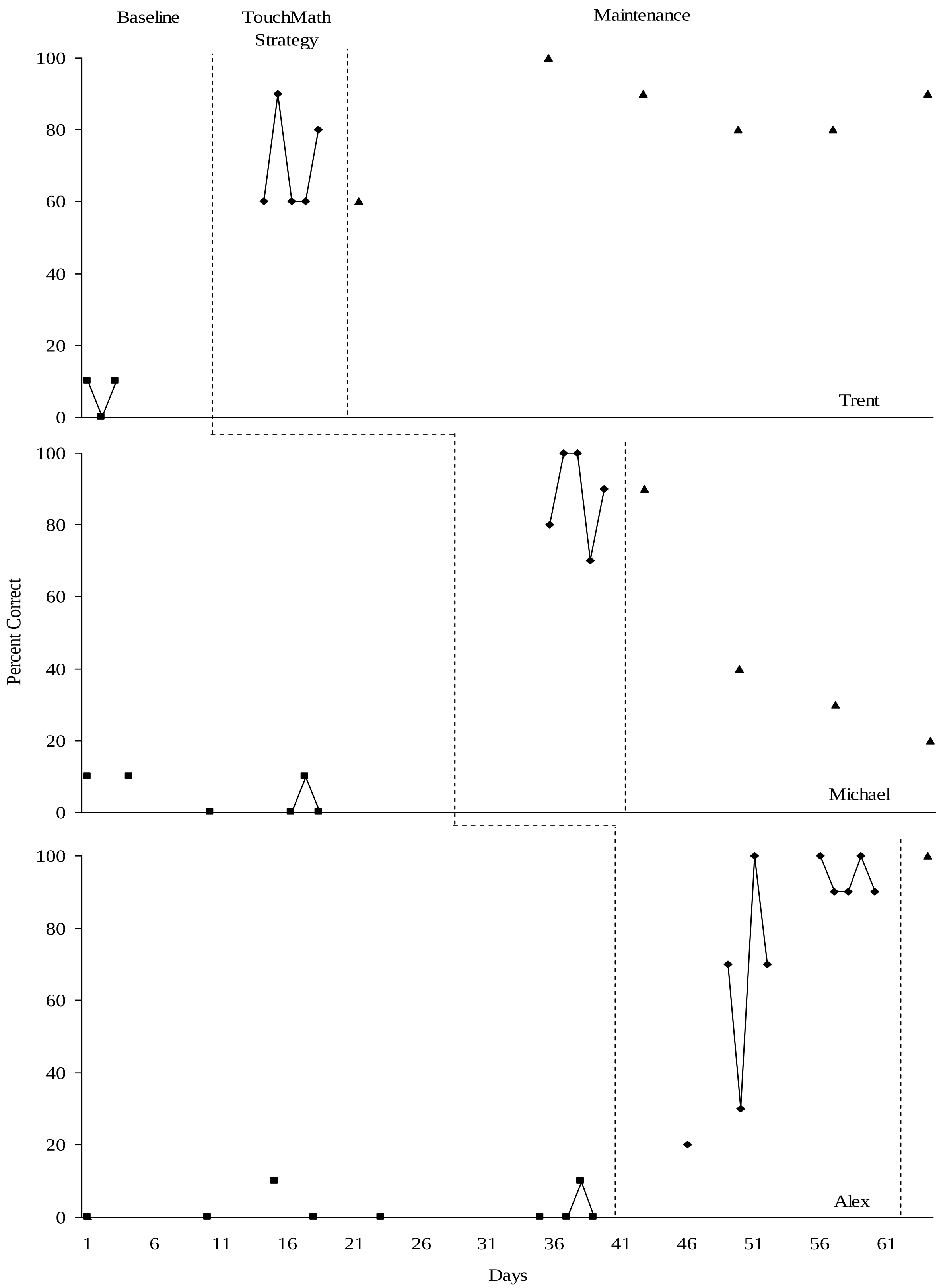

Figure 1. Percentage of correct responses for baseline, intervention, and maintenance conditions.

Social Validity Survey

A questionnaire was implemented to determine social validity for students, parents, and teachers. Wolf (1978) recommended three levels of social validity: (a) the study goals should be socially important, (b) the procedures should demonstrate social appropriateness, and (c) the participants should be satisfied with the results. A 10-statement Likert scale form was created to gather social validity data and followed the format designated by Wolf (1978).

The first area under scrutiny was whether the strategy was beneficial to the participant. The participants, students, and teachers all felt that the intervention was beneficial. The participants found that the strategy was easy to follow and improved their ability to solve subtraction problems with regrouping. The strategy facilitated organization of the steps needed to complete calculation requirements. The teachers appreciated the students' abilities to quickly acquire and successfully follow the number of steps needed to solve the subtraction problems with regrouping. All involved agreed that others would benefit from exposure to TouchMath and that it was easy to employ. The ease of use was also evaluated and the participants stated that once they understood the steps and sequence, strategy implementation was uncomplicated.

Social validity for the skills acquired by the participant was the next topic evaluated by the participants, teachers and parents. All groups stated that they agreed or strongly agreed that the skills gained were necessary for the participant to have before leaving school for real life situations. All involved agreed that the skill was grade appropriate and necessary for classroom requirements. The participants stated that they were neutral when considering the skills crucial for grade level requirements. All decided that the intervention was recommendable for others to employ.

The last area surveyed was whether the intervention was important to the participant. Since calculating money values is important to comprehend and utilize, all groups determined that it was an important and critical skill essential for independent living in the community by agreeing or strongly agreeing. No group found that the money subtraction skills were not valuable to the participants for school related requirements and community obligations.

CHAPTER 5

DISCUSSION, LIMITATIONS, AND IMPLICATIONS

The purpose of this study was to examine the efficacy of using a multi-sensory strategy via the use of the program TouchMath to facilitate the learning of two and three digit addition problems containing decimals for students with intellectual disabilities at the secondary grade level. The intervention strategy was developed to advance the aptitude of students with intellectual disabilities to calculate monetary values without calculators to facilitate independent community living. The results suggest that the intervention strategy was effective for participants in acquiring and maintaining the skills necessary to subtract 3-digit monetary values with regrouping. The group consensus concerning the intervention was favorable based on their responses to the social validity survey. This chapter presents discussions of the results concerning the intervention strategy and surveys. Study limitations are conveyed as well as future research and instructional implications.

Discussion

The present study assessed the implementation of TouchMath to solve 3-digit money subtraction problems with regrouping. Two questions were addressed by this study: 1) Does the use of a multi-sensory mathematics program (e.g., TouchMath) with students with intellectual disabilities at the middle and high school level have a positive effect on their ability to solve two and three digit addition problems with decimals; and 2) What are the students' or teachers' attitudes and perceptions toward the use of the TouchMath program as an effective instructional strategy in mathematics classes for students with intellectual disabilities?

The first question addresses the efficacy of the TouchMath method. During baseline, all four participants demonstrated an inability to solve 3-digit subtraction problems with regrouping, though screeners before the study established them all to be able to subtract without regrouping. There was an abrupt level change for all four participants with no overlapping data points indicating an increase in performance and continued level of competence. An ascending trend was observed for the participants during the intervention phase exhibiting emblematic performance when an academic intervention was employed. These observations provide evidence that the intervention was effective in teaching the participants to subtract 3-digit money values.

Once the participants were shown the steps and began the intervention probes, Trent work completely independent while the other participants would ask questions on occasion. The questions concerned whether the participant was following the proper steps or finding the correct answer. The researcher did not relay any answers or provide steps but offered positive reinforcement statements like, “try your best” or “try to follow your steps.” Two participants reached criterion in the allotted amount of time, four sessions. The last participant, Alex, took 14 sessions to reach criterion. During the first session, Alex scored well on the first probe but only scored 30% on the following probe. This low score caused Alex not to reach criterion in the allotted amount of time. On subsequent probe scores, Alex averaged 91.4% over the last seven probes. If the one probe were erased then Alex would have reached criterion in four sessions.

During maintenance, performance varied from participant to participant. Trent sustained an ascending trend throughout the study. After six sessions, Trent retained the necessary skill set to solve the subtraction problems. Michael demonstrated a descending trend across four maintenance sessions with a median score of 35%. After the minimum two-day period, Alex completed one maintenance session with a score of 100% before the termination of the study. The results deserve further research to determine the ability for students with intellectual disabilities to sustain the skills necessary to subtract 3-digit money values. To help continue maximum skill proficiency over time, refresher sessions to review the steps would be required and additional maintenance probes.

The social validity survey results indicated that the participants agreed that they appreciated the intervention and were pleased to have participated in the study. The participants thought that the skills developed were necessary for successful community living and its requirements. There were two highly rated questions in the survey by the participants. The first question was if they understood the strategy and what was expected of them. The second question was that the intervention was beneficial to help them subtract. Alex made a point of letting me know when he understood the process and that the strategy was truly helping him solve the problems easier and with more confidence. Alex shared his delight in being able to accomplish the tasks placed before him.

The participants agreed the least with questions concerning grade and classroom requirements. Two of the three participants felt that the target skills were not necessary for grade level requirements. The participants thought that a calculator negated the need for working the problems out on paper. One participant did not believe the skill set to be appropriate for classroom requirements though the classroom instructor has the class do activities and lessons with menu and grocery store item values on a daily basis. The classroom instructor and paraprofessional assisting with the study agreed with all aspect of the survey. The classroom instructor was interested in the outcome of the study to determine if it would be an appropriate strategy to utilize in the classroom. With the positive outcome, the instructor stated that she would like to retain the materials and implement them during regular classroom instruction.

The parents reported the only two responses that received less than neutral replies. The parents agreed with all the aspects of the survey except two areas. The first area was understanding the strategy and what was expected of them. This can be attributed to the lack of necessary participation required by the parents. The other question was if the skills were necessary for classroom requirements. This may be due to the use of calculators by the students for assignments in the classroom.

Results in Relation to Research

This study supports and extends the literature regarding students with intellectual disabilities and money value subtraction with regrouping. TouchMath is a recent multisensory strategy offered to facilitate mathematical skills. There are few published studies concerning multisensory methods such as TouchMath. Students with intellectual disabilities demonstrated low aptitudes for subtraction with regrouping based on scores during the baseline phase. The study by Horton, Lovitt, & White (1992) could not provide conclusive evidence for the use of calculators for subtraction with regrouping. This study presents clear evidence for a strategy that aids in the performance of this skill. This study affirms previous studies' success that added visual stimulus components and kinesthetic properties to instruction (Frank & Wacker, 1986; Sandknop, Schuster, Wolery, & Cross, 1992).

Every study published or unpublished that utilized TouchMath only examined its effects with elementary school populations. This is the first study to focus on secondary populations. Furthermore, this is the first study that utilized TouchMath to subtract money values as a confounding variable to basic subtraction with regrouping. Other studies (Berry, n.d.; Scott, 1993; Strand, n.d.) had successfully implemented the TouchMath strategy for subtraction but did not add the confounding variables of money values and regrouping. This study extends previous research and provides evidence to support the employment of TouchMath to achieve skills that are more difficult. One study (Dulgarian, n.d.) examined subtraction with regrouping and was successful in teaching various elementary students with disabilities to use TouchMath to solve those problems. The study results affirm this research.

Limitations

There are inherent limitations to academic single-subject research methodology studies. The number of participants makes it difficult to support arguments for generalization to other populations. This study contained a population selected based on availability and does not represent the characteristics of typical school populations. The results cannot be generalized to other disabilities, age groups, race, or gender. First, the participants were male and in 9^{th} and 10^{th} grade. Secondly, a wide range of disabilities was not employed; the students were classified with intellectual disabilities and autism. Lastly, the school population does not have a diverse ethnic population. Hispanic, Asian, nor other minority populations were utilized in this study.

Instruction was done on a one-to-one basis and would need to be modified for group instruction or study. The study encompassed only one specific skill set limiting the ability to generalize the study findings to other mathematical skills. Due to participant capability levels, addition and subtraction without regrouping were not considered nor were higher skill level problems. Maintenance data was inconsistent and only one probe was gathered from the last participant. Further investigations are warranted examining maintenance capacities.

Limitations notwithstanding, this study demonstrated an effective strategy to teach students with intellectual disabilities how to subtract 3-digit money values with regrouping. A successful single-subject study was utilized to measure the participants' responses to an intervention. The findings advocate future research questions to expand the evidence to support the use of kinesthetic strategies like TouchMath. The results also present arguments for classroom instruction or research proven methods for remediation and intensive interventions to help insure skills acquisition.

Implications for Practice and Future Research

Based on the success of this study, there are implications for instructors as well as future research. Even though students with intellectual disabilities reach the secondary school level, these same students still do not have many of the mathematical skills necessary to excel in school or proficiently perform in the community. Schools have progressed toward calculator use for students with intellectual disabilities because students have not acquired the basic skills nor retained those skills. Results from this study have offer implications for classroom instruction. The study results present evidence that the TouchMath strategy can help students solve 3-digit money value subtraction problems with regrouping. Since students with disabilities learn from concrete kinesthetic strategies, these results provide a possible method to teach subtraction skills.

As students do not often gain the skills in lower grades, research for remedial methods for secondary students can provide alternatives to help students with intellectual disabilities obtain mathematical skills. TouchMath is a strategy that can be utilized for the Responses to Intervention (RTI) guidelines required by state and federal agencies as an intervention. The inconclusive data during the maintenance phases indicate that review instructional sessions would be beneficial with this strategy and research. With a lack of research utilizing TouchMath, future replication of effects studies will provide supplementary evidence substantiating its effectiveness.

To date, no published study has examined the effects of the TouchMath method to teach students with intellectual disabilities to subtract money values. Few, if any, studies using TouchMath have explored its effects with high school populations, which concentrated almost exclusively on elementary populations. More consideration needs to be given toward higher addition and subtraction skills for middle and high school students. A group instructional approach should be investigated to determine if the strategy can be employed on a larger scale to reach more than one student at a time.

This study focused only on part of the entire TouchMath intervention. The student is eventually expected to have the visual stimulus phased out and then removed. Further consideration towards fading the intervention is necessary to determine the efficacy with the entire strategy. The probe problems employed in this study presented one instance of regrouping within the problem. Generalization to more difficult skills such as multiple regrouping opportunities or regrouping with zero in the problem should be examined.

Summary

To sum, this study has continued research into multisensory approaches to teach students with intellectual disabilities. This study also offers opportunities to expound upon the findings and continue the research into the use of multisensory methods to teach mathematical skills to high school students before entering adulthood and achieving independent living. The more methods employed by an instructor, the greater the likelihood that students will acquire the expected knowledge and skills. Technology has been the emphasis of late to teach effectively and build interest in learning, but sometimes it may take well-developed and applied low-tech methods to increase student response. Additional studies are needed to convince educators to pay attention to strategies like TouchMath.

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APPENDIX A

Sample of Money Math Problems

Name ____ Date ____________________

$9.36	$4.41	$5.18	$6.25	$5.92
- 4.54	- 3.71	- 1.55	- 3.34	- 0.64

$2.46	$1.38	$0.14	$8.44	$4.71
- 0.73	- 1.81	- 0.43	- 1.53	- 2.93

APPENDIX B

Data Record Sheet

Data Record

Student ______________________________________

Researcher																			
Parapro																			

Researcher																			
Parapro																			

Researcher																			
Parapro																			

APPENDIX C

Social Validity Survey

Social Validity Survey
(Student, Teacher, Parent)

1. Touch Math is a beneficial strategy to help with subtraction.	1	2	3	4	5
2. Subtraction is an important skill to have for real life situations.	1	2	3	4	5
3. Subtraction is an important skill to learn before leaving school.	1	2	3	4	5
4. I would you recommend this strategy to someone else.	1	2	3	4	5
5. I understood the Touch Math strategy and what was expected of me.	1	2	3	4	5
6. Touch Math was easy to use.	1	2	3	4	5
7. Touch Math was an effective strategy?	1	2	3	4	5
8. The target skills are necessary for grade level requirements?	1	2	3	4	5
9. The target skills are necessary for classroom requirements?	1	2	3	4	5
10. The target skills are necessary for community life requirements.	1	2	3	4	5

Note: 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree

Comments:____

APPENDIX D

Training Procedure Fidelity Checklist

Procedure Fidelity Checklist

Completed by: ___________________________ Date: _____________

Training Procedures

Procedure	Yes	No
The researcher introduced the lesson.		
The researcher showed the student the number poster.		
The researcher showed the student the touch points for the numbers.		
The researcher modeled the counting the touch points.		
The researcher allowed the student to place touch points according with the help of the poster.		
The researcher allowed the student to place touch points according without the help of the poster.		
The researcher modeled how to solve a problem with touch points.		
The researcher allowed the student to complete problems with assistance.		
The researcher allowed the student to complete problems without assistance.		
The researcher reviewed any mistakes and corrected them with the student.		
The researcher offered feedback as needed.		
The researcher collected the worksheet.		
The researcher provided positive feedback for cooperation.		

APPENDIX E

Probe Procedure Fidelity Checklist

Procedure Fidelity Checklist

Completed by: ____________________________ Date: ______________

Probe Procedures

Procedure	Yes	No
The researcher reminded the student of touch point procedure.		
The researcher gave the student directions on how to complete the worksheet.		
The researcher gave the student the necessary time to complete the worksheet.		
The researcher collected the worksheet.		
The researcher provided positive feedback for cooperation.		

APPENDIX F

Parental Consent Form

The University of Georgia
College of Education
537 Aderhold Hall
Athens, GA 30602
678-407-5185; FAX 706-542-2929

(parent)

Parental Permission Form

I agree to allow my child, **_____________________**, to take part in a research study titled, "The Effects of Touch Math to Facilitate Learning Multiplication in High School Classrooms," which is being conducted by Hugh Waters and Dr. Richard Boon, from the Special Education Department at the University of Georgia (678-407-5185). I do not have to allow my child to be in this study if I do not want to. My child can stop taking part at any time without giving any reason, and without penalty or loss of benefits to which my child is otherwise entitled. I can ask to have the information related to my child returned to me, removed from the research records, or destroyed.

The following points have been explained to me:

The purpose of this study is to investigate the use of Touch Math that can be used in secondary mathematics classrooms to teach mathematical content.

As a part of the regular curriculum, my child will be taught using two different instructional methods, Touch Math and guided notes, and these methods are based on best practices and previous research.

If I allow my child to participate in this research project, my child will be asked to complete such tasks as taking pretests and posttests, which will take about 10 minutes, before and after each condition and allowing researchers to observe and take notes during the instructional period. If I do not want my child to take part in the project, their scores on the pre- and posttest measures will not be recorded and included in the project. Also, the researchers would like permission to ask my child questions about their mathematics class. These procedures will be instituted during classroom activities. The researchers would also like to look at some of his/her tests. These tests include test scores from mathematics class and test scores from existing school records of standardized tests such as IQ scores, arithmetic, broad reading, and reading comprehension measures.

Benefits: While some students may improve their ability to learn and comprehend mathematical information as a result of learning to use Touch Math, there is no guaranteed benefit to participation in this research study.

Foreseeable Risks: There are no foreseeable risks or discomforts to participants.

Voluntary: My child's participation is voluntary, and they may withdraw from the study at any time and for any reason and will not affect their grade. There is no penalty for not participating or withdrawing.

Confidentiality: All data collected in this study will be confidential; all person-identifiable data will be coded so that no one, including individual students, parents, teachers, schools, or districts can be identified.

The researcher will answer any questions about the research, now or during the course of the project, and can be reached by telephone at: 770-784-2920. I may also contact the professor supervising the research, Dr. Richard Boon, Special Education Department, at (678) 407-5185.

- I understand the study procedures described above. My questions have been answered to my satisfaction, and I agree to allow my child to take part in this study. I have been given a copy of this form to keep.

Hugh Waters

Primary Researcher

________________________ ________________________ ____________

Name of Parent or Guardian **Signature** **Date**

Please sign both copies, keep one and return one to the researcher.

Additional questions or problems regarding your child's rights as a research participant should be addressed to The Chairperson, Institutional Review Board, Human Subjects Office, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu

APPENDIX G

Minor Assent Form

The University of Georgia
College of Education
537 Aderhold Hall
Athens, GA 30602
678-407-5185; FAX 706-542-2929

(student)

Minor Assent Form

Dear Participant,

You are invited to participate in my research study titled, "The Effects of Touch Math to Facilitate Learning Multiplication in High School Classrooms." The project will be conducted to examine the effects of sensory cognitive math strategy compared to traditional textbook instruction for high school aged students in mathematics class. The project is intended to investigate ways to improve students' school performance in mathematic instruction for students with special needs.

The project will examine how teachers can help you learn better in secondary mathematics class. As a part of the special education curriculum, you will be taught using Touch Math instructional methods, sensory input and guided notes, and these methods are based on best practices and previous research.

In this research project, you will be asked to complete such tasks as taking pretests and posttests before and after each condition and allowing researchers to observe and take notes during each condition. Also, the researchers would like permission to ask you questions about your mathematics class and look at some of your tests, such as pre- and posttests scores. These tests will include scores from mathematics class, and test scores from your school records such as IQ scores, arithmetic, reading and reading comprehension measures. These procedures will take place during mathematics block time. If you decide to be part of this study, you will allow me to work with you in your mathematics classroom. You will talk to me about your mathematics class. You will allow me to watch you and take notes and follow along while you are using the visual stimulus.

Your participation in this project will not affect your grades in school. I will not use your name on any papers that I write about this project. I hope to learn something about the effects of Touch Math that will help other students in the future. Finally, while you may improve your ability to learn and comprehend mathematical information as a result of learning to use Touch Math, there is no guaranteed benefit to participation in this research study.

If you want to stop participating in this project, you are free to do so at any time. You can also choose not to answer questions that you don't want to answer.

If you have any questions or concerns you can always ask me or call my professor, Dr. Richard Boon at the following number (678) 407-5185.

Sincerely,

Hugh Waters

I understand the project described above. My questions have been answered and I agree to participate in this project. I have received a copy of this form.

__________________________ __________________
Signature of the Participant Date

Please sign both copies, keep one and return one to the researcher.

For additional questions or problems about your rights as a research participant please call or write: The Chairperson, Institutional Review Board, Human Subjects Office, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, GA 30602-7411; Telephone (706) 542-3199; E-mail Address: IRB@uga.edu