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Using the multisensory approach of touch math to teach basic mathematical operations to students with significant disabilities

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USING THE MULTISENSORY APPROACH OF *TOUCH MATH* TO TEACH BASIC MATHEMATICAL OPERATIONS TO STUDENTS WITH SIGNIFICANT DISABILITIES

by

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Abstract

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The current study examines how the multisensory approach of the *Touch Math* program is used in a school that educates students with significant disabilities to improve their basic operation addition skills. The students who participated in this study struggled with traditional teaching of basic operation skills, and they were having difficulty maintaining fact knowledge, with modifications to their current instruction. The study was conducted in a school in Atco, New Jersey over an eight-week period. The current study used baseline assessments, which the two single digit addends without touch points, to determine the student participant's individual single digit addend knowledge. Then the students explicitly taught the multisensory approach of how to use touch points to count up and all to create a sum of two single digit addends. After being taught how to use the touch points to help add two single digit addends, students were given post-intervention assessments, with touch points on the two single digit addends to determine their individual progress and possible improvement in basic operation addition skills. Although an individual's results varied, all students showed improvement in their basic operation addition facts, by using the multisensory approach from the *Touch Math* program to add two single digit addend.

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Chapter 1

Introduction

1.1 purpose of study. Many students with significant disabilities, including those with cognitive impairments, autism spectrum disorders, severe and specific learning disabilities, and multiple disabilities, have difficulty learning basic mathematical concepts and operations. These significant disabilities affect the students' abilities to both develop basic operation skills and maintain basic operation facts in a meaningful and consistent way. In my classroom I have noticed that my students' abilities and skills in the area of basic operations is inconsistent and scattered. Therefore, I decided to study whether the use of the multisensory *Touch Math* program will help students with significant disabilities learn and maintain skills in basic operations and basic operation facts.

This study is of importance to special educators who teach students with significant disabilities because basic operations can be incorporated into skills that students can apply both inside and outside of the classroom. Basic operations skills can a bill, counting change to give and receive a payment, measuring an object, determining elapsed time, following a recipe, counting forward and backwards, and skip counting. Therefore, this study will investigate whether using a multisensory approach as an instructional technique, in the area of basic operations improves this skill for students with significant disabilities. Using a multisensory approach for instructional approaches for students with significant disabilities will provide an opportunity for them to use more than one sense to obtain a skill or concept in multiple and varying lessons.

Overall, the pencil and paper method does not appear to be meaningful to my students, and the students do not have mastery of basic operations skills and facts. Therefore, this study will investigate whether using the multisensory approach of the

Touch Math program will improve the mathematics skills of students with significant disabilities. It is hypothesized that the *Touch Math* program will lead to an improvement in students with significant disabilities' mastery of basic operations skills and facts.

1.2 key terms. *Touch Math:* according to the program's website, (www.touchmath.com, found on 10-28-13) is a multisensory program that uses its signature touch points to engage students of all abilities and learning styles. The *Touch Math* program is intended for students in grade range of pre-school through second grade, as well as, the use of this program is intended for special education students and intervention purposes.

Multisensory approach instruction: is when instructors incorporate techniques and strategies to engage students' learning on multiple levels. Instructors encourage students to use multiple senses to gather information to complete a task, link prior knowledge to new learning, problem solve, incorporate non-verbal skills, create an understanding between concepts, and store information and use information in recall. (www.lexiconreadingcenter.org retrieved on 10-28-13)

Basic operations: are mathematical problems that incorporate number facts that are created through addition, subtraction, multiplication, and division. According to www.mathisfun.com (retrieve on 10-28-13) definitions of basic operations, addition is bringing two or more numbers (or things) together to make a new total. Subtraction is taking one number away from another. Multiplication is repeated addition, and division is splitting into equal parts or groups.

Significant disabilities: According to the New Jersey's Administrative Code, Chapter 6A:14 (www.nj.gov/education/code/current/title6a/chap14.pdf, retrieved on 10-

28-13) definitions of significant disabilities falls under the following special education classification categories:

Autistic: a pervasive developmental disability that significantly impacts a student's verbal and nonverbal communication, which adversely affects a student's educational performance. The onset of a student's pervasive development disability is evident before the age of three. Other characteristics of a student who is classified as Autistic is the student may engage in often are repetitive activities and stereotypical movements, the student may be resistant to environmental changes or changes in their daily routine, as well as, the student may have an unusual response to sensory experiences and have a lack of responsiveness to others.

Cognitively impaired: refers to a student with a below average general cognitive functioning that coexists with significant deficits in adaptive behavior. This impairment in cognitive functioning and adaptive behavior is manifested during the developmental period in utero and it greatly affects a student's educational performance. It is broken into three categories based on the severity of both the student's cognitive functioning and adaptive behavior in a school, home and community setting: *mild cognitive impairment, moderate cognitive impairment,* and *severe cognitive impairment.*

Multiply disabled: refers to a student who has two or more disabling conditions, and these disabling conditions interfere with their educational needs, as well as, their educational needs cannot be met in a special education program that only addresses one of their disabling conditions.

Specific learning disability: refers to a student who has a disorder in one or more of the basic psychological processes that pertains to the understanding or use of expressive and receptive language, and their disorder may manifest itself and interfere with a student's ability to listen, think, speak, write, spell, or the ability to perform mathematical calculations. A student's specific learning disability can be determined when there is a severe discrepancy between a student's current academic achievement and intellectual ability in one of the following areas: basic reading skills, reading comprehension, oral expression, listening comprehension, mathematical calculations, mathematical problem solving, written expression, or reading fluency.

1.3 implications. The intention of this study is to show an improvement in the achievement of learning facts of basic operations using the multisensory approach of the *Touch Math* program, specifically for students with significant disabilities.

This study is not to promote of the *Touch Math* program as the only multisensory approach to improve basic operations skills for students with significant disabilities. The results of this study could be applied in classrooms with students who have less significant disabilities, such as a mild to moderate learning disability in either an inclusion or resource classroom setting. This study would provide these instructors a multisensory approach mathematical program to use to help improve students' achievement in the area of basic operations.

This study will be conducted in a school for students with significant disabilities educational and related services needs, but this study is intended to show a variety of teachers how to use a multisensory approach and strategies to improve students' achievement in the area of basic operations.

Overall the purpose of this study is intended to show whether using the multisensory approach of the *Touch Math* program will demonstrate achievement and knowledge in the area of basic operations for students with significant disabilities.

Therefore this study could be a useful tool in the future for educators who instruct students with significant disabilities to provide a resource in the area of basic operation skills using a multisensory approach. The materials used in this study could also be used in the future as a possible positive link between students with significant disabilities' improved state standardized test score and the use of a multisensory approach for instructional purposes. This study's use of a multisensory approach could be used in not only helping improve basic operation skills, but this approach could be used in other areas of instruction and improving skills to help students' with significant disabilities transition into adulthood with a set routine of strategies to help with solving problems in an environment outside of a classroom.

Chapter 2

Review of the Literature

The intention of this study is to investigate whether the use of the multisensory approach of instruction within the *Touch Math* program will lead to an improvement in the achievement of basic mathematical operations for students with significant disabilities. The literature is reviewed for difficulties and deficits students have with a mathematical disability. The literature is also reviewed to determine if using a multisensory approach of instruction improves the achievement of students with special needs in the area of basic operations. Also, the literature is reviewed that discusses instructional strategies and techniques to teach basic operations to students with both mild and significant disabilities, and to improve their skills and achievement in this area. The last area of literature that is reviewed examined the use of the *Touch Math* program and how its use improves students' with significant disabilities achievement in the area of basic operations.

2.1 mathematical learning disabilities: difficulties and deficits. In Geary's (2004) article describing the difficulties and weaknesses a student with a mathematical learning disability has, the following were cited: counting, arithmetic, working memory difficulties, weak conceptual knowledge, semantic memory deficits, and visual-spatial deficits.

A student with a mathematical learning disability who has a weakness within the area of counting displays the following types of difficulties: one-to-one correspondence, stable order, counting cardinally, abstract counting, and order irreverence.

Within Geary's article, he featured a counting procedure and a study regarding counting. Geary and colleagues' (Geary, Bow-Thomas, and Yao, 1992) procedure, for students with both mathematical and reading disabilities, featured the use of a puppet to count a set of objects. The puppet would count objects correctly, and at times the puppet counted the objects incorrectly. It was for the student to identify if the puppet counted correctly or not. The puppet would perform the procedure of counting cardinally, abstract, and order irreverence, and the student's responses would indicate their understanding of counting principles.

After discussing this counting procedure, Geary also discussed another study that he performed regarding counting weaknesses. In this study, students who were in first and second grade, with an IQ score range of 80-120, and had either or both a mathematical and reading disability, participated in this study. The student participants were assessed in a series of experimental and achievement tests. Results from these experimental and achievement tests found that student participants did not fully understand all of the counting principles. Results from the assessments, also showed that the student participants have had difficulties within the counting notation of their working memory when monitoring the counting process. Poor counting knowledge appears to contribute to the student participants' delayed competency in using counting to solve arithmetic problems.

Continuing with Geary's 2004 article, a student with a mathematical learning disability who has a weakness within the skill area of arithmetic, is unable to or struggles with counting on or counting all to solve basic addition problems. This inability to count on or all to solve basic addition problems is connected to a student's understanding of counting. Students with this inability have trouble making memory representations through direct retrieval and/or decomposition of basic facts and storing them into their long-term memory. It is suggested that students with this inability to count on or all when solving basic addition problems would benefit from both rigorous and lenient criterion. A rigorous criterion is where a student would state answers they were certain are correct. A lenient criterion is where a student would state any answer correct or not, to automatize basic facts. When both types of criterion are implemented in their arithmetic instruction, it will lessen both students' error in answering more complicated questions and relying on their working memory.

Within the area of skill area of arithmetic it was noted that (Geary, 1990; Hanich, et al, 2001;) (Geary, et al 1999; Geary et al., 2000) students with either a mathematical and reading learning disability or both, use the same types of problem solving strategies to solve arithmetic problems as their non-disabled peers, however they differ in how they develop strategies to solve arithmetic problems. Students with learning disabilities in both the areas of mathematics and reading commit more counting errors, and use developmentally immature counting-all procedures more than non-disabled peers. The immature counting-all procedures that these types of students tend to rely on include counting on their fingers, verbal counting, and retrieval strategies with weak connections, when solving arithmetic problems.

Students with mathematical learning disabilities also have procedural deficits. They have difficulties with solving multi-step arithmetic problems. They tend to use immature strategies when solving an arithmetic problem, such as counting on their fingers. Students that have procedural deficits not only tend to commit more errors in solving multi-step problems, based on their immature strategy development, but in their alignment of numbers, when they are writing down partial errors, including errors when carrying or borrowing.

These types of procedural errors are linked to difficulties with a student's working memory. A student who has difficulties with working memory, struggles with information representation and manipulation of number words, as well as, poor attention, which could interrupt their execution of mathematical procedures. A student who has working memory difficulties, displays weak problem solving procedural strategies that include counting on their fingers and the tendency to over or under count. Both of these types of strategies place high demands on a student's working memory, when solving arithmetic problems. When students are working on multi-step problems, they tend to miscount, loose track of where they are in solving the problem, and how they process the language of the problem.

Students with a mathematical learning disability, have difficulties with conceptual knowledge. Students have a poor understanding of both concepts and procedures. They tend to have a developmental delay in more complicated multi-step problems, and have a difficult time detecting errors. Overall this is due to a student's frequent counting errors.

Students with a mathematical learning disability also frequently, have difficulties with semantic memory. Students with semantic memory weaknesses have difficulty storing and retrieving arithmetic facts from their long term memory. They tend to commit more errors when solving arithmetic problems, and have slower reaction time patterns, which is associated with dyscalculia. Students with this type of memory storage difficulty are unable make a connection between the problem and generating an answer quickly. Students also have difficulties with language retrieval, which will interfere with their ability in solving both simple and complicated arithmetic problems.

Students with a mathematical learning disability may also have visual-spatial difficulties. They have a performance deficit on spatial working memory tasks, either through their ability to represent information or the ability to maintain their attention on a spatial task. These difficulties occur with multi-step problems and complex mathematical problems.

More importantly, Geary's 2004 article discusses the difficulties and deficits within the skill areas of mathematics that students with learning disabilities have. It shows that students' mathematical deficits and difficulties are based in number sense, and how they use and generalize various strategies to solve both simple and complex problems. This article indicates that students who have mathematical difficulties and deficits could benefit from instructional strategies that help them generalize mathematical skills that are based in number sense and counting, and rely less on their processing skills and working memory.

Geary's 2004 article, can be connected to the current study's student participants who have significant disabilities, who are struggling with fact automaticity, and will benefit from the multisensory approach to instruction from the *Touch Math* program, of counting up or all of the touch points to complete basic operation addition problems. The students who participate in this current study will be explicitly taught how to count up and all, and how to strategize to solve problems, without relying on weak strategies, such as counting on their fingers, where they tend to loose track or miscount.

2.2 multisensory approach to teach mathematics to students with learning disabilities. In a longitudinal study of the multisensory approach to improve basic operation skill achievement of students with mild learning disabilities, by Dev, Doyle, and Valente's 2002, eleven students, ranging in age from six to seven years old, participated in this two-year study. Before the intervention of the study was conducted, the eleven student participants were assessed using the WRAT-III. After the formal assessment, the researchers examined how to improve developmental language and mathematical skills using the *Orton-Gillingham* and *Touch Math* program as intervention tools in this study. (For the purposes of this review, only the results of the *Touch Math* program will be discussed.)

The authors of this study used the *Touch Math* program in a general education classroom setting for students in first and second grade. During the intervention, the instructional use of this program was performed daily, and lessons for first grade students varied in length from twenty to twenty-five minutes. For students in the second grade, the teachers reviewed concepts of the *Touch Math* program, but the teachers did not reteach the skills of this program to these students on a daily and consistent basis.

At the end of this longitudinal study, the eleven students were assessed on the WRAT-III. For student participants, their results of this assessment were compared to their initial assessment WRAT-III scores, conducted two years prior. In their initial scores, seven of the participants' scores in the area of mathematical skills were at the pre-first grade (primer) level, three of the participants' scores were at the early first grade level, and one participant's score was at the intermediate first grade level. After the participants received the instruction in the *Touch Math* program over the two-year period, three-fourths of the student participants scored above grade level within the area of mathematical skill development. It was also noted that after the study was completed the authors found that those students that participated in this study were no longer in need of special education services.

In Kaufmann and Pixner's (2012) replication study, they examined previous studies that used the multisensory approach and its use in combination with number fact training. The authors reviewed various studies that displayed strong evidence that indicated that the use of a multisensory approach is superior to instructing students using one modality when teaching basic facts. They placed a heavy emphasis on a particular study, by Domahs, et.al, (2004) that examined the effectiveness of the multisensory approach within a remediation study that was directed to re-teach number fact knowledge in neurological patients with acquired calculation disorders by linking multiplication problems with color. Multiplication factors were presented in different colors, and each color was to be associated to a unit or digit of its respective problem. This reviewed study was conducted over a five-month period, and instruction was conducted three times per week. The results of this reviewed study found that a designated color representation of multiplication problems were proved to be a important cue in facilitating the patient's performance of the given multiplication problems, but the patient who participated in the study did not generalize using this strategy in non-multiplication basic operation problems.

Therefore, the authors of this article wanted to replicate this study and provide a similar type of cueing system to use for elementary students. Kaufmann and Pixner conducted a pilot study dividing twenty-two students in third and fourth grade into two groups. Twelve students participated in the experimental group, and ten students participated in the control group. The experimental group was given an intensive training period of visual cueing strategies once per week, over an eight week period. Within this intensive training period, student participants were instructed on using a number/color association to solve multiplication problems. It was noted in the study that the number/color association was consistently used during the entire intensive training period. Multiplication facts were presented visually to student participants. Each factor of the problem was printed in its designated color associate, when students were solving the problem's product. When products were being visually presented they were given a color association, and the factors within the problem were not color associated. The control group was given attention and memory instruction to learn multiplication facts during the eight week instructional period. These student participants were not given a number/color association to solve multiplication problems.

The effectiveness of this intensive intervention was evaluated through a pre-intervention and post-intervention standardized arithmetic test, as well as, a standardized assessment being given eight weeks after the intervention ended to determine the intervention's stability. The students that participated in the pilot program were given a rating scale and questionnaire to determine their perception of the program.

Kaufmann and Pixner compared the experimental and control group results by both the student participants' age and intellectual ability. Results of the standardized assessment after the intervention was conducted showed a significant increase in the area of standardized calculations for students in both groups. Also, student participants in both groups showed improvement in their performance of solving multiplication facts after the intervention period ended. However, students in the experimental group displayed a higher performance increase compared with the control group. Kaufmann and Pixner's study produced promising results, and these results will encourage further research that should include a larger sample size and different types of control groups. Further research should also explore different types of multisensory approaches to basic operations, and determine if other approaches improve students' basic operation skills.

In Mancl, Miller, and Kennedy’s (2012) multiple-probe-across-participants study design, they examined the effectiveness of explicit instruction along with the use of the concrete-representational-abstract sequencing with integrated cognitive strategies to instruct students how to subtract when regrouping is involved. There were five fourth and fifth grade student participants, and they were chosen to participate based on their school’s personnel identifying that each of them had a learning disability in mathematics. Also, student participants were screened before the intervention was conducted. The screening examined their ability to solve both computation and word subtraction problems that involved regrouping. Students who scored below 50% were eligible to participate in the intervention of the study.

The students that participated in this study received thirty minutes of a Tier-3 mathematics intervention that used direct instruction in a resource classroom. The student participants were placed in this type of classroom setting during the study, due to their low achievement in specific grade level academic skills. Student participants were given a baseline assessment before intervention instruction began. During the intervention, student participants were probed during the intervention to monitor their progress, and the effectiveness of the intervention.

Within the intervention, student participants were provided with the following: eleven teacher scripted lessons that provided explicit regrouping instruction, graphic organizers for the students to use as both a cueing system and a graphic organizer to solve the subtraction problems, manipulatives, place value charts, student folders, and a chart to show students’ their progress in obtaining regrouping skills. The intervention’s scripted lessons included concrete lessons, representational lessons, a strategy lesson, and abstract lessons. In each lesson, the same five explicit teaching components consistently used to teach previously taught skills, included: advanced organizers, describing and modeling, guided practice, independent practice, and practicing problem solving skills.

The students that participated in this study produced the following results: In the baseline assessment, scores for the participants ranged from 0% to 40%. In the probes during the intervention, their scores ranged from 40% to 100%.

Based on these articles, it appears that a multisensory approach can be used in developing mathematical skills. This approach to instruction needs to be done daily and consistently, and students need to be given multiple modalities to learn and review mathematical concepts. When reviewing these articles, it can also be noted that when students are given strategies within the multisensory approach to instruction that students are given can be faded, skills areas should improve, and students should be able generalize the multisensory strategies in other settings.

In Witzel and Allsopp's (2007) article, they discussed how to engage students with high incidence disabilities, and their use of manipulatives to learn mathematical skills. The disabilities that were included were the following: specific learning disabilities, attention deficit disorder, and mild to moderate cognitive impairments. They felt that the use of manipulatives would allow students with these types of disabilities have the opportunity for a multisensory experience to learn and achieve skills, with confidence and success.

Witzel and Allsopp (2007) felt that there are three instructional techniques that allow the use of manipulatives to teach mathematical skills: linking prior knowledge to new concepts, an emphasis on thinking-aloud modeling, and applying multisensory cueing. These three instructional techniques were applied in two sixth grade inclusion classroom settings. They used these techniques in these two classroom settings to teach the addition of fractions.

This article stated how the three instructional techniques were used, but it did not provide statistical data to say that it improved their skills in adding fractions. The authors concluded that these instructional techniques were a good resource for teachers to use. However, it was noted that students with low incidence disabilities, severe cognitive impairments and multiple disabilities, would benefit from statements of relevance, during instruction. Teachers should provide manipulatives with application that can be useful, and meaningful connections, along with the stated instructional strategies.

In Strand's (2001) experimental control group study, she examined the effects of the multisensory approach within the *Touch Math* program versus a non-intervention based mathematical program for first grade students.

There were two control groups of student participants. In the first control group the student participants were from two different schools, thirty-seven student participants in School A and twenty-two students in School B. There were three teachers who taught the student participants. In this control group, 95% of the student participants were Caucasian, and came from a middle class socioeconomic background. In the second control group, student participants were from one large school, and there were sixty-one first graders, who were taught by three teachers. Within this control group, 95% of the student participants were Caucasian, and came from a middle class socioeconomic background.

Both control groups were established at the beginning of the school year, and the teachers in both control groups were given specific parameters to implement mathematical instruction to the students. The teachers in the first control group were instructed how to use the *Touch Math* program in their classroom. The student participants in this control group were exposed to the method of using touch points, in addition to their standard mathematical curriculum, which included the *Addison Wesley* textbook series. In the second control group, the teachers taught the student participants through their standard mathematical curriculum. The student participants in this control group were not given any interventions, and were taught strategies that were based on previously learned skills within the *Addison Wesley* textbook series.

At the end of the school year, both control groups were given a one-page worksheet. This worksheet had sixteen problems, and the problems ranged in the degree of difficulty. When analyzing the results of the student participants' worksheet, Strand looked at eight comparative scores. The comparative score categories that she examined included: problems with the same process, single digit addition, single digit subtraction, double digit addition with and without regrouping, double digit subtraction with and without regrouping, and the students' overall total score. It was noted that when she analyzed the students' skills that there were skills more challenging than expected for them, however, their performance in mathematical computation areas could be assessed.

It was found that, when comparing the performance of the eight mathematical operations problems, the first control group responded more accurately to all of problems on the worksheet, with 80% accuracy. The second control group achieved 44% accuracy with their responses to all of the problems on this summative assessment. Overall, the first control group did better than the second control group on all of the mathematical skills assessments, except simple addition. Therefore, this study reflects that use of the touch points within the *Touch Math* program as an intervention to either stand-alone or coincide with standard mathematical curriculum. This study also shows that the use of the touch points is a universal intervention that can be applied in various basic operation skills.

Overall, the studies that were reviewed indicated that students with mild disabilities benefitted from a multisensory approach of the touch points within the *Touch Math* program, either as a stand-alone program or when it coincides with a standard mathematical curriculum. The more opportunities that a student has to learn and review mathematical skills through the systematic and explicit use of this intervention, the better a student becomes at being able to solve problems and generalize basic operation skills.

2.3 instructional strategies and techniques to teach basic operations to students with significant disabilities. In Browder, Jimenez, Spooner, Saunders, Hudson, and Bethune's (2012) conceptual model, they examined how the instruction of early numeracy skills was given to students with moderate and significant disabilities. The early numeracy skills that they included in their conceptual framework for instruction to students with these types of disabilities included: number identification, rote counting, representation of numbers through one-to-one correspondence, number conversation, composing and decomposing numbers, magnitude of numbers, early measurement concepts, understanding the effect of basic operations, and patterning.

Within this conceptual framework for instruction in these early numeracy skills, they wanted students, with both high and low incidence disabilities, to gain access to skills through the targeting of specific early numeracy skills, the use of systematic prompting and feedback, varying daily instruction through story-based lessons, and to promote the generalization of the skills to grade-level content through inclusive embedded content.

When developing this conceptual framework, Browder, et. al., (2012), had three special education teachers and five students in second through fifth grade in both an inclusive and self-contained classroom environment participate. The student participants had moderate to significant disabilities which included intellectual disabilities or autism. The student participants received instruction in early numeracy skills three to four times per week. Lessons were taught in a repeated manner, and each lesson was taught to the student participants three times. Students were assessed at the end of each unit of instruction, and there were a total of four units taught to the student participants.

When the students were assessed, the researchers decided to use inter-rater reliability to compare the intervention of repeated instruction of the same concept within early numeracy skills, and its consistent use. Inter-rater reliability had high fidelity, and it showed that this intervention and it consistent use was valid, at 97%, over 60% of lessons. Overall, the researchers felt that the student participants benefitted from repeated instruction of targeted skills. The three teachers that participated in this conceptual framework plan to use this type of instruction in the future. The teachers also stated that this type of instruction for early numeracy skills was easy to implement. It prepared the student participants for the state alternate math assessment based on alternate achievement, and directly prepared them for the end of the unit assessments.

This article is important because it shows how students with both moderate and significant disabilities should be provided with systematic prompting and feedback, within varied and repeated teaching of concepts, given access to linking skills in a meaningful manner, and be frequently assessed to determine their progress in concepts and skills. This type of repeated instruction of concepts and skills and frequent assessment will be applied in the current study. Students will be taught how to apply touch points to numbers, count up using touch points to solve addition problems in repeated lesson, and will be frequently assessed to determine progress their automaticity of the addition of basic facts.

Browder, Spooner, Ahlgrim-Delzell, Harris, and Wakeman (2008) conducted a meta-analysis of sixty-eight studies that examined teaching mathematical skills to students with significant cognitive disabilities. They grouped together studies based on mathematical skills and study methodology components. Mathematical skills that were reviewed included: numbers, computation, and/or measurement. The study methodology components that were included in groupings were the following: the National Council for Teachers of Mathematics components and mathematical skills represented in included studies, evidence that individuals with significant cognitive disabilities can learn mathematics, and evidence-based practices for single subject designed studies. Studies that involved computation focused on how to instruct students with significant cognitive disabilities to perform counting, calculation, and/or number matching skills. Studies that involved measurement focused on how to instruct students with these types of disabilities to perform money skills.

Overall, their literature review and meta-analysis found that the methodology components indicated strong evidence for teachers to use systematic instruction to teach specific mathematical skills. Researchers found in their review that they were concerned with the components of mathematics and specific types of skills that have been acquired by students with significant disabilities. They felt that there was a limitation in current research on teaching mathematics to this population. They felt that there was a gap in how students in this population had access to the general curriculum. They question whether all of the components of mathematical skills were relevant for students with significant cognitive impairments. The researchers of this literature review and meta-analysis felt that giving this student population access to the general curriculum requires setting priorities for students who need intensive instruction to master and generalize skills, and should include targets in each of the five major component areas of mathematics.

This literature review and meta-analysis highlighted the fact that students with significant cognitive impairments benefit from systematic and explicit instruction. Therefore, students would benefit from this type of instruction to improve upon, to hopefully master, and generalize mathematical skills.

Browder, Wakeman, Flowers, Rickelman, Pugalee, and Karvonen (2007) discussed the importance of developing a curriculum and assessments for students with significant disabilities that are linked to the general education curriculum. The authors of this article stated that very few guidelines exist for teaching and assessing skills that are linked to grade-level content curriculum, and that there is a lack of guidelines to teach students of this population. This article also provides a conceptual framework linking instruction and assessment for grade-level content skills for these students.

After the authors of this study discussed the various challenges that students with significant disabilities have in being asked to preform general education skills, they agreed upon criteria and assessment requirements that would be linked to general education content area skills, and that truly reflect their students' mastery of these skills.

Browder, et. al, (2007) felt that curriculum for students in this population have targets of achievement in academic content areas. These targets of achievement should be linked to the student's assigned grade level, which is based on their chronological age.

They also mentioned that functional activities and materials should be used to promote understanding, and that these activities should focus on prerequisite skills and some partial attainment of grade level curriculum. They also felt that students in this population should have the opportunity to meet high expectations, be able to demonstrate a range in their depth of knowledge, show achievement within their symbolic level, and to show growth across grade levels.

The authors of this conceptual framework then discussed criteria of instruction and assessment for teachers to use to link the framework to grade level content areas. They stated that curriculum for students in this population, have academic content that is linked to both state and national standards. Curriculum should be linked to the student's assigned grade level, which is based on their chronological age. It should be linked to general education grade level content, but it should differ in its depth and complexity.

Curriculum should focus on prerequisite skills or skills learned at a different grade level, and it should be stated in a student's individual education plan, and be able to be applied in state-level alternative assessments. There should be a distinction in achievement across grade levels. The focus of students' achievement within the curriculum should promote access to activities and materials, along with accommodations and modifications to support progress. The targets of achievement within the curriculum should maintain fidelity with original grade-level standard, as well as specify student's performance. Lastly, there should be multiple levels of access to the general curriculum to allow students use different forms of symbolic communication to demonstrate their learning.

These studies, literature reviews, guidelines, and frameworks all mentioned creating a guideline for curriculum and instruction in mathematical skills that should be systematic, explicit, and broken into smaller tasks, for students with significant disabilities. Curriculum and instructional approaches should be linked to general education. It should be relevant to their needs and skill acquisition. Also, the skills that students are working on should be individualized and monitored frequently to indicate both acquisition and generalization.

Browder, Lee, and Woods (2013) discussed and presented a guideline to teach mathematical skills that are delegated by the United States Department of Education's *Common Core*, to students with significant cognitive disabilities. Browder, Lee, and Woods stated that the mathematical skills delegated by the *Common Core* should be taught in each grade level. Mathematical skills that should be taught within kindergarten through eighth grade should include: counting, operations and algebraic thinking, numbers and operations in base 10, numbers and operations in fractions, measurement and data, geometry, ratios, and proportional relationships. The authors of this presentation also felt that students in these grade levels should be instructed in skills that include the following: the number system, expressions and equations, statistics and probability, and functions. Students in high school should be taught the following mathematical skills: numbers and quantity, algebra, functions, modeling, geometry, and statistics and probability.

Browder, Lee, and Woods then discussed in their presentation how to teach the mathematical skills of the *Common Core* to students with significant disabilities. They stated that those educators who teach mathematical skills to students with significant disabilities should instruct them in the following way: initially present new information or skills with a personal or relevant story, then provide students with a graphic organizer to complete newly learned information or demonstrate a newly learned skill, and finally present students with a task analysis so students can demonstrate skill and/or complete the stages of a multiple step skill or process.

Browder's, et al, (2013) presentation also included a pilot study that they conducted to examine instructional techniques to teach mathematical skills that were delegated by the *Common Core* to students with significant disabilities. In their study, there were twelve students with various significant disabilities' whose intelligence quotients were indicated as 74 or less. It was noted in their presentation that the student participants used various modes of communication and accommodations within their classroom setting, while participating in this study. Six special education teachers participated in this study. They provided the student participants with systematic and scripted lessons that reinforced evidence-based practices of systematic prompting and task-analysis instruction. The special education teachers also used data tracking sheets to monitor the students' task analysis accomplishments within each lesson.

The content that was systematically taught to the student participants included: algebraic equations, data analysis, geometry: area and volume, geometry: coordinate planes, basic operations, fractions, decimals, as well as, exponents.

In the area of algebraic equations, the following instruction was conducted in this pilot study: within the elementary and middle school grade levels student participants were instructed to solve one-step algebraic equations with a missing variable, and high school student participants, were instructed to solve two-step algebraic equations with two missing variables, and incorporate their work within a table, which was based on a word problem with a real world application.

In the area of data analysis, the following instruction was conducted in this pilot study: within the elementary grade level, student participants were taught how to collect data and ask questions, organize and record data in a table, create and graph data using a bar graph, and interpret the data, by answering questions. Within the middle school grade level, student participants were instructed how to determine the number of outcomes, the probability of events, as well as, describe probability as less/more, or likely to occur. Within the high school grade level, student participants were instructed on how to solve a two-step equation with two variables using a table, and the table was to be used to solve for y, if x was provided for.

Within the area of geometry: area and volume, the following instruction was conducted in this study: at the elementary grade level, student participants were instructed on how to find area using formulas and tile manipulatives. In the middle school level, student participants were instructed on how to find the area of a two dimensional objects and the volume of a three dimensional objects using both formulas and a calculator. In the high school level, student participants were instructed on how to find the appropriate unit of measure and how to find the volume of a box.

In the area of basic operations, students that participated in this pilot study were explicitly and systematically taught the following: in the elementary grade level, participants were instructed on how to solve a one-step word problem using one of the four basic operations and use of a calculator. In the middle school grade level, participants were instructed on how to solve a multi-step ratio and percent problems, and how to calculate percentages within a realistic application. In the high grade school level, participants were instructed on how to solve two-step equations with a rational number.

Within the area of fractions, decimals, and exponents, students that participated in this pilot study were systematically and explicitly taught the following: in the elementary grade level, participants were taught how to identify, order, and compare fractions. In the middle grade school level, student participants were instructed on how to convert fractions into decimals, solve problems involving fractions, and locate and compare both decimals and fractions on a number line. In the high school grade level, student participants were instructed on how to convert fractions to decimals, and how to write decimals using scientific notation.

Within the area of geometry: coordinate planes, students that participated in this study were systematically and explicitly taught the following: in the elementary grade level, student participants were taught how to define and identify both the x-axis and y-axis, a point of origin, and a number line. These students were taught how to locate and graph points within the first quadrant of a coordinate plane. In the middle school level, student participants were taught how to plot points on a coordinate plane, and form line segments within a coordinate plane to create polygons. In the high school level, student participants were taught how to identify different types of transformations including: reflections, rotations, and translations, as well as, congruency when a two-dimensional shape is transformed.

After this systematical and explicit instructional period, a total of sixty-nine lessons, Browder, Lee, and Woods indicated that students with significant disabilities could learn mathematical concepts within the *Common Core State Standards*. However, the overall performance results of the student participants, varied by content and by the type of student who completed the task analysis of each lesson. The authors of this pilot study noted that students' rate of learning concepts varied, as well as, their previous knowledge of mathematical concepts. It impacted their performance of the task analysis within each lesson.

In Browder, Jimenez, and Trela's (2012) single subject design study, they examined the effect of grade-aligned mathematical instruction on skill acquisition within a large urban school system, for middle school students with moderate cognitive disabilities. A special education teacher, who taught in a self-contained classroom, instructed middle school aged students with either moderate or severe cognitive disabilities executed the intervention in this study. Within this single subject design study, student participants were probed intermittently to determine their acquisition of skills through the demonstration of task-analysis instruction. Their teacher nominated students that were chosen to participate, after meeting specific study criteria. The criteria that student participants needed meet included: having a specific intelligence quotient, being able to interact with the intervention materials, and the ability to communicate either verbally or with an augmentative communication device.

The researchers gave four student participants that met the study's criteria for participation a pre-test before intervention instruction, a unit of study test based on a mathematical standard after instruction, and a maintenance test one to three weeks after the unit of study was completed. The student participants received task-analysis instruction on each mathematical standard for five weeks, and then were assessed on that unit of study. After the end of unit assessment, student participants were given intermittent maintenance assessments to determine if they acquired and maintained previously learned skills.

The results from this study indicate that there is mutual relationship when comparing task-analysis instruction, to the pre unit, post unit, and maintenance testing results of the student participants. Therefore before instruction began, a baseline was established, instruction in needed areas should be given, and frequent assessments should be given to determine the student's rate of skill acquisition and their generalization of skill application.

2.4 using the *Touch Math* program as a multisensory approach to teach basic operations. In Wisniewski and Smith's (2002) action research study, they examined the effectiveness of the *Touch Math* program to improve mathematical achievement for special education students in third and fourth grade. There were four students, who attended a resource room class for academic services for a part of the school day that participated in this study. Before the intervention of the *Touch Math* program, students were given a pre-test of forty problems. After an extended period of explicit instruction with this program, the students were given a post-test with the same amount of problems. They received instruction in the *Touch Math* program twenty minutes each day, and were probed using a Mad Minute computation probe once a week, over a fourteen-week period. The weekly probe that was given to the students did not have a time limit, and students could use manipulatives, such as touch points or a number line to complete the assessment.

The following results were shown of the students' achievement and progress based on the pre-test and posttests. Student #1 achieved the following: in the pre-test of a five minute interval 85%, and on the post-test of a five minute interval, 100%. Student #2 achieved the following: 98% in the pre-test of a ten-minute interval, and on the post-test of a four-minute interval 95%. Student #3 achieved the following: on the pre-test within a seven minute interval 100%, and on the post-test of a four minute interval 100%. Student #4 achieved the following: on the pre-test within an eight-minute interval, 23%, and on the post-test, 93%, within a four-minute interval.

Overall results show that the specific strategies of the *Touch Math* program can be used to aide in the automaticity of basic operation facts.

This article relates to the current study because student participants will be instructed on how to place touch points on numbers, and to count up or all touch points to solve addition problems. The students will then be intermittently probed on fact families using the strategy of counting up or all touch points. These intermittent probes will determine their attainment of mathematical facts. Also, these intermittent probes will determine if the student participants are using the strategy efficiently.

In Fletcher, Boon, and Chiak's (2010) study, they examined three middle school students with significant disabilities, and the use of the *Touch Math* program, in an alternating-treatment design. In this study, the participants were instructed how to solve single-digit addition problems using both a number line and the *Touch Math* program. Within the alternating-treatment, the authors of this study compared participants' achievement of solving single-digit problems with a number line versus their achievement of solving single-digit problems with the *Touch Math* program, and the effectiveness of both strategies.

After a baseline assessment and intermittent probes during the intervention process, the following results were reported: student participants achieved 4% accuracy in the baseline assessment. There were significant improvements in the students' use of touch points compared to their use of a number line to solve single-digit addition problems. All three of the student participants were able to utilize touch points to solve addition problem more quickly and accurately than the use of the number line. After being given the strategy of using touch points to aide in solving the addition problems, the students averaged 92% accuracy on a probed assessment. When the students were given the strategy of using a number line to aide in solving the addition problems, the students averaged 30% accuracy. Finally, when the authors replicated their study, the student participants averaged 96% accuracy.

This article relates to the current study, because student participants will be instructed explicitly and systematically to use touch points and to count up or all to solve basic addition problems. Through the eight-week length of the current study, it is intended that the students will be able to generalize the strategy of using touch points, to solve basic operation addition problems.

Both of these studies indicate that students' mathematical skills improve with the use of the *Touch Math* program versus traditional techniques including a number line or a manipulative. Students were able to use the touch points in aiding them to solve basic operation problems. The *Touch Math* program provides a meaningful strategy for students to solve basic operation problems.

2.5 summary. The current research study uses the *Touch Math* program as a strategy to provide visual, auditory, and tactile cues to improve students with significant disabilities achievement of basic operation addition facts. Student participants use touch points as a visual, auditory, and tactile cue to help them count up to solve answers to addition problems. Before this strategy is taught to the student participants, they will be given a baseline assessment to determine their basic operation fact knowledge. Then the strategy of counting up with touch points will be explicitly taught to the students over an eight week period, with intermittent assessments each week within the intervention period, to determine if there is an improvement in student participants' achievement in addition basic operations. The studies that were mentioned that used the *Touch Math* program as a strategy, indicated improvement in students' with mild, moderate, or significant disabilities, achievement in basic operations. Hopefully, the student participants will display achievement in their basic operation skills, when using the *Touch Math* program.

Chapter 3

Methodology

In this study, I used the *Touch Math* program as a multisensory approach to teach basic addition operations to students with significant disabilities in a small group setting, within a self contained classroom setting. This intervention took place over an eight-week period, in a self-contained classroom setting, in a non-profit private Special Education school in Atco, New Jersey.

3.1 subjects. Five students participated in this study. The students ranged in ages from eleven through sixteen years of age, with a mean age of thirteen years, eight months. Student participants are in various grades, with a range of fifth through ninth grade, with a mean grade of seventh grade.

Student A (I.O.): is an African American, eleven years, three month old, fifth grade male. I.O. resides in a large urban area in Camden County, with his mother, and three siblings, one of which is his twin. His twin attends the same non-profit Special Education school, but is not in the same classroom.

He has asthma, which requires the use of an inhaler before a physical activity, and he needs breathing treatments if an asthma attack occurs. He also has severe allergies to bee stings and insect bites, which would require the use of an epi-pen if he were having anaphylaxis. His medical conditions do not affect his academics.

I.O. has been attending this school since December 2012, after having severe academic difficulties, due to attention and lack of academic progress, in the public school that he previously attended. He has been in this current self-contained classroom setting since July 2013. He is classified as Multiple Disabled, with an IQ of 58, based on his most current Special Education evaluations.

He receives all academic skills in this self-contained classroom setting, and group speech services one time per week. His related service schedule does not affect his academics, and he receives instruction in mathematical concepts five days per week.

Student B (G.M.): is a Caucasian, thirteen years, six month old, seventh grade male. He resides in a small suburban area within Camden County, with his parents, and four other siblings.

G.M. has been attending this non-profit private Special Education school since the beginning of the 2007 school year, due to his severe medical issues and lack of academic progress. He has been in this current self-contained classroom setting since July 2013. He is classified as Multiple Disabled, with an IQ of 48, based on his current Special Education evaluations. He receives all academic services in this classroom setting, and has a one-on-one assistant. The one-on-one assistant helps G.M. with remaining on task, reinforces and reviews academic concepts, and helps keep him safe when a medical emergency occurs.

G.M.'s severe medical issue is a seizure disorder with grand mal types of seizures. If G.M. does have a seizure at school, and the seizure continues for ten minutes, he receives anti-seizure medication. If a seizure occurs at school, his one-on-one aide, one other classroom staff member, and the school nurse will help make sure he is safe during the seizure, clean up anything, and give him any needed medical attention. If the seizure activity has ceased within ten minutes, he will be picked up by his mother, and goes home for the remainder of the school day. If he has seizures after he gets home, he will not attend school until the seizure activity has ceased. If his seizures have not ceased after ten minutes, a medical emergency service will be called, he will be escorted to the hospital, by his one-on-one aide, the school nurse, and his mother.

The seizure activity does affect his continuous daily attendance at school, and the length of his school day. His continuous seizure activity not only affects his school day, but it has a tremendous impact on his academic progress and retention of academic skills.

He receives individual speech services three times per week, group speech services once per week, individual OT services once per week, group OT services once per week, individual PT services once per week, and group PT services once per week. His related services schedule is quite full, and he only receives instruction in mathematical concepts, three times per week.

Student C (A.D.): is an African American, fourteen years, six month old, eighth grade female. She resides in a suburban area of Camden County, with other similar aged peers in a residential group home.

This residential group home setting is temporary. This residential group home setting is for children and teenagers with various special education needs, who do not live with their biological families, due to domestic issues. Services for these children are provided through New Jersey's Department of Youth and Family Services. A.D. mentions frequently that she wants to go back home, and her case manager expressed that she will be returning to live with her biological family, who reside in an urban area of Union County, towards the end of the school year.

Due to her temporary group home setting residential setting, Student C, attends meetings and appointments regarding progress towards returning to live with her biological family, which affects her attendance throughout the length of the school day, and continuous daily attendance.

A.D. has been in this self-contained classroom setting since May of 2013, due to her residential situation. Before entering this classroom setting, she was in a self-contained classroom setting in the public school she attended in Union County. She is classified as Multiple Disabled, with an IQ of 46, based on her current Special Education evaluations. She receives all academic services in this classroom setting, and has a one-on-one assistant. A.D.'s one-on-one assistant helps her remain on task, reinforce and review academic skills, as well as, reinforce appropriate behavior modifications to shape her behavior.

She receives multiple medications for mood deficits, anxiety, attention, and anger displacement. The medication that she takes is on a scheduled daily routine that occurs at home. The medication affects her academic progress and retention, as well as, her personal affect.

She receives individual speech services once per week, group speech services once per week, individual OT services once per week, group OT services once per week, individual PT services once per week, group PT services once per week, individual counseling services once per week, and group counseling services once per week. Her related service schedule is quite full, and it impacts her instruction in mathematical concepts, and she receives instruction in this area three times per week.

Student D (D.S.): is a Caucasian, fourteen years old, seven month, ninth grade male. He resides in a large suburban area in Burlington County, with his parents, and three younger siblings, who happen to be triplets.

D.S. has been attending this school setting, and had been a student in this specific classroom, since July 2013. Previously, D.S. attended a county wide special services school, but no longer attends this special services school, due to his parents concern regarding the lack of his academic progress. He is classified as Autistic, with a non-verbal intelligence composite of 79, based on his current Special Education evaluations. An overall IQ was not reported, due to his limited communication and achievement in completing tasks within an evaluation. He receives all academic services in this self-contained classroom. D.S. has a one-on-one assistant who helps him remain on task, complete tasks, reinforce and review academic skills, and reinforce appropriate behavior modifications to shape his behavior.

D.S. takes medication for both attention and anxiety. He takes his medication at home. The medication that he takes affects his attention, mood, and his retention of academic skills and progress.

He receives individual speech services twice per week, group speech services once per week, individual OT services once per week, and group OT services once per week. His related services impact his mathematical instruction, and he is instructed in mathematical concepts three times per week.

Student E (S.Y.): is a Caucasian, sixteen years, two month old, ninth grade male. He resides in a small suburban area in Gloucester County, with his parents, and his younger adopted sibling.

S.Y. has been a member of this classroom since September of 2012. Previously S.Y. was instructed at home for several years, due to his parents being unhappy with the special education services that he was receiving at various other county wide special services schools. He is classified as Other Health Impaired, with an IQ of 40, based on his current Special Education evaluations. S.Y. receives all academic services in this self-contained classroom setting. He has a one-on-one aide/behavior support assistant. This person helps S.Y. remain on task, reinforces and reviews academic skills, as well as, implements and maintains a daily behavior modification plan to shape his behavior.

S.Y. has Fragile-X Syndrome. He has frequent medical appointments and evaluations due to this genetic disorder. He does take medication related to the characteristics of this disorder. These include medications for anxiety and attention. He takes these medications on a daily basis at home. These medications affect his learning, attention, and behavior. They also impact his academic progress and retention of academic skills.

He takes medication for allergies and digestive tract issues. He takes these medications on a daily basis at home, and it does not affect his academics or interrupt his school day. S.Y. also has asthma and uses an inhaler, on an as needed basis.

He receives individual speech services twice per week, group speech services once per week, individual OT services twice per week, and group OT services once per week. His related service schedule is quite busy, and it affects his instruction in mathematical concepts. He receives instruction in this academic area three times per week.

3.2 setting. This single subject, multiple probe design study is taking place in a self-contained classroom, within a non-profit Special Education school, in Atco, New Jersey.

This classroom serves eight students with various disabilities including: cognitive impairments, autism spectrum disorders, specific learning disabilities, other health impairments, and multiple disabilities. Seven out of eight students have a one-on-one assistant. Each one-on-one assistant reinforces academic skills and behaviors, through positive behavior support and modification, as well as, helps students with individually based needs.

All of the students in this classroom setting receive academic instruction in all curriculum areas both small and whole group settings. For the purpose of this study, I will implement the multisensory approach of the *Touch Math* program in a small group setting. There will be five students participating, and they were selected based on their individual needs in the skill area of basic operations.

3.3 methods. In this classroom, mathematical skills are taught thirty minutes daily. Each student is taught based on their individual needs, and they are either taught in a small group or large group setting.

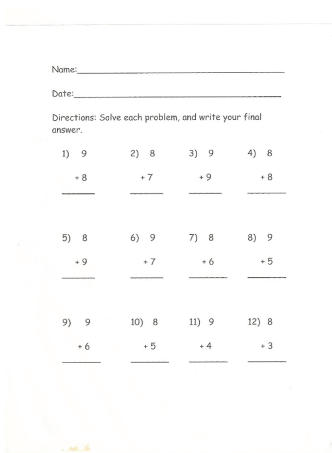
The baseline assessments, explicit teaching, and intermittent assessments took place in a small group setting, over an eight-week period. The small group had at least three of the student participants on a daily basis for instructional and assessment purposes.

3.4 materials. During the intervention of applying and counting up touch points of the *Touch Math* program the student participants used the following: candy, stickers, cereal, highlighters, white boards, dry erase markers, erasers, pencils, *Touch Math:* touch point flash cards, *Touch Math:* touch point addition worksheets on the first grade level, *Touch Math:* touch point number lines, and the *Touch Math* application on the iPad.

The student participants used manipulatives such as candy, stickers, and cereal to help make the concept of touch points more concrete, through number sense skills. The students used dry erase markers and highlighters to help distinguish double touch points that need to be touched twice, which are the numbers six through nine. Students were given *Touch Math:* touch point flash cards, *Touch Math:* touch point number lines, and the *Touch Math* application on the iPad, to practice counting the touch points on each individual number, as well as, practice counting up a total of touch points when presented with two single digit addends.

Before beginning the intervention the students were provided with baseline assessments over a two-week period. Each baseline assessment was a teacher-made addition worksheet. The worksheets had a mix of fact family single digit addition problems, and each problem's addends did not have touch points.

Example of Baseline Assessment:

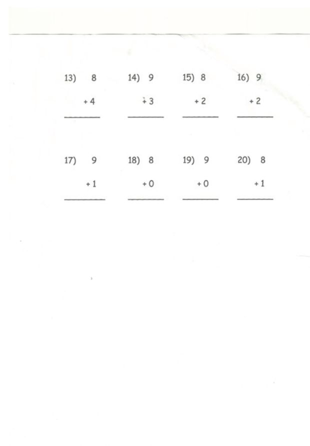


Name:____________________

Date:____________________

Directions: Solve each problem, and write your final answer.

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



13) 8 +4	14) 9 +3	15) 8 +2	16) 9 +2
17) 9 +1	18) 8 +0	19) 9 +0	20) 8 +1

During the initial portion of the intervention, the students were instructed on the following: how to apply and use touch points by counting up and all, using various materials, such as the *Touch Math:* touch point flash cards, *Touch Math:* touch point number lines, markers, and white boards, to teach both the strategy and approach to solving an addition problem. Students used the white boards and dry erase markers to practice counting up touch points of two numbers, to create a sum. They practiced various problems on their dry erase board. The students were given *Touch Math:* touch point addition worksheets to reinforce counting up and all touch points for homework. The students were given worksheets to complete for homework, four days out of the school week. These worksheets were on the first grade level of the *Touch Math* program, and were photocopied materials.

Within the eight-week intervention the students were provided with intermittent assessments, once per week. The intermittent assessments had a mixture of two fact family addition problems, with touch points.

Example of Intermittent Post-intervention Assessment:


Name:__________

Date:__________

Directions: Use touch points to solve addition problems.

1 + 0 =____

2 + 1 =____

2 + 2=____

2 + 3 =____

2 + 4 =____

1 + 7 =____

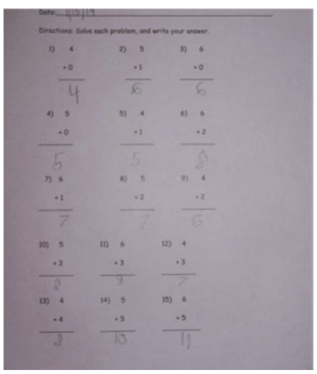
1 + 9= ____

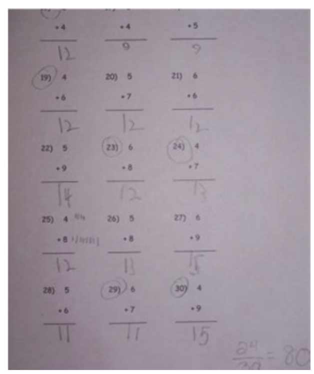
3.5 instruments. Within the eight-week process of using touch points to aide in solving addition problems, the students were given baseline and intermittent assessments. Baseline assessments were given to the students to determine their knowledge of sums with addition fact families one through nine. The intermittent assessments were given to the students after four weeks of explicit instruction, and this determined their progress in solving addition problems of fact families zero through nine, using touch points as an aide.

3.6 assessments. *Breakdown of baseline assessments:* The five student participants were given four baseline assessments. Each baseline assessment contained either two or three fact families. The number of fact families that were being assessed determined the number of problems contained on each of the assessments. The baseline assessments with two fact families contained twenty addition problems, and the baseline assessments with three fact families contained thirty addition problems.

The student participants were given one baseline assessment per class period. The class period was thirty minutes, and was a daily instructional period, however the student participants had various related services that impacted whether they received daily instruction in the area of mathematics. After the students were given each a baseline assessment, they were instructed to solve the addition problems to the best of their ability, independently, to complete within the class period of thirty minutes to complete. There were a total of four baseline assessments. The amount of fact families and problems varied on each baseline assessment.

Example of a student participant's baseline assessment:



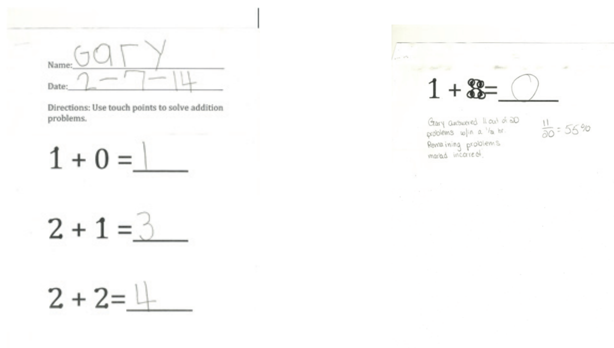


Baseline assessments took over two weeks to give to the students, due to their individual related service schedule, and inclement weather, which either caused school to be delayed or closed for the day.

Breakdown of post-intervention assessment: After the four weeks of the explicit instructional period of using the multisensory approach to instruction, where student participants used touch points to count up and all to create a sum for a single digit addition problem, they were given post-intervention assessments.

Each post-intervention assessment contained two fact families, with possible fact families of zero through nine, with addends of zero through nine. Each post-intervention assessment contained twenty problems, with touch points on each addend. When the student participants were given a post-intervention assessment, they were instructed to use the touch points on the assessment and touch point number line to help them count up and solve for each problem. The students were given thirty minutes to complete each post-intervention assessment.

Example of a student's post-intervention assessment:



Overall the post-intervention assessments took two weeks to complete. This was due to both student participant's individual related service schedule, and inclement weather, which was due to a delay or school closure.

3.7 intervention. After the student participants were initially assessed on the four baseline assessments, over a two- week period, explicit instruction of counting touch points and counting up all of the touch points began. The intervention was given daily, for a thirty minute increment, and the group of student participants ranged from a group of three to a group of five, depending on their individual related schedule or absences. The intervention took place over a four-week period.

Breakdown of the intervention: In the initial phase of the intervention, the student participants were instructed in placing the touch points on numbers and counting up all of the touch points. Students learned how to do this by counting touch points on flash cards with the touch points, or drawing touch points on a given number, as well as, placing manipulatives, such as candy or stickers on a given number.

After the students were given several opportunities to place the touch points on numbers physically or by drawing them and then counting the points, this skill was then reinforced through the *Touch Math* program's application on the iPad. This application allowed the student participants the opportunity to review touch point placement and counting the touch points up, through several multiple sensory input process, including sight, touch, and sound. This portion of explicit instruction took place for one week.

After the student participants were instructed in how to place touch points on numbers and how to count up the points, the second portion of the intervention began. The student participants were instructed how to count all of the touch points on two single digit addends in an addition problem. These concepts were modeled through several teacher-provided examples on the white board, the students wrote the problems on their own individual white board, and they went through each example step-by-step. Students wrote each number and their touch points on the white board, and used the *Touch Math* number line to help count up the touch points to create a sum. Then, as a small group, they counted up all of the touch points for each addend to create a sum for the teacher given examples. After being given the teacher examples that they worked on together, the students were given independent work in the form of touch point worksheets from the first grade level of the *Touch Math* program. These worksheets had various single digit addition problems. Each problem's addends had touch points already placed on it. Student participants were given a *Touch Math* number line, with numbers that had touch points on them as a visual reminder to help with counting up, if they were struggling. Also for students who needed extra reinforcement of counting up all of the touch points, there were three one-on-one assistants and the teacher to go over the touch points, and both visually and verbally prompt the student participants to count up the touch points.

As the students were practicing independently with these types of worksheets in the classroom, they also reinforced the concept of adding two single digit addends with touch points, by completing worksheets, at home. They were given homework four days per week. The worksheets were similar to the worksheets that they completed independently in the classroom. These worksheets contained various single digit addition problems. Each problem's addends had touch points on it. The process of independent practice, including both in the classroom and at home, took place for three weeks. After the intervention phase was completed, the student participants were given post-intervention assessments.

Chapter 4

Results

4.1 premises of the study. In this current study, five students with severe and significant disabilities, who attend a school that serves students with special education needs, participated in the explicit use of touch points, as a multisensory approach of instruction to improve their basic operation addition skills.

Students were given baseline assessments of addition facts, which include fact families zero through nine, with addends zero through nine. Then, students were explicitly taught how to use the touch points to both count up and count all, to create a sum for an addition problem. After four weeks of explicit instruction of using touch points as a strategy to solve addition problems, the students were given post-intervention assessments. These post-intervention assessments included touch points that were placed on fact family addends. Fact families that were included in these assessments were zero through nine, with addends of zero through nine.

The baseline assessments, explicit instruction of the intervention, and post-intervention assessments took place over eight weeks.

4.2 procedures. The five student participants were assessed on their basic operation fact knowledge for addition problems. The facts families that they were assessed on included facts zero through nine. The fact families were broken into groups of two, and students were assessed on these groups of facts once per week.

After the student participants were given fact family baseline assessments, they were instructed how to apply and count up touch points. First the students applied touch points on flash cards using manipulatives, such as stickers and candy. Secondly, the students reinforced applying touch points on the iPad, using the *Touch Math* application.

Finally, the students applied touch points by drawing touch points on numbers. After the student participants practiced applying touch points they were instructed how to count up touch points to create a sum for an addition problem. The students were provided with addition problems without touch points, and then they placed touch points on each number and counted up to create a sum.

After four days of practice counting up while applying touch points, the students were assessed on fact families, two fact families at a time. These assessments did occur once per week, and determined students' progress in obtaining addition fact family knowledge. During the intermittent assessments, students were able to use number lines and flash cards, both of which have touch points, if necessary.

The baseline assessments, intervention of explicit teaching with intermittent assessments, took eight weeks.

4.3 results of baseline and post-intervention assessments data for each student participant. Student A (I.O.), Baseline Assessment: He was given four baseline assessments, within a two-week period. On the first baseline assessment, Student A was assessed on the following facts family addends: zero, one, and two. He was assessed on a total of thirty problems, and he answered all of the questions correctly. He scored 100% accuracy.

On the second baseline assessments, Student A was assessed on the following fact family addends: four, five, and six. He was assessed on thirty questions, and answered twenty-four out of the thirty questions, correctly. He scored 80% accuracy.

On the third baseline assessment, Student A was assessed on the following fact family addends: three and seven. I.O. attempted all of the questions, and he answered thirteen out of twenty questions correctly. He scored 65% accuracy.

On the fourth baseline assessment, Student A was assessed on the following fact family addends: eight and nine. I.O. attempted all of the questions, and he answered eleven out of twenty questions correctly. He scored 55% accuracy.

Student A (I.O.), Post-intervention assessment: He was assessed on five post-intervention assessments, within a two-week period. On the first post-intervention assessment, I.O. was assessed on fact family addends of one and two. He attempted all twenty problems, answered all twenty problems correctly, and scored 100% accuracy.

On the second post-intervention assessment, I.O. was assessed on fact family addends of three and four. He attempted all twenty problems, answered all twenty problems correctly, and scored 100% accuracy.

On the third post-intervention assessment, I.O. was assessed on fact family addends five and six. He attempted all twenty problems, answered all twenty problems correctly, and scored 100% accuracy.

On the fourth post-intervention assessment, I.O. was assessed on fact family addends of seven and eight. He attempted all twenty problems, answered all twenty problems correctly, and scored 100% accuracy.

On the fifth post-intervention assessment, I.O. was assessed on fact family addends of nine and zero. He attempted all twenty problems, and answered nineteen out of twenty questions correctly. I.O. scored 95% accuracy.

Student B (G.M.), Baseline assessment: He was to be given four baseline assessments, within a two-week period. Unfortunately G.M. had an influx of seizure activity, during that two-week period, and was only able to complete one out of the four baseline assessments.

On this baseline assessment G.M. was unable to complete the assessment. He attempted fifteen out of thirty problems on the first baseline assessment. The first baseline assessment contained fact family addends: zero, one, and two. He answered eleven out of the fifteen questions that he attempted correctly, but was graded on all thirty problems. Therefore he scored 37% accuracy.

Student B (G.M.), Post-intervention assessment: He was assessed on five post-intervention assessments within a two-week period. On the first post-intervention assessment, G.M. was assessed on fact family addends of one and two. G.M. attempted eleven out of twenty problems within the class period. Due to him only finishing eleven problems, the remaining problems within the assessment were voided and marked incorrect. Therefore, his accuracy score was based out of the total number of questions he answered correctly out of the total number of problems. He answered eleven questions correctly out of twenty problems on this assessment, therefore G.M. scored 55% accuracy.

G.M. was given a second post-intervention assessment. On this assessment, he was assessed on fact family addends of three and four. He attempted eleven out of twenty problems within the class period. The remaining problems on the assessment were marked incorrect, he answered those eleven problems accurately, and his accuracy score was 55%.

On the third post-intervention assessment, G.M. was assessed on fact family addends of five and six. He attempted fourteen out of twenty problems on this assessment within the class period. The remaining problems were marked incorrect, and his accuracy score reflects the problems that he did answer. He scored 70% accuracy.

On the fourth post-intervention assessment, G.M. was assessed on fact family addends of seven and eight. He attempted twelve out of twenty problems on this assessment within the class period. The remaining problems were marked incorrect, and his accuracy score reflects the problems that he did answer. He scored 70% accuracy.

On the fifth post-intervention assessment, G.M. was assessed on fact family addends of nine and zero. He attempted nine out of twenty problems on this assessment within the class period. The remaining problems were marked incorrect, and his accuracy score reflects the problems that he did answer. He scored 45% accuracy.

Student C (A.D.), Baseline assessment: She was assessed on four baseline assessments, within a two-week period. On the first baseline assessment, with the fact family addends of zero, one, and two were assessed. She attempted all of the questions, and answered twenty-six out of thirty questions correctly. A.D. scored 87% accuracy.

On the second baseline assessment, where the fact family addends of four, five, and six were assessed, she attempted all of the questions, and answered twenty-one out of thirty questions correctly. A.D. scored 70% accuracy.

On the third baseline assessment, where the fact family addends of three and seven were assessed, she attempted all of the questions, and answered eight out of twenty questions correctly. She scored 40% accuracy.

On the fourth baseline assessment, A.D. was assessed on the fact family addends of both eight and nine. She attempted all of the questions, and answered fourteen out of twenty questions, correctly. She scored 70% accuracy.

Student C (A.D.), Post-intervention assessment: She was assessed on five post-intervention assessments, within a two-week period. On the first post-intervention assessments, A.D. was assessed on fact family addends of one and two. She attempted all of the problems on this assessment. She answered nineteen out of twenty problems correctly, and scored 95% accuracy.

On the second post-intervention assessment, A.D. was assessed on fact family addends of three and four. She attempted all of the problems on this assessment. She answered seventeen out of twenty problems correctly, and scored 85% accuracy.

On the third post-intervention assessment, A.D. was assessed on fact family addends of five and six. She attempted all of the problems on this assessment. She answered seventeen out of twenty problems correctly, and scored 85% accuracy.

On the fourth post-intervention assessment, A.D. was assessed on fact family addends of seven and eight. She attempted all of the problems on this assessment. A.D. answered fourteen out of twenty problems correctly, and scored 70% accuracy.

On the fifth post-intervention assessment, A.D. was assessed on fact family addends of nine and zero. She attempted all of the problems on this assessment. A.D. answered all twenty problems correctly, and scored 100% accuracy.

Student D (D.S.), Baseline assessment: He was assessed on four different baseline assessments, within a two-week period. On the first baseline assessment, he was assessed on fact family addends of zero, one, and two. D.S. attempted all of the problems on this assessment, and answered two out of thirty questions, correctly. He scored 0.07% accuracy.

On the second baseline assessment, he was assessed on fact family addends of four, five, and six. He attempted all of the questions, answered zero out of the thirty questions correctly, and scored 0% accuracy.

On the third baseline assessment, he was assessed on fact family addends of three and seven. He attempted all of the questions, answered zero out of the twenty questions correctly, and scored 0% accuracy.

On the fourth baseline assessment, D.S. was assessed on fact family addends of eight and nine. He attempted all of the questions, answered zero out of the twenty questions correctly, and scored 0% accuracy.

Student D (D.S.), Post-intervention assessment: He was assessed on five post-intervention assessments within a two-week period. On the first post-intervention assessment, D.S. was assessed on fact family addends of one and two. He attempted sixteen out of the twenty problems on this assessment. The four problems that he did not answer were marked incorrect. He scored 80% accuracy.

On the second post-intervention assessment, D.S. was assessed on fact family addends of three and four. He attempted all of the twenty problems on this assessment. He answered all of the questions correctly, and scored 100% accuracy.

On the third post-intervention assessment, D.S. was assessed on fact family addends of five and six. He attempted all twenty problems on this assessment. He answered nineteen out of twenty questions correctly, and scored 95% accuracy.

On the fourth post-intervention assessment, D.S. was assessed on fact family addends of seven and eight. He attempted all twenty problems on this assessment. He answered nineteen out of twenty questions correctly, and scored 95% accuracy.

On the fifth post-intervention assessment, D.S. was assessed on fact family addends of nine and zero. He attempted all twenty problems on this assessment. He answered eighteen out of twenty questions correctly, and scored 90% accuracy.

Student E (S.Y.), Baseline assessment: He was given four baseline assessments within a two-week period. On the first baseline assessment, S.Y. was assessed on fact family addends of zero, one, and two. He attempted all thirty questions, and answered fourteen questions, correctly. S.Y. scored 47% accuracy.

On the second baseline assessment, S.Y. was assessed on fact family addends of four, five, and six. He attempted all thirty questions, and answered eleven out of the thirty questions correctly. He scored 37% accuracy.

On the third baseline assessment, S.Y. was assessed on fact family addends of three and seven. He attempted all of the problems, and answered four out of the twenty questions accurately. He scored 20% accuracy.

On the fourth baseline assessment, S.Y. was assessed on fact family addends of eight and nine. He attempted all of the problems, and answer five out of the twenty questions accurately. He scored 25% accuracy.

Student E (S.Y.), Post-intervention assessment: He was assessed on five post-intervention assessments within a two-week period. On the first post-intervention assessment, S.Y. was assessed on fact family addends of one and two. He attempted all twenty problems on this assessment. He answered all of these questions correctly, and scored 100% accuracy.

On the second post-intervention assessment, S.Y. was assessed on fact family addends of three and four. He attempted all twenty problems on this assessment. He answered nineteen out of twenty questions correctly, and scored 95% accuracy.

On the third post-intervention assessment, S.Y. was assessed on fact family addends of five and six. He attempted all twenty problems on this assessment. He answered all of these questions correctly, and scored 100% accuracy.

On the fourth post-intervention assessment, S.Y. was assessed on fact family addends of seven and eight. He attempted all twenty problems on this assessment. He answered all of these questions correctly, and scored 100% accuracy.

On the fifth post-intervention assessment, S.Y. was assessed on fact family addends of nine and zero. He attempted all twenty problems on this assessment. He answered all of these questions correctly, and scored 100% accuracy.

4.4 comparison of results for assessments for each student participant. When comparing an individual's achievement in the area of single digit addition, the percentage of the number correctly answered questions for each fact family's addend in a student participant's baseline assessment versus their post-intervention assessment was examined. The result for ten problems per addend on the baseline was compared against the ten problems on the post-intervention assessment.

Student A (I.O.): When examining the fact family addend of zero, I.O. answered all addends on both the baseline and post-intervention assessment correctly. He achieved no improvement on this addend, and there was no change in the development of this addend.

When examining the fact family addend of one, I.O. answered all addends on both the baseline and post-intervention assessment correctly. He achieved no improvement on this addend, and there was no change in the development of this addend.

When examining the fact family addend of two, I.O. answered all addends on both the baseline and the post-intervention assessment correctly. He achieved no improvement on this addend, and there was no change in the development of this addend.

When examining the fact family addend of three, I.O. answered all addends on the baseline incorrectly and post-intervention correctly. Although a percentage cannot be determined, I.O. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the fact family addend of four, I.O. answered seven out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Therefore he achieved 43% improvement on this addend, and there was a positive change in development.

When examining the fact family addend of five, I.O. answered all addends on both the baseline and post-intervention assessment correctly. He achieved no improvement on this addend, and there was no change in the development of this addend.

When examining the fact family addend of six, I.O. answered seven out of ten questions correctly on the baseline, and all of the questions correctly on the post-intervention assessment. He achieved 43% improvement on this addend, and there was a positive change in the development of this addend.

When examining the fact family addend of seven, I.O. answered five out of ten questions correctly on the baseline, and all of the questions on the post-intervention correctly. He achieved 100% improvement on this addend, and there was a positive change in the development of this addend.

When examining the fact addend of eight, I.O. answered five out of ten questions correctly on the baseline, and all of the questions on the post-intervention correctly. He achieved 100 % improvement on this addend, and there was a positive change in the development of this addend.

When examining the fact family addend of nine, I.O. answered six out of ten questions correctly on the baseline, and nine out of ten questions correctly on the post-intervention assessment. Therefore, he achieved 50% improvement on this addend, and there was a positive change in the development of this addend.

See Figure A, for I.O.'s achievement and development of each addend, comparison between the baseline and the post-intervention assessment of each addend.

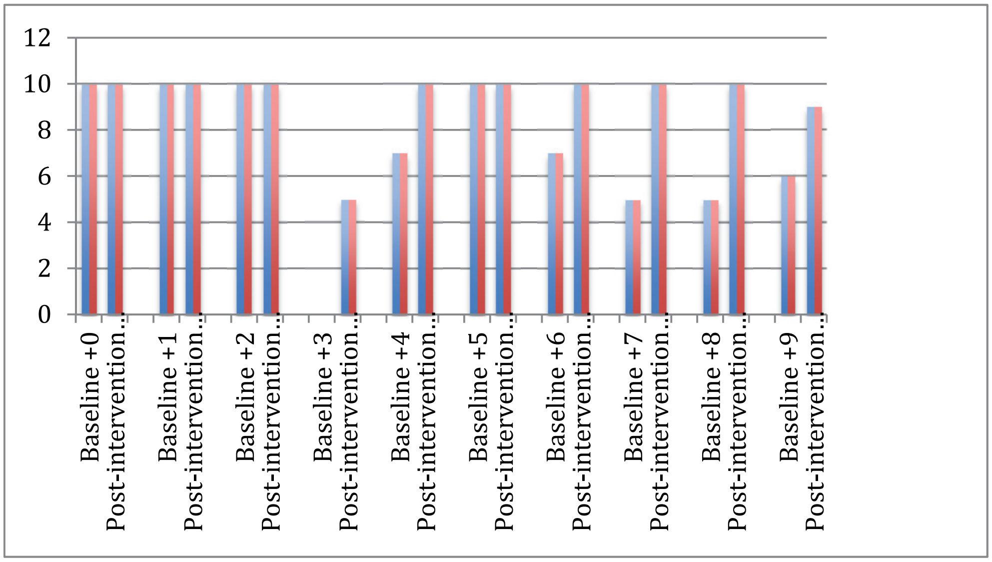


Figure A

Student B (G.M.): When examining the fact family addend of zero, G.M. five out of ten questions correctly on the baseline, and five out of ten questions correctly on the post-intervention assessment. Therefore, he achieved no improvement on this addend, and there was no change in development of this addend.

When examining the fact family addend of one, G.M. answered three out of ten questions on the baseline correctly, and he answered seven out of ten questions on the post-intervention assessment correctly. Therefore, he achieved 13.3% improvement on this addend, and there was a positive change in the development of this addend.

When examining the fact family addend of two, G.M. answered three out of ten question on the baseline correctly, and he answered four out of ten questions on the post-intervention assessment correctly. Therefore, he achieved 25% improvement on this addend, and there was a positive change in the development of this addend.

When examining the fact family addend of three, G.M. answered zero out of ten questions correctly on the baseline, and five out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, G.M. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the fact family addend of four, G.M. answered zero out of ten questions correctly on the baseline, and answered six out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, G.M. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the fact family addend of five, G.M. answered zero out of ten questions correctly on the baseline, and answered seven out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, G.M. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the fact family addend of six, G.M. answered zero out of ten questions on the baseline, and answered seven out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, G.M. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the fact family addend of seven, G.M. answered zero out of ten questions on the baseline, and answered seven out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, G.M. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the fact family addend of eight, G.M. answered zero out of ten questions on the baseline, and answered four out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, G.M. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the fact family addend of nine, G.M. answered zero out of ten questions on the baseline, and answered five out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, G.M. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

See Figure B, for G.M.'s achievement and progress in development of each individual addend, comparison between the baseline and the post-intervention assessment of each addend.

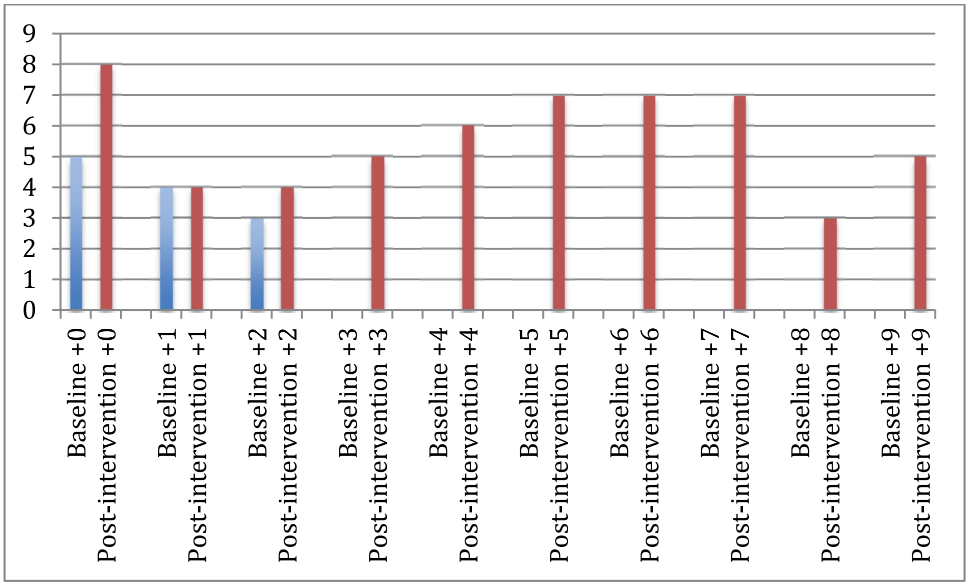


Figure B

Student C (A.D.): When examining the fact family addend of zero, A.D. answered eight out of ten questions on the baseline, and answered all of the questions on the post-intervention assessment correctly. Therefore she achieved a 25% improvement on this addend, and showed a positive change in the development of this addend.

When examining the fact family addend of one, A.D. answered nine out of ten questions on the baseline, and answered all ten questions on the post-intervention assessment correctly. Therefore she achieved 11% improvement on this addend, and showed that a positive change was made in the development of this addend.

When examining the fact family addend of two, A.D. answered nine out of ten questions on the baseline, and nine out of ten questions on the post-intervention assessment correctly. Therefore, she achieved no improvement on this addend, and there was no change made in the development of this addend.

When examining the addend of three, A.D. answered three out of ten questions on the baseline correctly, and eight out of ten questions on the post-intervention assessment correctly. Therefore, she achieved 16.6% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of four, A.D. answered eight out of ten questions on the baseline correctly, and nine out of ten questions on the post-intervention assessment correctly. Therefore, she achieved 12.5% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of five, A.D. answered six out of ten questions on the baseline correctly, and nine out of ten questions on the post-intervention assessment correctly. Therefore, she achieved 50% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of six, A.D. answered seven out of ten questions on the baseline correctly, and eight out of ten questions on the post-intervention assessment correctly. Therefore, she achieved 14% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of seven, A.D. answered six out of ten questions on the baseline correctly, and six out of ten questions on the post-intervention assessment correctly. Therefore, she achieved no improvement on this addend, and no change was made in the development of this addend.

When examining the addend of eight, A.D. answered eight out of ten questions on the baseline correctly, and eight out of ten questions on the post-intervention assessment correctly. Therefore, she achieved no improvement on this addend, and no change was made in the development of this addend.

When examining the addend of nine, A.D. answered seven out of ten questions on the baseline correctly, and nine out of ten questions on the post-intervention assessment correctly. Therefore, she achieved 28.5% improvement on this addend, and there was a positive change made in the development of this addend.

See Figure C for A.D.'s achievement and progress of each individual addend, comparison between the baseline and the post-intervention assessment of each addend.

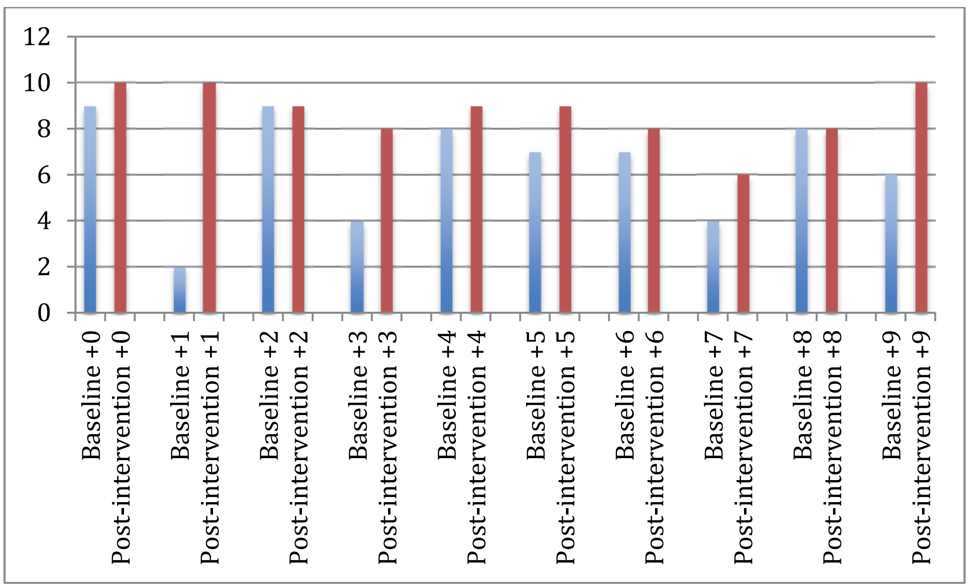


Figure C

Student D (D.S.): When examining the addend of zero, D.S. answered zero out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, D.S. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the addend of one, D.S. answered two out of ten questions on the baseline correctly, and nine out of ten questions on the post-intervention assessment correctly. Therefore, he achieved 350% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of two, D.S. answered zero out of ten questions on the baseline correctly, and seven out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, D.S. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the addend of three, D.S. answered zero out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, D.S. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the addend of four, D.S. answered zero out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, D.S. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the addend of five, D.S. answered zero out of ten questions on the baseline correctly, and nine out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, D.S. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the addend of six, D.S. answered zero out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, D.S. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the addend of seven, D.S. answered zero out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, D.S. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the addend of eight, D.S. answered zero out of ten questions on the baseline correctly, and nine out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, D.S. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

When examining the addend of nine, D.S. answered zero out ten questions on the baseline correctly, and eight out of ten questions on the post-intervention assessment correctly. Although a percentage cannot be determined, D.S. showed an improvement from the baseline assessment to the post-intervention assessment, and shows a positive change in the development of this addend.

See Figure D, for D.S.'s achievement and progress in each individual addend, comparison between the baseline and the post-intervention assessment of each addend.

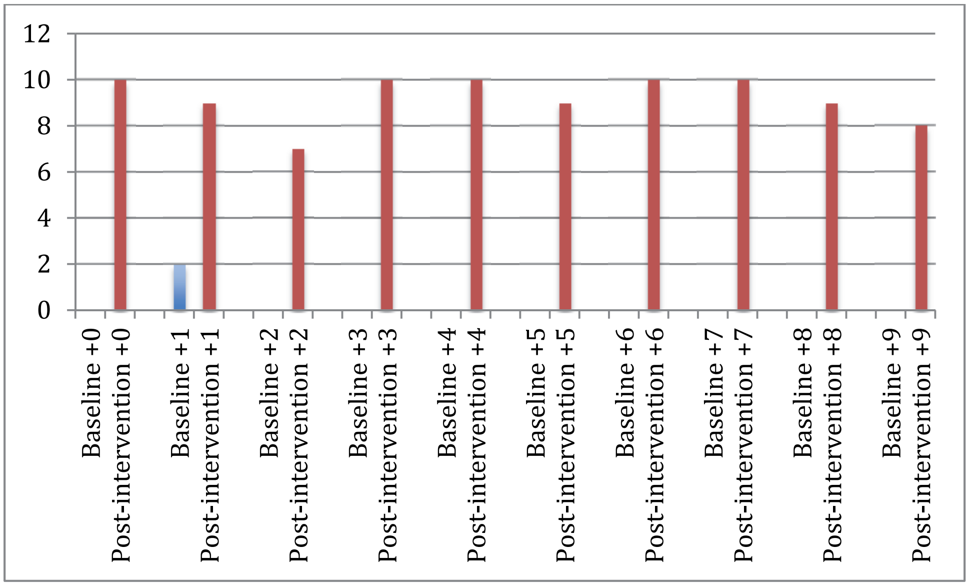


Figure D

Student E (S.Y.): When examining the addend of zero, S.Y. answered all of the questions on the baseline correctly, and all of the questions on the post-intervention assessment correctly. Therefore, he achieved no improvement on this addend, and there was no change made in the development of this addend.

When examining the addend of one, S.Y. answered three out of ten questions on the baseline correctly, and all of the questions on the post-intervention assessment correctly. Therefore, he achieved 233% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of two, S.Y. answered two out of ten questions on the baseline correctly, and all of the questions on the post-intervention assessment correctly. Therefore, he achieved 25% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of three, S.Y. answered one out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Therefore, he achieved 90% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of four, S.Y. answered five out of ten questions on the baseline correctly, and nine out of ten questions on the post-intervention assessment correctly. Therefore, he achieved 80% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of five, S.Y. answered one out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Therefore, he achieved 90% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of six, S.Y. answered four out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Therefore, he achieved 67% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of seven, S.Y. answered two out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Therefore, he achieved 25% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of eight, S.Y. answered three out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly.

Therefore, he achieved 42.8% improvement on this addend, and there was a positive change made in the development of this addend.

When examining the addend of nine, S.Y. answered three out of ten questions on the baseline correctly, and all ten questions on the post-intervention assessment correctly. Therefore, he achieved 42.8% improvement on this addend, and there was a positive change made in the development of this addend.

See Figure E, for S.Y.'s achievement and development of each individual addend, comparison between the baseline and the post-intervention assessment of each addend.

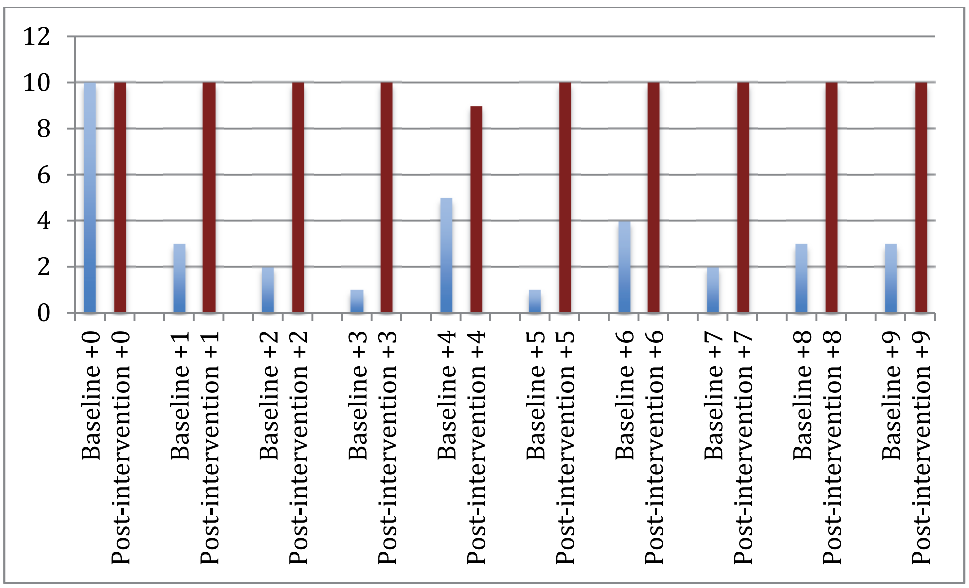


Figure E

4.5 group of each individual addend. Addend 0: When examining the addend of zero, there was a 36% increase in the number of correct answers from the baseline assessment to the post-intervention assessment,

Addend 1: When examining the addend of one, there was a 70% increase in the number of correct answers from the baseline assessment to the post-intervention assessment.

Addend 2: When examining the addend of two, there was a 67% increase in the number of correct answers from the baseline assessment to the post-intervention assessment.

Addend 3: When examining the addend of three, there was a 975% increase in the number of correct answers from the baseline assessment to the post-intervention assessment.

Addend 4: When examining the addend of four, there was a 56% increase in the number of the correct answers from the baseline assessment to the post-intervention assessment.

Addend 5: When examining the addend of five, there was a 61% increase in the number of the correct answers from the baseline assessment to the post-intervention assessment.

Addend 6: When examining the addend of six, there was a 67% increase in the number of the correct answers from the baseline assessment to the post-intervention assessment.

Addend 7: When examining the addend of seven, there was an 87% increase in the number of the correct answers from the baseline assessment to the post-intervention assessment.

Addend 8: When examining the addend of eight, there was a 64% increase in the number of the correct answers from the baseline assessment to the post-intervention assessment.

Addend 9: When examining the addend of nine, there was 64% increase in the number of the correct answers from the baseline assessment to the post-intervention assessment.

See Figure F, for the overall improvement percentage of each individual addend, comparison between the overall percentage achieved on each addend on baseline assessments versus the post-intervention assessments, based on group achievement.

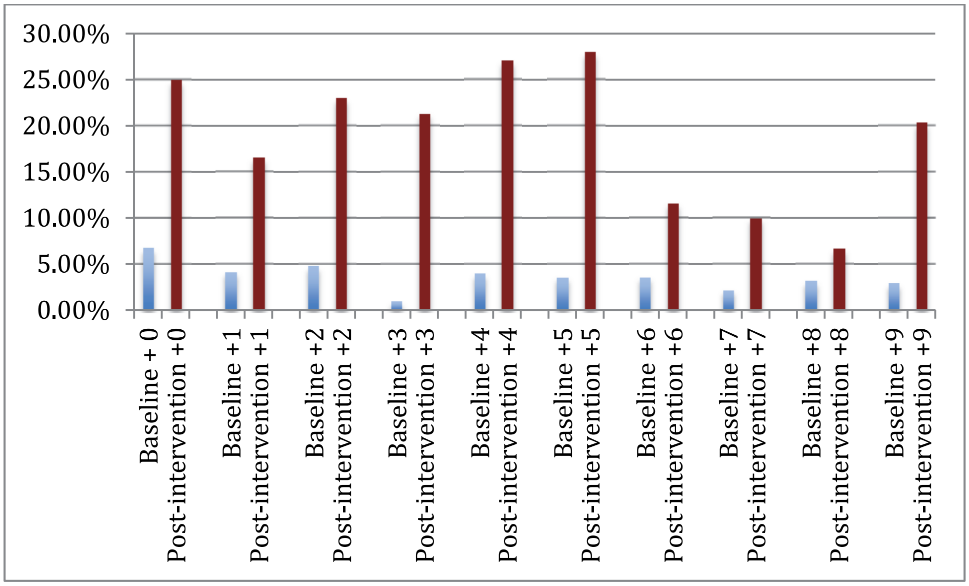


Figure F

When looking at the average percentage for each individual addend based on the student participants' baseline and post-intervention assessments, it shows that their scores improved after being explicitly taught the intervention of using the touch points.

Chapter 5

Discussion

5.1 current study. The current study was conducted in a school, located in Atco, New Jersey, that serves students with severe and significant disabilities. There were five student participants with various disabilities, including severe and specific learning disabilities, cognitive impairments, autism spectrum disorders, and multiple disabilities, ages eleven through sixteen years old, in a self-contained classroom that participated in this study.

This study was conducted because the student participants' basic operation addition skills were varying, and their rate of progress towards mastering addition skills was slow. The student participants were not responding to a paper and pencil method, and learning their addition basic operation facts. Along with the use of manipulatives, a number line, and the painful attempt of trying to memorize facts, the student participants continued to struggle with strengthening their basic operation addition skills. A multisensory approach to instruction was provided over an eight-week period to improve basic operation addition skills. The student participants were explicitly taught the multisensory approach of counting up touch points on two single digit addends, through the use of the *Touch Math* program.

This multisensory approach to instruction through the *Touch Math* program were chosen as the instructional strategy to use for these particular student participants, based on previous research. There have been a number of studies that linked the multisensory approach of the *Touch Math* program to improving, students with specific learning disabilities, basic operation skills. There also have been previous studies conducted to determine the best approach to teach basic operation skills to students with severe and significant disabilities. These studies indicated that using a multisensory approach to instruction when teaching basic operation addition skills are the best instructional approach for students with severe and significant disabilities. Therefore similar instructional approaches would be used during the intervention of this current study.

Before the implementation of the intervention of using the touch points on two single digit addends, the students were given baseline assessments of fact families, with addends zero through nine. All of the student participants' results on these baseline assessments varied, and no one student's results showed mastery across all of the addends. Therefore the intervention of counting up all touch points was provided to the student participants.

The intervention was provided to the student participants over a four-week period, where they were explicitly taught how to count up all the touch points on two single digit addends to create a sum. Initially, the student participants were taught how to apply the touch points to numbers and count up the touch points to state a number. The student participants were then taught how to count up the touch points on two single digit addends to create a sum. The student participants used various materials during this explicit teaching, including a number line with touch points, the *Touch Math* application on the iPad, as well as, using manipulatives such as stickers and candy to create touch points to solve single digit addition problems.

During the intervention period, it appeared that the student participants were responding to the intervention, and were developing their basic operation addition skills. Based on their response to the intervention, the student participants were assessed on post-intervention assessments. These assessments contained addends zero through nine, with the touch points already being applied to the two single digit addends.

The student participants' results show that they each made individual progress on solving addition problems of each addend. Comparing the baseline assessment score to the post-intervention assessment score, determined the percentage of improvement for each individual addend. Although each student participant's improvement percentage of an individual addend varied, they all showed improvement in solving two single digit addends using touch points.

Therefore, the multisensory approach of instruction, of using touch points to help solve basic operation addition problems appears to help students with severe and significant disabilities, and can be linked to previous research.

This current study can be linked to Geary, et al's, (2004) research that focused on creating a strategy based intervention to improve students with learning disabilities' arithmetic skills, using the *Touch Math* program. That study showed that students with learning disabilities in the area of mathematics commit more counting errors, and use developmentally immature counting-all procedures more than non-disabled peers. Students with mathematical learning disabilities could benefit from instructional strategies that help them generalize mathematical skills that are based in number sense and counting, and rely less on their processing skills and working memory.

In a longitudinal study of the multisensory approach to improve basic operation skill achievement of students with mild learning disabilities, by Dev, Doyle, and Valente's 2002, eleven students, ranging in age from six to seven years old, participate in this two-year study. Student participants were given a WRAT-III assessment before and after the daily intervention of the *Touch Math* program to determine improvement in basic operation skills over a two year period.

This longitudinal study relates to the current study in its format of determining achievement and improvement of basic operation skills. In Dev, et al's 2002 longitudinal study, they used formal assessment tools to determine if there was an achievement growth in the student participants' skills, after being explicitly instructed within the multisensory approach of the *Touch Math* program over a two year period. This study showed that there was improvement in their achievement of basic operation skills, based on the baseline assessment, daily and explicit teaching of the multisensory approach of the *Touch Math* program, and post-intervention assessment.

The current study had informal baseline and post-intervention assessments. However the student participants were not explicitly taught the multisensory approach of the *Touch Math* program over an eight-week period. Within this short intervention period, the students that participated in the current study, their skills in basic operations, improved. Therefore, Dev, et al's 2002 and the current study both show that with baseline, explicit intervention, and post-intervention assessment that student participants skills improved.

In Strand's 2013, experimental control group study, there were two groups of student participants, one group received supplemental instruction through the *Touch Math* program, and the other group did not receive supplemental instructional support. The instructional support was provided to that particular control group for a year. At the end of the school year, the students in both control groups were assessed on various basic operation concepts. It was found that the students that received instructional support from the *Touch Math* program achieved more accuracy on the various problems on the assessment that their peers who did not receive instructional support.

This study shows that students that were given supplemental instruction, and a strategy based intervention, their skills in basic operations improved. Strand's 2013 study relates to the current study, in regard to providing student participants a strategy to count up all of the touch points to add to single digit addends. This strategy improved the student participants' skills in solving single digit addends.

Regarding providing instructional materials and basic operation curriculum for students with significant disabilities. There have been several meta-analysis studies and curriculum guides for educators to provide mathematical instruction to students with significant disabilities.

Within these studies and curriculum guides, the work of Browder, Jimenez, Spooner, Saunders, Hudson, and Bethune's (2012) conceptual model, they examined how the instruction of early numeracy skills was given to students with moderate and significant disabilities. They felt that students with significant disabilities struggles, included: number identification, rote counting, representation of numbers through one-to-one correspondence, number conversation, composing and decomposing numbers, magnitude of numbers, early measurement concepts, understanding the effect of basic operations, and patterning. They indicated that students with significant disabilities would benefit from a multisensory approach to instruction to teach these skills. They noted that the *Touch Math* program would be a beneficial instructional material for students with significant disabilities.

The *Touch Math* program was used in the current study to help the student participants improve their basic operation skills. The student participants used touch points to help add and develop and strengthen the following skills: number identification, rote counting, and composing number. Using the touch points when adding, improved the student participants basic operation skills, and indicates that the *Touch Math* program and its instructional techniques are beneficial to students with significant disabilities.

5.2 limitations of the current study. Based on the current study, there were limitations that affected the overall outcome. Limitations included the following: student participants, the structure of the intervention, the structure of both the baseline and post-intervention assessments, and the results of the interventions.

Within the limitations of the student participants, there were various constraints that affected the current study, including the students' schedules, their rate of learning the strategy, and having it reinforced by other classroom staff members.

Four out of the five student participants had related services during the time that mathematical instruction was given. These four student participants were not instructed in mathematical concepts five days within a school week.

Another constraint included student participants' rate of learning the intervention and having it reinforced by other classroom staff. This was evident when examining student participants that have a one-on-one assistant compared to student participants that did not have a one-on-one assistant. Student participants that did have a one-on-one assistant could have been more frequently monitored through out the process of learning how to add numbers with touch points. Student participants that did have a one-on-one assistant appeared to have more opportunities to have touch point concepts reinforced, and monitoring during the entire intervention process. Therefore, this had a positive affect on their learning and reinforcement of the touch point strategies to help them add two single digit numbers.

Within the limitations of the structure of the intervention, the following occurred: structure of the classroom where the intervention and assessments occurred, how the assessments were structured, and the rate of the student participants' consistent practice of the intervention.

The student participants had a challenging environment to complete the baseline assessment, intervention, and post-intervention assessment. The students were in a small group within a classroom with students that did not participate in the current study. Therefore, the non-participating students and classroom staff distracted the student participants.

Also the assessments and intervention took place in the class period right before lunch, and some of the student participants were focused on lunch. It appears that some students rushed through assessments and independent practice to eat lunch.

The most glaring limitation of the structure of the intervention and its consistency of implementation was the structures of the school day. This current study took place in the height of the winter. Due to the frequency of the inclement weather, school was either delayed or closed for the day. Students did not receive the consistency of the intervention and assessments in a daily manner, and it affected the rate of learning and maintaining the intervention.

When examining the limitations of the baseline and post-intervention assessments, their structure and aides to complete theses assessments affected their results. When the student participants completed the baseline assessments, the amount of problems on these assessments varied. Two of the baseline assessments had twenty problems, and two of the baseline assessments had thirty problems. Compared to post-intervention assessments, where each assessment had twenty problems. Based on the amount of problems on the type of assessment, it affected the percentage of achievement for each fact family addend both for the individual and the overall average for the addend when comparing the group's overall achievement of the group.

5.3 implications of the current study. After the current study was completed, and the limitations of this study were examined, there are implications from those limitations. Implications could be made in the following areas of limitations in student participants, structure of the intervention, and the structure of the baseline and post-intervention assessments.

Within the area of limitations of student participants, the following can be implicated: students that participate in the study should receive the maximum amount of instruction time to be thoroughly assessed and instructed in the assessment. For students that do participate in a study on in an intense intervention, they should receive instruction in that intervention every day at the same time, for the same amount of time. When students do not consistently receive the intervention, it could affect their rate of learning the intervention and progress towards maintaining a skill or concept.

The students that participated in this study had various rates of progress of using the intervention of the touch points to help them solve single digit addition problems. Due to their various rates of progress towards maintaining the use of the touch points to solve single digit addition problems, there are two student participants that would not be included in future studies. Those student participants are Student A and Student B. Student A would not be included in a similar future study due to him having a majority of the mastery of achievement in all of the addends, and it did not appear that he needed the intervention to help with his addition skills. Student B would not be included in a similar future study due to his seizure activity. His seizure activity affected his consistency of the intervention and his percentage of achievement was affected due to his influx of seizures during the baseline assessment. Student B should receive an intervention to help recall a strategy to help solve addition problems, but should not be assessed on the strategy to see if it bettered his addition skills. Based on these two student's rate of achievement in improving their addition skills, students who almost have a skill mastered and students who have consistent difficulties within a school day should not be included in an intervention based study.

When examining the limitations of the structure of the intervention, the following can be implicated: this intervention should be implemented at the beginning of the school year. The students that participated in the current study struggled a majority of the year before the intervention began. In future studies that provide similar interventions, it would be best to be done in the beginning of the school year.

Also, this intervention was provided to the student participants right before lunch, which was a major distraction for them. They were worried about lunch, and did not appear focused during the instructional period. This type of intense instruction would be best done at a different point in the school day, preferably earlier in the day.

In future studies, students that participate in similar future studies should be assessed and instructed in a smaller and quieter area away from distractions.

When examining the limitations of the structure of the baseline and post-intervention assessments, the following implications can be made: the baseline assessments did not have the same number of problems on each assessment. The baseline assessment should have been broken up into two fact addends, instead of either two or three fact addends. It appeared that some student participants struggled with the assessments with more questions. In future studies, student participants would benefit from assessments that have a consistent amount of questions throughout the study.

Also, it appears that during the post-intervention assessments some participants rushed through the assessments, and their accuracy score is not truly reflected. Specifically Student C appeared to rush through these post-intervention assessments, and it appears that due to her rushing that her individual achievement score does not truly reflect her maximum ability to add. In future intervention studies, there should be close monitoring of students during the assessment period, and providing a quiet area to complete the assessments.

The post-intervention assessments show that student participants benefitted from intense intervention instructional approaches of using touch points to count up when adding two single digit addends. Future studies that address increasing basic operation skills should include baseline and post-intervention assessments to determine if the intervention worked; but, more importantly, did the students make progress in both obtaining and maintaining a skill?

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