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Is TouchMath an Effective Intervention for Students with Autism?

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IS TOUCHMATH AN EFFECTIVE INTERVENTION FOR STUDENTS WITH AUTISM?

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ABSTRACT

The TouchMath program was created in 1976 to help students struggling with basic mathematical computations (Bullock, 2005). Although the research has found TouchMath to be an effective intervention for students in the general and special education populations, only four studies have found the program to be effective for students with Autism Spectrum Disorder (Berry, 2009; Cihak & Foust, 2008; Fletcher, Boon, & Cihak, 2010; Yıkmış, 2016). The purpose of the study was to determine how the intervention can affect accuracy and fluency for students with ASD. The study focused on single-digit plus single-digit addition problems with three participants diagnosed with ASD in grades 5-6, all of whom attended rural school districts in East Texas. A multiple-probe design was used for progress monitoring, using cold and hot probes, with three phases to the intervention: baseline, intervention, and generalization. An additional modification was made to the TouchMath curriculum involving faded TouchPoints that were used to aid in generalization. An analysis of results showed the TouchMath program to likely be ineffective for students with ASD, however more research is warranted. Limitations to the study are discussed.

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CHAPTER 1

Introduction

As the number of students with Autism Spectrum Disorder (ASD) increases, general and special education teachers will need to continue their search for new and innovative methods of educating this group of students in a way that is effective and beneficial for student success. Many students with ASD have exceptional mathematics skills, while others continue to struggle with basic mathematical computations (Adkins & Larkey, 2013). Often, students struggling with basic math skills fail to naturally acquire math strategies. They are also unable to apply strategies effectively and do not consistently use the same strategy for problem solving (Wendling & Mather, 2009). Due to changes in state assessment, special education students are now, more than ever, expected to acquire math computation abilities and perform on the same level as nondisabled peers (Texas Education Agency, n.d.).

The state of Texas administered the State of Texas Assessments of Academic Readiness (STAAR) Modified Exam for the final time during the 2013-2014 academic year (Texas Education Agency, n.d.). Previous STAAR Modified exam accommodations included larger print, fewer items per page, as well as three answer choices to multiple choice questions (Texas Education Agency, 2011). Students who receive special education services and accommodations are now required to complete the same state exam as those enrolled in general education. According to the Spring 2017 Texas

Education Agency report for the STAAR 7th grade mathematics scores (Texas Education Agency, 2017), 72% of all special education students in the State of Texas did not meet the Approaching Grade Level performance standard. When comparing the percentages of correctly answered questions from the reporting category Computation and Algebraic Relationships, the total average for all students was 57% state wide. While economically disadvantage students averaged 51%, English as a second language (ESL) achieved 44%, At-Risk scored 45%, and all special education students only attained 37%.

Students receiving special education services continue to fall below the projection curve of general education students in academic performance, with students with ASD being among the lowest in 11 out of 13 federal disability categories (Wei, Lenz, & Blackorby, 2013). With the standards of academic performance being raised for those with special needs, general and special education teachers need strategies and curriculum that can reach every student. Students with ASD exhibit more difficulties in calculation and basic mathematical skills than students with other disabilities due to deficits in executive functioning abilities, especially when paired with weaknesses in working memory (Doobay, Foley-Nicpon, Ali, & Assouline, 2014). Interventions in mathematical instruction are limited (King, Lemons, & Davidson, 2016). Research has found that the most effective learning strategies for students in elementary grades with special needs includes direct teaching of basic skills with the ability to practice through self-instruction (Kroesbergen & Van Luit, 2003). The purpose of this study is to determine the effectiveness of a modified TouchMath program for teaching basic mathematics computation skills in addition for those students diagnosed with ASD in 5^{th} and 6^{th} grade.

CHAPTER 2

LITERATURE REVIEW

The number of children being diagnosed with Autism Spectrum Disorder (ASD) is increasing every year. In fact, the percentage increased from 1.47% in 2010 to 2.76% in 2016 (Xu, Strathearn, Liu, & Bao, 2018). According to The American Psychiatric Association's Diagnostic and Statistical Manual, Fifth Edition (DSM – 5; American Psychiatric Association, 2013), ASD is described as a developmental disorder demonstrating continual deficits with social interactions and communication skills across different environments (American Psychiatric Association, 2013). Although the etiology of ASD is still unknown, researchers have studied the anatomy and physiology of the brains from people with autism over the past 20 years (Akshoomoff, 2005). Neuroimaging has detected several regions of the brain from people with autism to be enlarged in volume for certain areas and in other areas the volume is decreased when compared to neurotypical brains (Akshoomoff, Pierce, & Courchesne, 2002; Getz, 2014). Areas with consistent abnormalities across wide populations of adults and children with ASD include the cerebellum, corpus collosum, amygdala, and hippocampus. Abnormalities in the function of these specific brain regions tend to coincide with the typical characteristic behaviors associated with ASD (Akshoomoff et al., 2002; Akshoomoff, 2005).

The increased brain volume is due to an overgrowth of neurons, resulting in an abundant amount of inefficient connections that reduces the efficiency of neural pathways (Getz, 2014). Brain regions exhibiting a decrease in volume is due in part to a diminution in neuron connections (Campbell, Chang, & Chawarska, 2014). An inverse relationship has been found with the length and strength of neuron connections: the lower the connection efficiency, the higher the severity of ASD symptoms (Lewis et al., 2014). Zilbovicius et al. (1995) reported evidence of a delay in the development of the pre-frontal cortex due to a reduction in functional connections between brain regions in children with ASD, which can lead to potential problems with executive functioning.

Results from the comparison of cognitive, adaptive, and psychosocial differences between neurotypical youth and students with high functioning ASD have found students with ASD have a relative weakness in processing speed when compared to neurotypical students (Doobay et al., 2014). This weakness could relate to deficits in executive functioning, which is the necessary cognitive process needed for cognitive flexibility, planning, self-regulation, response inhibition, task initiation, and working memory (Blijd-Hoogewys, Bezemer, & van Geert, 2014). As children grow, the connections between synapses can then increase in strength, as they are used more often, allowing for faster processing speeds (Getz, 2014). This is an important factor in early intervention in both behavioral and academic areas for students with ASD (Dawson et al., 2010).

Students with ASD demonstrate a wide range of strengths and weaknesses in mathematic skills. All students receiving special education services tend to fall below the performance levels of their peers in general education in both applied problems and calculations. When comparing students within the 11 federal disability categories, students with ASD scored in the lowest three disability groups, along with intellectual disabilities and multiple disabilities (Wei et al., 2013). Researchers have studied the growth trajectories for each disability category and students with ASD were found to have significantly slower growth rates in calculation when compared to their peers in special education (Wei et al., 2013). These results suggest that students with ASD demonstrating weaknesses in mathematical computations will require more individualized instruction with effective computation strategies in place to increase their rate of performance.

Students with ASD who demonstrate mathematical strengths can also have difficulties utilizing consistent methods of calculation. One method often utilized by students with ASD is the recall strategy, also known as rote memory. Although students with ASD can perform well with rote memory, researchers have found they generally are unable to fully explain how they solved a problem 66% of the time, as this requires executive functioning skills (Haas, 2010). As the curriculum increases throughout the student's educational career and becomes more complex, eventually rote memory can become less effective as the amount of information required to remember significantly increases. By applying mathematical strategies provided by the TouchMath curriculum, students with ASD can begin to develop executive functioning skills (Kroesbergen et al., 2003). TouchMath also provides students with other means of problem solving that do not rely solely on rote memory alone.

As the number of students with ASD increases, teachers and school staff will continue to look for effective ways to support these students within the classroom. The research in mathematic interventions for students with ASD has been limited. Barnett and Cleary (2015) conducted a literature review for effective evidence-based interventions focusing on mathematics interventions for students with ASD. The review only involved 11 articles, three of which included the TouchMath program. A similar review was conducted by King, Lemons, and Davidson (2016) who found many of the articles were related to behavioral interventions, with few effective interventions for mathematic instruction for students with ASD and only one article pertaining to TouchMath. Of those interventions, many of them pursued general mathematic function or computation skills and one-to-one student/teacher ratio of direct teaching strategies. Researchers have found that when working with elementary age students with special needs, interventions involving the learning of basic skills of mathematics are more effective than problem-solving based skills (Kroesbergen et al., 2003). Students also benefit more from direct instruction from a teacher than a computer-based program or mediated/assisted instruction (Kroesbergen et al., 2003). With limited research involving mathematical instruction for students with ASD, there is a significant need for researchers to provide effective interventions and curriculum that can accommodate this population.

Basic math computation is the foundation for all math problem solving abilities given that mathematics is a cumulative and hierarchical process (Wendling et al., 2009). The foundation for all higher-level mathematics is number sense (Feikes & Schwingendorf, 2008). Number sense refers to the overall knowledge of numbers and operations and the ability to apply this knowledge to make mathematical decisions and develop efficient and useful strategies for problem analysis (Reys et al., 1999). Students who have a firm understanding of number sense are successful in understanding the meaning of numbers and the relationship numbers can have through different operations such as the difference in 3 + 2 versus 3 x 2 (Schneider & Thompson, 2000). Once this understanding is acquired, fluency can begin to develop. Fluency is based on the ease and accuracy in which basic math calculations are carried out (Locuniak & Jordan, 2008).

Calculation deficits and mathematical difficulties in fluency have been linked to poorly established number sense abilities (Gersten, Jordan, & Flojo, 2005; Mazzocco & Thompson, 2005). Locuniak and Jordan (2008) conducted a study to determine if the level of number sense acquisition found in kindergarten students can predict calculation fluency in second grade better than cognitive abilities. The study found that the most successful students in second grade were those who had developed a firm understanding of number sense at the acquisition stage in kindergarten. One of the defining characteristics of students with math difficulties is a deficiency in calculation fluency, which stems from the ability to comprehend number sense (Locuniak et al., 2008). In order to develop fluency, students must acquire number sense and then be provided opportunities to work with numbers in many different ways (Boaler, 2015).

The complexity of math continues to increase as students move up in grades, so the demand for students to obtain knowledge and reasoning abilities substantially increases (Wendling et al., 2009). Eventually, math evolves from the concept of numerals and their relationships, to more complex word problems that require problem solving abilities. According to Ferrini-Mundy and Martin (2000), "Problem solving means engaging in a task for which the solution method is not known in advance (p. 52)." Students use prior knowledge to solve problems and in doing so, they can develop new understandings, making successful problem solving the ultimate goal for students in mathematics (Ferrini-Mundy et al., 2000).

In a survey completed by Bryant, Bryant, and Hammill (2000), teachers reported that students with learning disabilities rated word problems in mathematics as the most difficult type of problem for those students. Wendling and Mather (2009) stated an effective problem solver requires the abilities to: "(a) represent the problem accurately, (b) visualize the elements of the problem, (c) understand the relationships among numbers, (d) use self-regulation, and (e) understand the meaning of the language and vocabulary" (p. 198). The researchers also specified that the most difficult issues students with math difficulties demonstrate with problem-solving is understanding what the question is asking and then following the multiple steps required to answer the question. Regardless of the difficulties found with problem-solving, efficiency in basic number sense and fluency are necessary for success in higher-level mathematics.

The instructional hierarchy, described by Haring and Eaton (1978), is based on four stages of learning. The hierarchy is utilized to assist teachers in determining the stage of learning their students are in, their proficiency in obtaining new skills, and guidance in choosing academic interventions that are the most appropriate and relative to their proficiency level (Burns, VanDerHeyden, & Boice, 2008; Daly & Martens, 1994). During the first stage, known as acquisition, students learn new skills with performance focusing on getting the correct answer (Cates & Rhymer, 2003). Students' performance is often inaccurate and slow during this phase, and they can benefit from interventions involving explicit teaching, modeling, and an increase in immediate feedback (Ardoin & Daly, 2007). Once accuracy is acquired, the focus shifts to fluency during the second stage of learning. Students benefit most from interventions providing opportunities for repeated practice and immediate feedback during the fluency stage. This allows students to focus on accuracy while increasing their response time (Daly, Hintze, & Hamler, 2000).

The third stage of learning is generalization, in which performance conditions offer different stimuli that were presented during the fluency stage. For example, instead of answering 3 x 5 on a flash card, the student is now expected to apply their knowledge of 3 x 5 in real world situations. To attain skill generalization, students should be given ample opportunities to practice their acquired, fluent skills across diverse situations

(Cates & Rhymer, 2003). Adaptation is the fourth and final stage of the instructional hierarchy and is the most complex stage (Hall, 2016). Adaptation is achieved by applying a learned skill to a new concept, such as applying the knowledge of multiplication to the process of long division (Cates & Rhymer, 2003). Students will need support in breaking down problems that require multiple operations to solve into smaller steps and will benefit from immediate feedback and opportunities for repeated practice (Cates & Rhymer, 2003).

According to Kroesbergen and Van Luit (2003) direct instruction focusing on basic skills of mathematics is the most effective means of working with children with special needs. The TouchMath curriculum provides effective strategies for students with ASD by strengthening their foundational skills and building their executive functioning. This can give students with ASD a strong platform to support them as the hierarchical and cumulative mathematics curriculum increases in complexity. In 1976, the TouchMath program was created to aid struggling students with mathematical computation. According to the TouchMath manual (Bullock, 2005), the program provides tactile reference points, known as TouchPoints, to form connections between the concrete and abstract concepts of the numeral. TouchMath can be used as a supplemental program for those struggling with basic mathematical computation in addition, subtraction, multiplication, and division (Bullock, 2005).

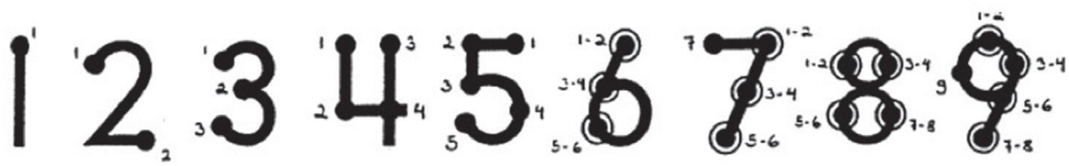
The TouchMath Program

Students with ASD who have demonstrated proficiency in computation abilities have only been successful through the use of rote memory (Haas, 2010). Kramer and Krug (1973) discussed the difference between the advantages and disadvantages of rote addition versus the use of manipulatives. Rote addition is based on the ability to memorize basic math facts. This allows for fast paced work, and does not require the need for manipulatives, which overall allows for less conspicuous problem solving as opposed to counting on fingers. A disadvantage that Kramer and Krug found with rote addition, was that it does not teach the process of addition, nor does it aid in generalization. Rote addition was simply based on memorization, and if students could not understand the meaning of 2 + 5, they could not comprehend using this form of problem solving.

For those students who could not memorize the math facts, Kramer and Krug (1973) allowed for the use of manipulatives during problem solving. The researchers mentioned that some students were incapable of memorizing fundamental combinations and "these students may never be able to depend on rote: therefore, they must rely upon an alternative system if they are to use addition" (p. 141). The researchers sought to find a curriculum that allowed for a progressive transition to rote memory, but no such curriculum was found. One of the researchers devised a reference point pattern placed on the numbers, which allowed students to count all or count on to solve the math problems.

In 1976, Janet Bullock developed the program called TouchMath that modified Kramer and Krug's reference points and called them "TouchPoints" (Bullock, 2005).

Bullock's (2005) TouchMath program focuses on students learning the value of a number by placing points, known as TouchPoints, onto the numeral. TouchPoints are the reference points that correspond to the value of the number. The TouchPoints are systematically placed on the numerals with numerals 1 through 5 having single TouchPoints. Students are to touch and count each single TouchPoint one time, while numerals 6 through 9 contain double TouchPoints requiring the student to touch and count twice (How it works, n.d.).



By combining tactile, visual, and auditory sensations, the TouchMath approach is multisensory in nature and allows for the numerals to be presented simultaneously in a concrete, semi-concrete, and abstract manner. Students first learn the position of the TouchPoints on each numeral, then touch and count the TouchPoints to form a concrete understanding of the value of the number (Yıkmış, 2016). For addition, students can either count all TouchPoints to find the sum or apply the counting on strategy: saying the highest value number and continuing to count the TouchPoints (Bullock, 2005). This is similar to students using their fingers as references; however, the TouchPoints allow for the student's counting to be less conspicuous. For subtraction, students are to count backwards from the highest numeral in the problem, and for multiplication and division the students utilize skip counting, visual cues from the TouchPoints, and multisensory step by step strategies to acquire accuracy with these higher-level math skills (How it works, n.d.).

The program is derived from Piaget's preoperational stage and Bruner's enactive theory of development in which students are actively engaged through touching the points while counting aloud, allowing them to understand the concept being taught (Green, 2009). As the TouchPoints are faded out with practice, students eventually understand the abstract meaning of the number and how it can be used to solve problems, coinciding with Bruner's symbolic stage and Piaget's formal operational stage (Green, 2009). It also breaks down the process of addition, subtraction, multiplication, and division into smaller, logical steps that prohibits the need for storage of mathematical facts (Scott, 1993).

The TouchMath program also aligns with Haring and Eaton's (1978) instructional hierarchy. Students begin with acquiring knowledge of the meaning of numerals, and the foundational computation skills of addition and subtraction utilizing TouchPoints. With direct teaching, modeling, opportunities to practice, and immediate feedback, students become more accurate and eventually the TouchPoints are removed to build and increase fluency (Yıkmış, 2016). With repeated practice, and immediate feedback, fluency is accomplished and then students can generalize the TouchMath strategies to more complex math problems with different stimuli. When students are introduced to the concept of multiplication and division, students can adapt their knowledge of the TouchPoints from sequential counting to skip counting.

Coleman and Lamb's (1985) review and evaluation of TouchMath noted several strengths and weaknesses of the program. Strengths of the program included offering hands-on, visual aids to promote the ease of learning the value of numbers and fundamental computation skills, which in turn reduces the dependency of rote memory. This aspect is particularly beneficial for students with special education needs, who have issues with memorization. TouchMath visuals allow these students to proceed to new skills, instead of being held back due to the inability to memorize math facts. There were also some weaknesses mentioned by the authors, concerning gaps in the program that were not sufficiently explained in the teacher's manual; including, the concept of more than, and the use and comprehension of a number line. The worksheets provided in the program can also be overstimulating for some students with special needs, due to the amount of artwork used for visual appeal, and the amount of problems per page. Place value is also not incorporated as part of the curriculum, which is another concern, given that this is a skill needed to understand computation.

Despite the weaknesses found in the curriculum, there have been several studies that have found TouchMath to be effective across many grade levels and academic abilities. Aydemir (2015) conducted a review of 27 articles relating to the TouchMath program published between the years of 1990 and 2014. Many of those articles determined the TouchMath curriculum was effective over a wide spectrum of educational populations, such as students in general education, gifted and talented (GT), and special education programs. It has also been found that TouchMath can be effective for specific special education populations including students with learning and intellectual disabilities, physical disabilities, Down Syndrome, and Autism. Only four TouchMath studies were found that included students with ASD. All four studies were effective and all of them focused on addition, with one study targeting subtraction. Participants ranged in age from 7–10 years, with one participant being 14 years of age and in the eighth grade (Berry, 2009; Cihak & Foust, 2008; Fletcher, Boon, & Cihak, 2010; Yıkmış, 2016).

TouchMath in General Education

The results from studies involving TouchMath and the general education population have demonstrated overall increases in computation accuracy for elementary students and generalization into secondary level mathematics. All studies focused on addition, with two studies also involving subtraction (Calik & Kargin, 2010; Mays, 2008; Mostafa, 2013; Rudolph, 2008; Strand, 2001; Ulrich, 2004; Uzomah, 2012; Velasco, 2009). Improving computational accuracy and increasing overall mathematic performance is a vital asset to those involved in the education system.

For general education students in grades Kindergarten through 2nd grade, research has found the TouchMath program assists young elementary students in acquiring the concept of addition and increases accuracy, which is required to develop fluency (Mostafa, 2013; Strand, 2001; Uzomah, 2012; Velasco, 2009). Uzomah (2012) recommended kindergarten instructors seek out programs and methods that have manipulatives associated with the curriculum but are also within the student's developmental level. The TouchMath program meets Uzomah's criteria as an effective curriculum based on Piaget's theory of cognitive development.

The TouchMath program is also an effective supplemental resource to the general education curriculum, especially for students requiring more individualized instruction in a general education setting (Calik et al., 2010; Rudolph, 2008; Ulrich, 2004). Students have displayed marked improvement in basic computation skills within a one-week time frame, and those students found to exhibit low levels of improvement during instruction, including those considered GT, were able to increase their computation speed (Rudolph, 2008). Results from teacher surveys have reported that students learn more, understand mathematics better, and are more accurate when using TouchPoints (Jarrett & Vinson, 2005).

Students in the general education population display diverse abilities in mathematical learning requiring teachers to differentiate their instruction to meet the needs of all their students, especially in an inclusion classroom setting. While working with two 2nd grade inclusive classrooms during a six-week period, Mays (2008) found that the TouchMath curriculum can benefit all students, including low performing students, those with learning disabilities, and gifted students. This provides evidence that the TouchMath curriculum is effective for student success, regardless of their level of learning abilities, and can also be effective within a short period of time.

Although the TouchMath curriculum has been successful for some elementary age students, some students continue to use TouchPoints at the secondary education level. Despite the TouchMath research demonstrating positive outcomes for middle school students in grades 6-8 (Fletcher et al., 2010), a common concern for teachers is their student's ability to generalize the acquired skill to problems without TouchPoints. Vinson (2005) investigated these concerns by surveying 772 college students, in which 68% of the participants were found to have used TouchMath or similar strategies during high school or in current math courses. Vinson found that having achieved higher educational mathematic instruction, using TouchMath techniques prevented students from depending on memorization of math facts, which at times can lead to errors. Vinson also stated that secondary students, still using touchpoints would not have any other support methods to succeed without this technique and concluded the results provide credibility to the TouchMath curriculum.

Research has found the TouchMath program to increase academic performance for students in the general education population, including GT students, at both the elementary and secondary levels (Calik et al., 2010; Mostafa, 2013; Strand, 2001; Ulrich, 2004; Uzomah, 2012; Velasco, 2009). It has also been shown to decrease the number of errors made during calculation, increase mathematical accuracy and speed, can be implemented within a short period of time, and benefits students with diverse learning abilities (Jarrett et al., 2005; Mays, 2008; Rudolph, 2008). The evidence supports the premise that the TouchMath program can help students identified with disabilities improve their basic mathematic foundational skills.

TouchMath in Special Education

Several studies have found the TouchMath program to benefit students in special education settings as a supplement to the core curriculum and as an intervention focusing on individual performance. Most of these studies (8) focused on the effects of the TouchMath program in teaching addition, four studies examined subtraction, and two studies demonstrated positive student outcomes for all four mathematical operations (addition, subtraction, multiplication and division) for students receiving special education services (Dombrowski, 2010; Dulgarian, 2000; Green, 2009; Scott, 1993; Ronquillo, 2017; Waters & Boon, 2011). All studies provided evidence of an increase in student performance in mathematical computation using the TouchMath program as either a core curriculum, supplemental resource, or intervention (Aydemir, 2015).

When used as the core curriculum, the TouchMath program increased 75% of participants receiving special education services performance levels from below grade level to above grade level after one year of implementation, resulting in no longer qualifying for special education services (Dev et al., 2002). Researchers followed up with the student's progress three years later and all students were able to maintain general education status and continued with success in mathematic computation (Dev et al., 2002). Many students receiving special education services lack skills to help them be as successful as students in general education. By providing them with effective strategies, such as the TouchMath program, special education students can decrease problematic behaviors due to elevated frustration levels from the lack of ability to perform basic arithmetic (Green, 2009).

Students receiving special education services for mild intellectual or learning disabilities have become more successful in mathematic abilities after receiving TouchMath instruction. TouchMath has increased fluency and accuracy; is generalizable; and is considered socially valid by both students and teachers (Calik et al., 2010; Dulgarian, 2000; Scott, 1993; Simon & Hanrhan, 2004; Wisniewski & Smith, 2002). Researchers have also found the TouchMath curriculum to be successful for students with physical disabilities and Down Syndrome and were able to successfully generalize the TouchMath technique to subtraction (Avant & Heller, 2011; Newman, 1994). The aforementioned qualities of the TouchMath program provide an effective method for teachers and staff to intervene on behalf of students receiving special education services that require more individualized instruction and assistance.

<u>TouchMath and Autism.</u> The research on the effectiveness of the TouchMath program benefiting students with ASD is extremely limited. Two studies have compared the TouchPoints strategy to the use of a number line. In both studies, elementary and middle school students with ASD demonstrated significant increases in addition computation and preferred the TouchPoint strategy over use of the number line (Cihak et al., 2008; Fletcher et al., 2010). The research also has demonstrated effective generalization for students with ASD in which participants were able to solve mathematic

equations without the need for TouchPoints over an extended period of time (Berry 2009; Yıkmış, 2016). This is important because as the mathematical curriculum becomes more complex and abstract, the need for a solid foundation of basic computation skills, provided by the TouchMath program, becomes all the more important.

Although the research is limited, not all students with ASD have benefited from the TouchMath program. In a study completed by Berry (2009), eight out of 10 participants with ASD benefited from using TouchPoints while performing addition and subtraction problems and made significant math fluency gains. Two of the participants were unsuccessful with the TouchMath program because they were unable to comprehend the double circle TouchPoints and because of self-stimulatory behaviors exhibited from another participant. Results from this study suggest teachers should consider specific instructional needs and behavioral limitations of their students when planning the implementation of the TouchMath program.

Aydemir's review of the TouchMath program in 2015 found only 7% of the participants in the studies analyzed were diagnosed with ASD, while 30% had learning disabilities. The literature review conducted for this study found 36 articles within the literature involving the TouchMath program and only four studies, including one study conducted in Turkey, involved participants with ASD for a total of 18 students ranging in age from 7-10 years, 13-14 years, and 10 participants identified only as elementary age (Berry, 2009; Cihak et al., 2008; Fletcher et al., 2010; Yıkmış, 2016). Eight of the 36 articles, including one article pertaining to students with ASD (Berry, 2009), only appeared on the TouchMath website and no other publication forms of the article could be found elsewhere (e.g., thesis, dissertation, peer-review publication; Bedard, 2002; Berry, 2009; Dulgarian, 2000; Mays, 2008; Rudolph, 2008; Strand, 2001; Vinson, 2004; Vinson, 2005). Therefore, more research is warranted given the scarcity of TouchMath research including participants with ASD. In fact, more research overall is needed as TouchMath does not appear on the What Works Clearinghouse website ("WWC Summary," n.d.).

Other Findings. Of all the published research, there was only one article that found the effectiveness of the TouchMath curriculum to be inconclusive. The results from the study conducted by Velasco (2009) were considered inconclusive due to limitations involving the post-test treatment integrity when comparing the TouchMath program to the California Math and Phonemic Awareness programs. Nonetheless, the researchers concluded that students in the TouchMath group improved their math fluency skills by performing problems with more accuracy and speed on the post-test compared to their pre-test.

Summary and Critique of the Literature

A review of the literature suggests the TouchMath curriculum successfully increased student accuracy and fluency of basic mathematics skills in addition and subtraction for students in general education, GT programs, and special education (learning disabilities, mild intellectual abilities, physical disabilities, Down Syndrome, and ASD; Avant et al., 2011; Aydemir, 2015; Bedard, 2002; Berry, 2009; Jarrett et al., 2005; Mays, 2008; Newman, 1994; Rudolph, 2008; Scott 1993; Simon et al., 2004; Uzomah, 2012; Vinson, 2005; Wisniewski et al., 2002; Yikmis, 2016). The program allows multiple opportunities to build executive functioning skills and strengthen student's mathematic skills foundation for future abstract and complex mathematics curriculum found at the secondary level and is developed at the appropriate cognitive development level for elementary students (Uzomah, 2012). Vinson (2004) demonstrated that the TouchMath program related to the cognitive theories of Piaget and Bruner, and offers a visual, auditory, and tactile/kinesthetic approach for learners. Students with a wide spectrum of cognitive abilities have improved mathematic performance with the use of the program, regardless of their fine motor abilities (Avant et al., 2011; Newman, 1994). By fading the TouchPoints out during the learning process, participants in two studies were able to generalize these learned skills to solve mathematical problems without the need for visual TouchPoints. Researchers accomplished this by removing the TouchPoints and had the participants continue touching the numerals with their pencil in the same places where the TouchPoints had been. Over a significant amount of time, students began solving problems automatically (Berry, 2009; Yıkmış, 2016). By providing students in special education with the needed skills to be successful at math, the TouchMath program aided in increasing proficiency levels and improving problematic behaviors within the classroom (Green, 2009).

The research has shown the TouchMath curriculum can be an effective program, even as a supplement to the existing curriculum, for elementary students, and it also allows students to generalize the skill in higher education with less errors compared to those using rote memory (Aydemir, 2015; Vinson, 2005). Nevertheless, the TouchMath curriculum can only be effective if teachers and educational staff have access to the curriculum. Rains, Durham, and Kelly (2009) conducted a study involving kindergarten through 3rd grade teachers from the United States focusing on teacher awareness of the TouchMath program. The authors found that teachers who taught in the lower grades were familiar with the program, but as the grade level increased the teachers became increasingly unaware of the TouchMath instructional strategies. The study suggests teachers are more willing to utilize supplementary math materials; however, knowledge of availability of these resources can be limited.

There is a dearth of effective mathematic interventions for students with ASD (King et al., 2016). Due to deficits in executive functioning, many students with ASD will continue to struggle with basic computation and will require more individualized direct teaching instruction at the elementary level (Doobay et al., 2014). The four studies using the TouchMath program with students with ASD have shown significant increases in mathematical performance (Berry, 2009; Cihak et al., 2008; Fletcher et al., 2010; Yıkmış, 2016). As high stakes testing continues to increase, and the performance trajectory of students with ASD continues to fall below proficiency levels, there is a need for more research to find effective mathematic interventions for this population. Furthermore, it is important for the instructional strategies being taught to students with ASD allow for generalization to novel problems and skills.

Purpose and Research Question

The purpose of this thesis was to add to the limited research-base of the TouchMath program. The study investigated if the TouchMath strategies could increase the accuracy and fluency of single-digit plus single-digit problems for students with ASD in grades 5-6. The study also explored the generalizability of performing calculations without the use of TouchPoints by slowly fading the TouchPoints out during the intervention process. Unique to this study, smaller versions of TouchPoints were used and termed "faded" TouchPoints to remind the participants where to touch the numerals as they count. In the closing stages of the intervention sessions, all visible TouchPoints were removed from the integers and participants were asked to use their "imaginary" TouchPoints to solve the problem. Successful generalization occurred when participants could effectively perform an addition problem without using visual TouchPoints by transferring stimulus control from overt to covert. The following research questions were addressed:

R1: Can TouchMath increase the accuracy and fluency of single-digit plus single-digit, problems of students with ASD in grades 5-6?

R2: Can the TouchPoints be successfully faded while maintaining stable responding?

CHAPTER 3

Method

Participants

School principals from eight different rural school districts around East Texas were contacted about the study with a request to send prepared recruitment letters to all parents/guardians of potential participants. A total of five students with documentation of a diagnosis of ASD were recruited for the study in grades 5-6, but only three students met the criteria to participate. To be included in the study, students had to be able to recognize and write numbers 0-18, to count forwards to 18, as well as focus and remain on task for 10-minute increments. Students with prior exposure to the TouchMath curricula were excluded from the study. Other exclusionary factors included: students displaying limited verbal abilities and severe problematic behaviors, and high rates of absenteeism in a school setting which could lead to potential limitations for the study (Martínez-Mesa, González-Chica, Duquia, Bonamigo, & Bastos, 2016).

Data gathered prior to the beginning of the study indicated two participants did not meet criteria for the study. One student did not have a firm understanding of numerals and could not write the correct number when prompted. Another student was nonverbal and exhibited severe sensory and problematic behaviors that prevented participation in the study. Participant one, Anna, a fifth-grade Caucasian female, spent her entire day in the general education setting with accommodations and modifications set in place through special education services. Participant two, Sam, a fifth-grade Caucasian male, was also mainstreamed in the general education setting with similar special education services provided. Participant three, John, a sixth-grade Caucasian male spent his entire day in a self-contained life skills classroom.

None of the students had prior exposure to TouchMath or its procedures. Anna and Sam used rote memory (i.e., memorized addition math facts) during baseline to answer the addition problems, while John used a “100’s chart.” While in intervention, the researcher strongly encouraged Anna to utilize the TouchMath strategies for all assessment probes. In spite of this, she continued to primarily use rote memory and only used TouchMath as a supplement. Sam continued to use rote memory for all cold probes but then used the TouchMath strategies during the hot probes. Throughout the intervention, John was unable to complete the assessment probes utilizing the learned TouchMath strategies and reverted back to the 100’s chart he used during baseline.

Materials

Materials used in the study included assessment data using “addition: sums to 18” probes from the Measures and Interventions of Numeracy website ("MIND: Facts on Fire", n.d) to collect data during baseline, intervention, and generalization phases to determine the effectiveness of the program (See Appendix A). Intervention worksheets used in the study included: TouchMath worksheets for each step in the procedure provided by the TouchMath company and worksheets created by the researcher (See Appendices B-H). The researcher-created worksheets were formatted in a word processer using a similar font as the TouchMath curriculum and contained numerals with TouchPoints that were needed for criterion data collection and for introducing and implementing the faded TouchPoints. Visuals and manipulatives for the intervention sessions included: *Magnetic 3D Numerals* and *Student Number Cards* provided by the TouchMath company. Additional materials included: pencils, counters, verbal praise and tangible rewards for positive behavioral supports, and a computer for tracking data.

Procedure

Participants that met the inclusion criteria each worked in a one-on-one session with the researcher three times per week for five consecutive weeks. To obtain a stable trend of data points during baseline, MIND probes were administered prior to the intervention phases. Participants were asked to complete each probe within a two-minute time frame and were scored for digits correct per minute and percent of digits correct per digits attempted.

Practice worksheets and manipulatives were used during each intervention session to introduce the TouchPoints and new concepts (See Appendix B). At the beginning of each session, each participant independently completed a “cold probe” to monitor between-session growth., and a “hot probe” was also given post-session to measure within-session growth. Each probe was obtained from the MIND website and was identical in procedures to the baseline assessment. For sessions two through seven, data were collected to determine if the participant met the criterion of 80% concept mastery to move on to the next session. Once the TouchPoints were introduced at the conclusion of session two, students reviewed the TouchPoints before learning the next concept in each session with visuals and manipulatives, such as the *Student Number Cards*.

All intervention session procedures were derived from the TouchMath program. Session five involved the generalizability component, which was added to the curriculum for this study, termed faded TouchPoints, to aid in gradually fading out the need for TouchPoints represented on the numbers in the problem. The term imaginary TouchPoints was also developed for this study and is not a term associated with the TouchMath curriculum. Finally, in sessions four and five, the directions to “circle the largest number” was added to the curriculum to emphasize the importance of identifying the largest integer to apply the counting on strategy.

Throughout the sessions, participants were given positive reinforcement for exhibiting on-task behaviors (e.g., actively engaging in task, following directions). Immediate feedback and verbal praise (i.e., “nice job, good working”) were offered during the learning and practice intervals based on on-task behaviors. Tangible rewards including edibles and/or toys from a treasure box were given to participants at the end of each session. Feedback was not provided during or after the two-minute progress monitoring probes. The least-to-most hierarchy prompting system was utilized during the learning and practice sessions. Each prompting level ranged from the unassisted independent level to sequenced levels ranging from minimum to maximum amounts of prompting (Neitzel & Wolery, 2009). Participants were first asked to complete the task with a verbal prompt. Then visuals from the TouchMath *Student Number Cards* were offered for more assistance. If further prompting was required, the researcher would then model the task to be completed. Finally, if the participant continued to require prompting, physical hand-over-hand prompting was utilized (Neitzel & Wolery, 2009).

Intervention sessions proceeded as follows:

Session 1 - Teaching the TouchPoints 1-5

A cold probe was administered at the beginning of the session. Participants first became acquainted with the single TouchPoints for each numeral 1-5 by touching and counting the TouchPoints by first placing counters on the manipulative placement worksheets from the TouchMath program. Then, *Magnetic 3D Numerals* manipulatives, provided by the TouchMath program, were used during this session. Participants then practiced touching and counting each TouchPoint on the practice worksheet (See Appendices B-D). At the end of the session, a hot probe was administered.

Session 2 - Teaching the TouchPoints 6-9

A cold probe and criterion assessment were administered at the beginning of session two. Participants meeting the 80% criterion proceeded to the second session and became acquainted with the double TouchPoints for each numeral 6-9 by touching and counting the TouchPoints. Similar worksheets and manipulatives from session one were used to practice the double touch concept. Participants then practiced touching and counting each TouchPoint on the practice worksheet (See Appendices E-G). Last, participants completed a hot probe for progress monitoring.

Session 3 – Counting ALL – Single-digit plus Single-digit Addition Problems

A cold probe and criterion assessment were administered at the beginning of session three. Participants meeting the 80% criterion were introduced to the counting all strategy by counting all TouchPoints for single-digit plus single-digit addition problems to form single-digit and double-digit sums. Participants first practiced with the *Magnetic 3D Numerals* and then completed a practice worksheet (See Appendices H-I). The session concluded with a hot probe for progress monitoring.

Session 4 – Counting ON with TouchPoints

A cold probe and criterion assessment were administered at the beginning of session four. Participants meeting the 80% criterion were introduced to the counting on strategy with the use of TouchPoints. Then, participants were asked to identify and circle the largest numeral in the problem. To solve the addition problem, participants said the name of the numeral they circled and then continued to count on with TouchPoints on the lowest numeral. (See Appendices J-K). Participants were then administered a hot probe.

Session 5 – Counting ON with Faded TouchPoints

A cold probe and criterion assessment were administered at the beginning of session five. Participants meeting 80% from the previous intervention session were asked to identify and circle the largest numeral in the problem and then continue to count on with the faded TouchPoints for the first part of the practice worksheet. During the second part of the session, students simply identified and said the largest numeral and continued counting the faded TouchPoints on the lowest numeral to aide in the generalization in identifying the largest numeral (See Appendices L-M). Participants were then administered a hot probe.

Session 6 – Counting ON Strategy without TouchPoints

A cold probe and criterion assessment were administered at the beginning of session six. Participants meeting the 80% criterion were asked to identify the largest number in a problem and use their "imaginary" TouchPoints to continue counting and solve the problem without using TouchPoints (See Appendices N-O). The session concluded with a hot probe.

Session 7 – Generalization Assessment

Criterion assessment probes were administered at the beginning of session seven. Participants meeting the 80% criterion were given a generalization assessment without TouchPoints, similar to the baseline assessment (See Appendix P).

Research Design

A multiple-probe design was used to determine the effectiveness of the TouchMath program for students with ASD for addition problems with single-digit plus single-digit problems to form single-digit and double-digit sums. A multiple-probe design is a combination of the techniques of probe procedures and multiple-baseline (Horner & Baer, 1978). Versions of multiple-baseline and multiple-probe designs allow for replication of a condition across multiple participants with staggered implementation across subjects and account for practice effects (Riley-Tillman & Burns, 2009). Instead of collecting data simultaneously for all participants throughout baseline, as in a multiple-baseline design, the multiple-probe design intermittently collects baseline data with probes to determine the performance level of each participant (Cooper, Heron, & Heward, 2014).

The multiple-probe design consists of phase A (baseline) and phase B (intervention). During phase A, data are collected for all participants under the same conditions until stability within the data is reached. Once baseline data are stable, the intervention phase B is introduced to the first participant and continues until stability is reached again for the phase B data (Riley-Tillman et al., 2009). In addition to the primary phases, the current study also included a third phase, C (generalization).

Due to time constraints related to the end of the school year, stabilized data during phase B was unattainable and only two consecutive sessions were concluded for each participant before the next participant entered phase B. Participants began the intervention phase B once a stable baseline was established and an A-B pattern continued for all participants until they completed intervention sessions 1-6. The generalization session, phase C, consisted of the assessment in session seven to determine if the participants were able to maintain accurate and stable responses of single-digit plus single-digit problems forming single-digit and double-digit sums without visual TouchPoints.

When utilizing forms of multiple-probe designs, it is critical for all participants to display similar characteristics of academic and behavioral functioning (Riley-Tillman et al., 2009). This was considered when selecting participants for the study. Experimental control occurs when three demonstrations of effect are observed. For multiple-probe designs and variants, this can occur when effects are replicated across at least three participants. Stronger experimental control can be achieved by involving more participants, allowing for greater opportunities for replication. A minimum of three participants are required for multiple-probe design studies (Riley-Tillman et al., 2009).

Statistical analysis

Data were analyzed using visual analysis of changes in level, trend, variability, and percentage of nonoverlapping data (PND) of digits correct per minute (DC/PM) between phases. PND is found by calculating the percentage of data points in Phase B (intervention) that exceed the highest data point in Phase A (baseline; Parker, Vannest, & Davis, 2011). This percentage was used to estimate the effect size of the intervention. An effect size of 80% and greater is considered large (Scruggs & Mastropieri, 1998).

DC/PM served as a dependent variable and was calculated by dividing the number of correct digits divided by the total amount of time (2 min; Shinn, 1989). For example: in the problem 2 + 9, a participant who answers 11 would have two digits correct. If they had responded 12, the digits in the ones column would be incorrect, whereas the digit in the tens column would be considered correct (Deno & Mirkin, 1977). An increase in the total number of correct digits per minute indicate improved skill fluency. For students in grades 4-6 solving addition problems, 24 – 49 DC/PM is considered to be within the instructional level, and less than 24 DC/PM would indicate a need for academic intervention (Burns, VanDerHeyden, & Jiban, 2006). Hence, this study will refer to 23 or fewer DC/PM as being in the frustrational range, 24 - 49 DC/PM as being in the instructional range, and 50 or more DC/PM as being in the mastery range. Due to student response patterns, the percentage of digits correct for assessment probes was also calculated as a dependent variable to observe possible changes in accurate responding.

Inter-rater reliability was conducted for 25% of the intervention sessions. Staff from the local school districts completed an observation checklist for treatment integrity (See Appendix Q). A total of five sessions were conducted (one with Anna, one with Sam, and three with John) for observation inter-reliability.   All observation checklists resulted in 100% agreement. The probe assessments from all sessions were also scored by a second rater to calculate inter-rater reliability. Twenty-five percent of the assessment probes, three from each participant, were chosen randomly for inter-rater reliability in which scores for DC/PM were compared for accuracy. All assessment probes resulted in 100% agreement between the researcher and the second rater.

CHAPTER 4

Results

During baseline, Anna demonstrated stable responding for three consecutive sessions and her performance was within the frustrational level for fluency (*M* = 18.1; range = 18 to 18.5 DC/PM; see Figure 1). While in the intervention phase, Anna's responding on both cold and hot probes remained stable across all sessions with no change in variability (*M* = 17.0; range = 11 to 22.5). Her intervention data showed a slight increase in level and trend from the baseline phase (PND = 33% for cold probe; 50% for hot probe). Similar patterns of responding were observed during the generalization phase (*M* = 18.6; range = 14 to 26; PND = 40%). Throughout the study, Anna maintained accuracy of 100% for all sessions (see Figure 2).

Sam's baseline data showed some instability in responding, requiring the need for an additional session. Baseline data indicated Sam performed at the instructional level for fluency (*M* = 37.3; range = 30.5 to 42.0). During the intervention phase, Sam's performance on the cold probes remained stable throughout all sessions (*M* = 36.7; range = 28.0 to 43.0). He also demonstrated minimal changes in level, trend, or variability from the baseline phase (PND = 17% for cold probe). However, his hot probes indicated a negative effect on his level of responding (*M* = 12.8; range= 9.5 to 17; PND = 0%). Sam demonstrated a similar pattern throughout the generalization phase (*M* = 25.4; range

= 19 to 37; PND = 0%). For accuracy, Sam maintained sufficient accuracy, greater than 95%, throughout all phases.

John performed at the frustrational level during all phases. While in baseline, John maintained stable responding (*M* = .67 DC/PM; range = 0.50 to 1.00). During the intervention phase, John's responding on the cold and hot probes varied over the six sessions with no change in level (*M* = 2.29 DC/PM; range = 1 to 3.5). His intervention data showed an increase in trend with variable levels of responding from the baseline phase (PND = 100%). The time allotted with John for data collection only consisted of five weeks and due to end of year time constraints, only one session was available to collect data for generalization. John showed a decrease in data during the generalization phase with results similar to baseline patterns (*M* = 0.50; range = 0.50; PND = 0%). Throughout the entire study, John showed extremely variable rates of accuracy. During baseline, accuracy ranged from 14 to 33% and during the intervention phase he scored between 36 - 70%.

Figure 1

Fluency – Digits Correct per Minute

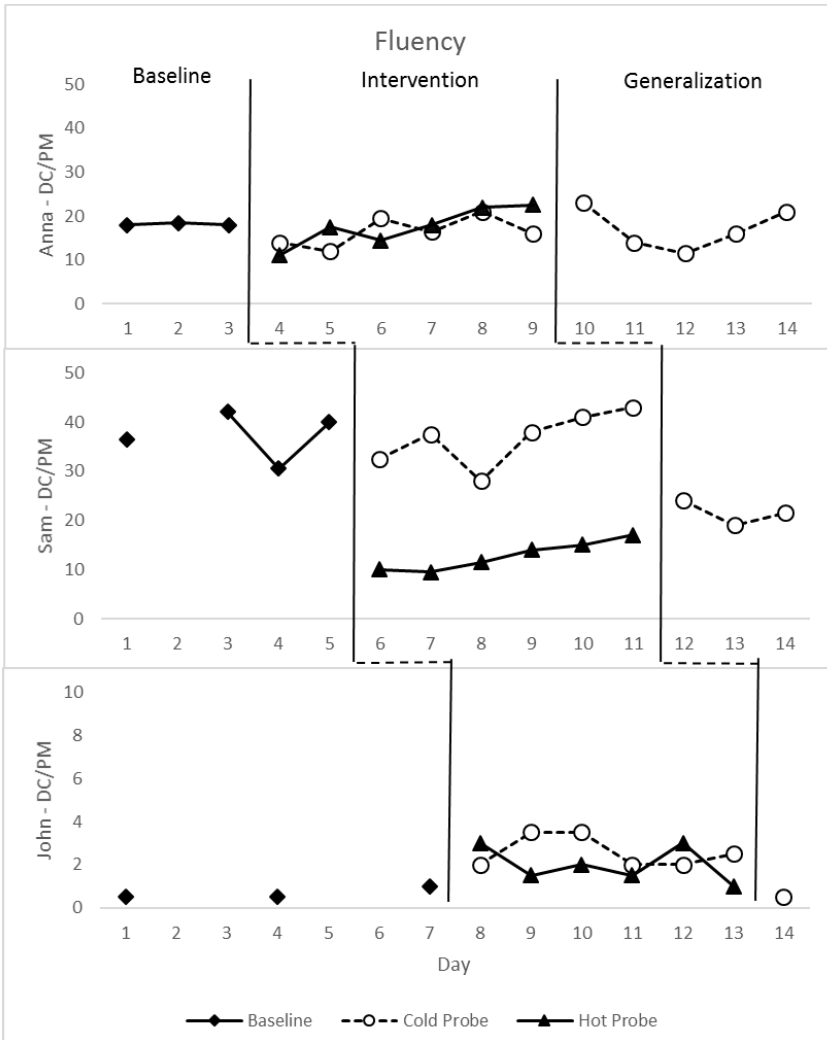
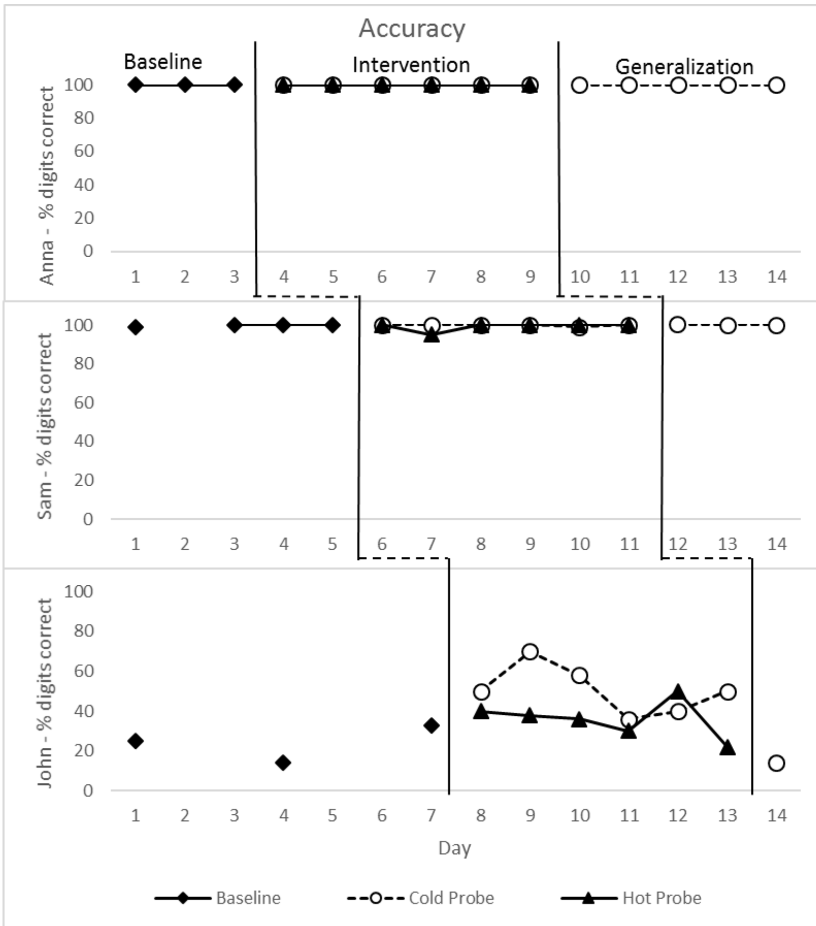


Figure 2

Accuracy – Percent Digits Correct



When assessing the effectiveness of the TouchMath intervention by comparing baseline and intervention phase data, PND effect sizes are classified as follows: very effective (scores above 90), effective (70-90), questionable (50-70), ineffective (below 50; Scruggs & Mastropieri, 1998). Johns' PND for fluency between the baseline and intervention phases fell in the very effective range with a score of 100% for cold probes, while Anna's and Sam's were in the ineffective range with a score of 33% and 13%, respectively. For accuracy, John exhibited a PND of 100% for cold probes, which is in the very effective range. The PND scores for both Anna and Sam were in the ineffective range with 0%. Both participants maintained stable accuracy of 95% or greater for all phases.

Participants provided a generally positive review of the intervention on a social validity questionnaire (See Appendix R). The questionnaire consisted of six questions and were measured using a Likert-type scale ranging from 1 *(strongly disagree)* to 6 *(strongly agree*). Participants scored 83% of the items as a 4 or a 5. They expressed they liked the study, thought the study was helpful, and that they would continue to use TouchMath over other strategies they had learned in the past. In contrast, participants did not agree that the TouchMath strategies were easy to use or that they improved their math calculation skill when using TouchMath strategies.

CHAPTER 5

Discussion

Researchers have found the TouchMath curriculum to be an effective intervention at increasing the math accuracy and fluency of students in general and special education. Four studies found in the literature pertained to students with ASD, all of which found TouchMath to be an effective intervention for students with ASD (Berry, 2009; Cihak & Foust, 2008; Fletcher, Boon, & Cihak, 2010; Yıkmış, 2016). The purpose of this study was to add to the limited TouchMath literature by focusing on single-digit plus single-digit addition problems and how the intervention can affect math accuracy and fluency for students with ASD. The study also sought to add to the research base by modifying the TouchMath curriculum, wherein faded TouchPoints were used to aid in generalization.

The current study obtained mixed results when comparing participants' baseline and intervention phase data. PND ranged from ineffective to very effective, with the intervention being effective for only one participant. In the beginning of each intervention session, a cold probe was administered to monitor between-session growth, while within-session growth was measured with a hot probe at the conclusion of the session. Anna's PND score for the cold probes, when comparing intervention to baseline, was 33% and Sam's PND was 17%, placing both Ann and Sam's PND in the ineffective range. In contrast, John's PND was 100%, which is in the very effective range.

Prior to intervention, Sam performed in the instructional range, while Anna and John were in the frustrational range. Sam's fluency remained level with baseline in the instructional range. Throughout intervention, Anna was able to perform at higher rates of fluency during intervention for two cold probes; however, she stayed within the frustrational level throughout intervention. John demonstrated the greatest increase in fluency and his PND score was in the very effective range, although his overall fluency remained in the frustrational range. When comparing cold probes to hot probes, Anna's PND score increased while Sam and John's decreased, demonstrating less learning for within-session growth than between-session growth. The difference in scores may have resulted from the use of prior strategies to complete the addition problems during cold probes, despite being reminded by the researcher to use TouchMath. Once the interventions session was complete, the researcher reminded the participants for a second time to use TouchMath, in which Anna and Sam were more compliant to do so.

Due to time constraints, only five days were permitted for Anna to be in the generalization phase, three days for Sam, and only one day for John. Anna primarily used rote memory, with TouchMath as a supplement, during the first generalization session, but then used the TouchMath strategies for the remainder of the generalization sessions. Her fluency rate decreased to below baseline levels, but then gradually began to trend upward towards the end of the study. During the three days of generalization with Sam, his fluency decreased significantly when compared to baseline. John performed below baseline for both accuracy and fluency during the only generalization session that was conducted. Although the data indicate the TouchMath program to be very effective for John during the intervention sessions, all PND scores for all participants fell within the ineffective range for the generalization sessions indicating they were unable to transfer the skill to novel problems.

Treatment integrity was compromised throughout the study as participants continued to use previously learned strategies during assessment probes, despite being repeatedly encouraged by the researcher to use the TouchMath strategies. Although treatment procedures were implemented by the researcher with 100% fidelity, the observation checklist did not consider the use of other types of strategies used by the participants. Anna continued to use rote memory for problems she was confident about but used the TouchMath counting on strategy for items that she could not recall the answer. Sam used rote memory for the cold probes but used the TouchMath strategies during the intervention hot probes. During hot probes, Sam's fluency dropped into the frustrational level, indicating the TouchMath strategies had a negative effect on his fluency rate. Although John was able to use the TouchMath strategies correctly during intervention practice, he still reverted back to using a 100's chart for cold and hot probes during intervention. When the researcher encouraged John to utilize the TouchMath strategies, he quickly voiced that he could not do it and began showing physical signs of frustration. Due to adherence to IRB procedures and the ethical duty of the researcher to prevent any participant from having adverse consequences as a result of being in the study, John was allowed to use his previously learned method during assessment probes.

It was not until after practicing the TouchMath strategies without visible TouchPoints in session six, that he agreed to try the hot probe with the TouchMath strategy of counting all. All participants were able to perform the generalization assessments probes using only the TouchMath strategies.

King et al. 2016 addressed the dearth of research for effective math interventions that exists with the population used in the current study. Many of the reasons for why there is a limited research base for students with autism were also encountered in this study. Issues involved during the study included: inclusion/exclusion criteria that affects the limited available research samples and the willingness of the participants to participate and adhere to procedures that are needed for adequate research to be conducted.

TouchMath is an acquisition intervention, which requires time and multiple opportunities to practice the new skills. Another limitation to this study was the limited amount of time that was available for the researcher to work with the participants. In previous studies performed with students with ASD involving TouchMath, one study was conducted over a two-year period (Berry, 2009) and the other study had participants remain in intervention between 7 - 21 days (Yıkmış, 2016). Only five weeks were available for data collection because it was the end of the school year. Three weeks were needed to successfully complete the baseline and intervention sessions. The study required at least three days to collect baseline data and six consecutive days to complete six sessions of intervention for each participant. Unfortunately, the time constraints did not allow for each participant to demonstrate growth during the intervention phase. While all participants met each intervention session criteria and successfully demonstrated understanding and application of the TouchMath strategies during each intervention session, they showed little-to-no growth during the intervention and generalization phases for accuracy and fluency. Avant et al. (2011) and Newman (1994) conducted a study using a multiple-probe design to see how TouchMath can affect student's accuracy with addition problems. Both studies utilized 2-3 days of pre-training sessions between baseline and intervention in which participants were taught the TouchMath strategies prior to collecting intervention data. The current study required six days of instruction, due to an additional session added to include "faded" TouchPoints, all of which occurred during intervention. By performing pre-training sessions, the amount of time needed to complete the intervention session can be reduced by half, allowing more time for each participant to demonstrate growth. However, these pre-training sessions should still be considered when determining one's rate of improvement.

Another limitation of the study was the limited population sample available. Eight rural East Texas school districts were approached for potential participants, and only five students with ASD were available for recruitment. All five participants varied in abilities from severe to mild levels of ASD and only three students qualified for the study. A key element when using a multiple-probe design is for participants to demonstrate similar behavioral and academic functioning (Riley-Tillman et al., 2009). While Anna and Sam displayed similar abilities, John demonstrated much lower academic and behavioral functioning. Throughout the study, Anna and Sam were able to follow directions from the researcher very well, transitioned from one session to the next with ease, and worked diligently with little prompting to complete the math problems. John, however, struggled to remain on-task without frequent reminders and required more prompts from the researcher. At times, the length of the practice worksheets seemed too long, requiring frequent breaks and encouragement from the researcher in order to finish the session. Once John demonstrated understanding the concept being taught, he was unable to generalize that concept to the assessment probe. The intervention procedures were also presented to John at a much faster pace than he was comfortable with. Although he met the 80% criterion on each criterion assessment probe, he still required more supports than the other participants, (i.e., prompts from the researcher for each step in solving the problem with the TouchMath strategies) as the TouchPoints were faded.

Even though the participants' academic and behavioral abilities were not as similar as the design required, the study may provide some insight into the type of student that may benefit the most from TouchMath. While John struggled with performing the TouchMath strategies without the visible TouchPoints, he demonstrated the greatest increase in fluency. Relatedly, Fletcher, Boon, and Cihak (2010) found participants with ASD and moderate intellectual disability who were functioning within the frustrational range benefited more from the TouchMatch curriculum than from use of a number line. Given the pre-existing data coupled with John and Anna's performance, future research should examine whether TouchMath is only beneficial for those students performing in the frustrational range.

An additional limitation that should be considered is Anna and Sam's successful use of rote memory for addition problems. Both Anna and Sam maintained sufficient accuracy, greater than 95%, throughout baseline and the intervention phases with rote memory and TouchMath. During baseline, Sam was performing at an average rate of 37 DC/PM and was considered to be well within the appropriate instructional level for a 5th grade student. During the generalization phase, it took longer for Sam to count the "imaginary" TouchPoints causing a decrease in DC/PM when compared to baseline. This suggests that the TouchMath program is not an effective intervention for those students performing at or above the instructional level. In fact, the use of TouchMath, as an acquisition intervention, may be contraindicated and create learning delays for students already functioning at these levels.

Overall, the current study may have found different results over a greater length of time. Future studies should examine the comparative benefit of TouchMath when accounting for students' instructional levels during baseline. The current study suggests that TouchMath may be beneficial for students in the frustrational range as an acquisition intervention but contraindicated for students within the instructional range. Furthermore, a comparison study between TouchMath and other acquisition interventions (e.g., taped problems, flash cards) is warranted given the available data. In particular, researchers should focus on the rate of learning over time when comparing studies.

In conclusion, the results of this study indicate TouchMath is likely an ineffective strategy for students with ASD. However, given the use of alternate strategies for all participants during intervention, more research is warranted, particularly for students within the frustrational range. Researchers may consider the instructional level of each student prior to implementing the intervention, as students within the frustrational level may show greater improvements than students within the instructional or mastery levels. Students exhibiting lower academic abilities than typically developing peers will likely require more intensive supports over a prolonged period of time. In the current study, only one of three participants demonstrated an increased rate of accuracy and fluency. Although John's data showed the intervention to be very effective, treatment integrity was a limitation throughout the intervention as John also used other problem solving strategies. Therefore, it cannot be determined what the effects of each strategy produced. Future researchers should consider other strategies students have previously learned before implementing the TouchMath strategy and how those learned strategies may affect the intervention.

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Appendix A
Assessment Data

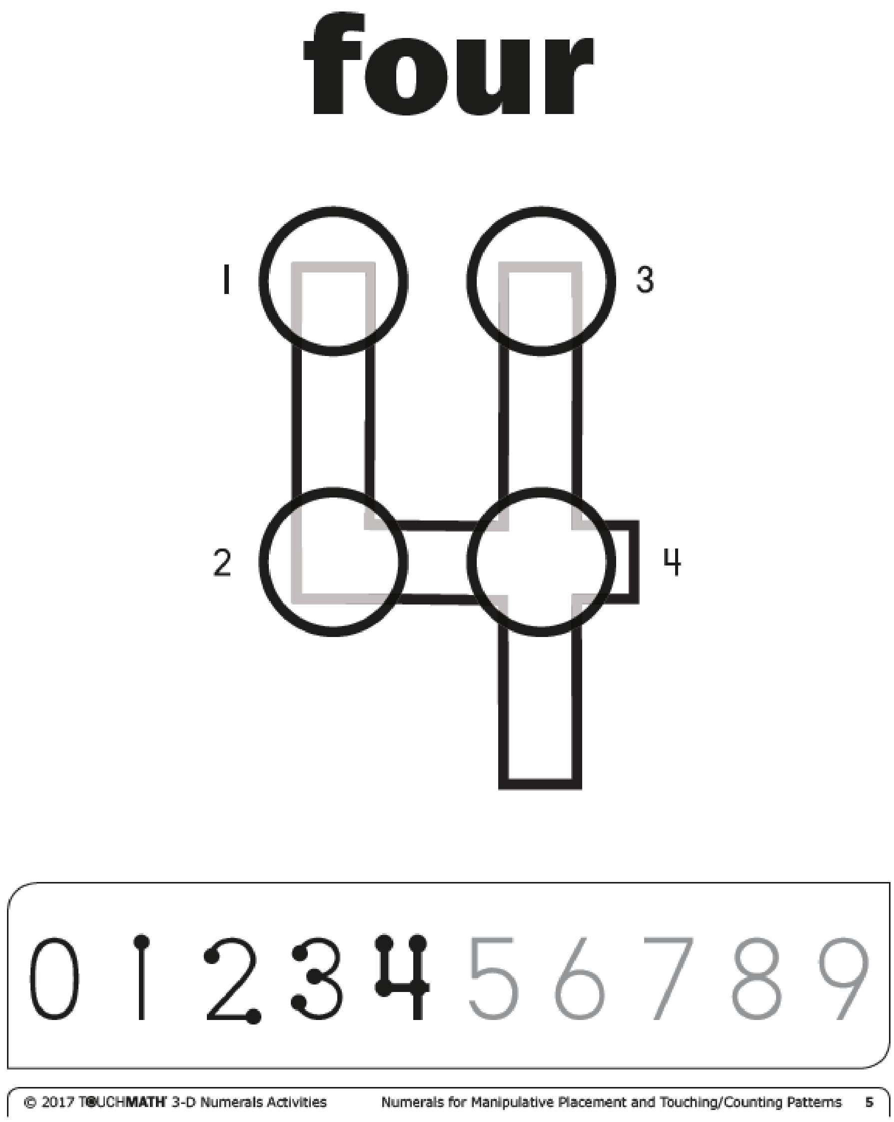
Example:
Addition to 18

Name:________________ Date:___________________

Set	1
Probe	1

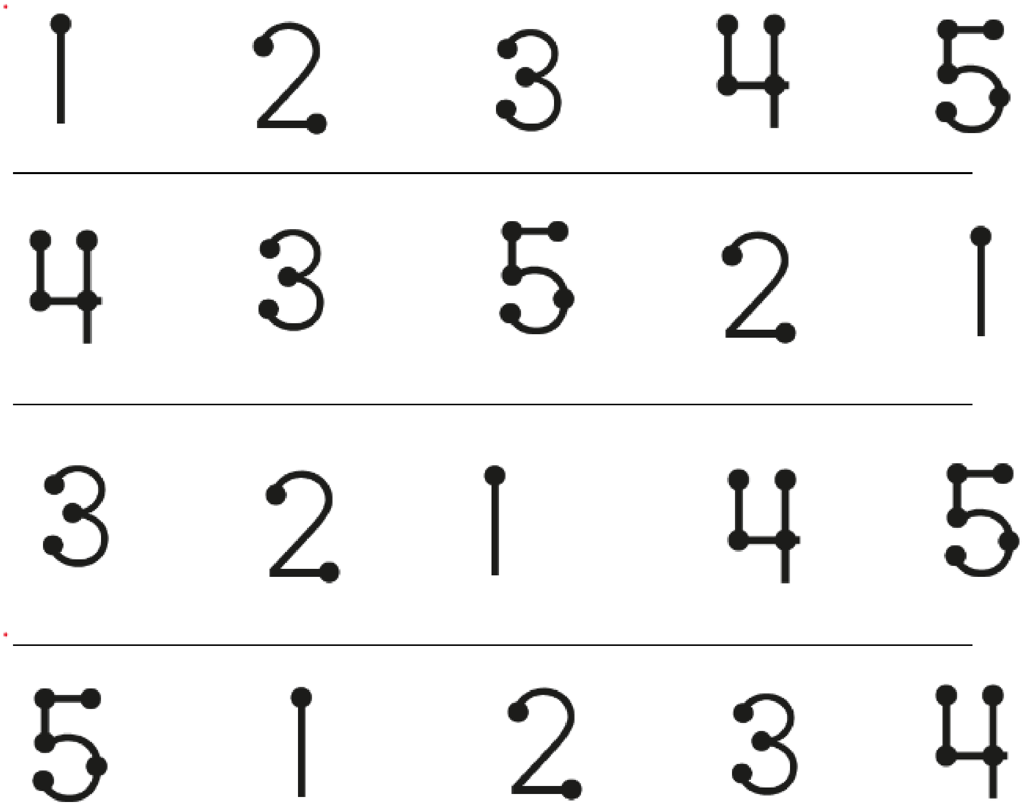
7	7	6	2	9	5	2	9
+ 4	+ 6	+ 9	+ 4	+ 7	+ 5	+ 2	+ 2
2	8	4	3	5	7	9	6
+ 8	+ 8	+ 9	+ 3	+ 2	+ 7	+ 3	+ 6
3	8	7	5	3	6	5	2
+ 7	+ 3	+ 8	+ 3	+ 4	+ 8	+ 7	+ 7
9	6	9	9	4	4	3	6
+ 8	+ 2	+ 9	+ 5	+ 6	+ 4	+ 3	+ 5
8	5	5	3	5	3	4	4
+ 4	+ 8	+ 4	+ 6	+ 5	+ 9	+ 5	+ 3
7	8	6	7	3	8	3	3
+ 5	+ 9	+ 4	+ 7	+ 5	+ 8	+ 3	+ 8
7	5	8	9	5	7	2	4
+ 3	+ 9	+ 7	+ 6	+ 6	+ 9	+ 3	+ 4
9	8	9	2	7	4	6	2
+ 4	+ 2	+ 9	+ 6	+ 2	+ 7	+ 7	+ 9
6	8	4	2	8	6	2	4
+ 6	+ 5	+ 2	+ 5	+ 6	+ 3	+ 2	+ 8

Appendix B
Teaching the TouchPoints 1-5



Appendix C
Practice with TouchPoints 1-5

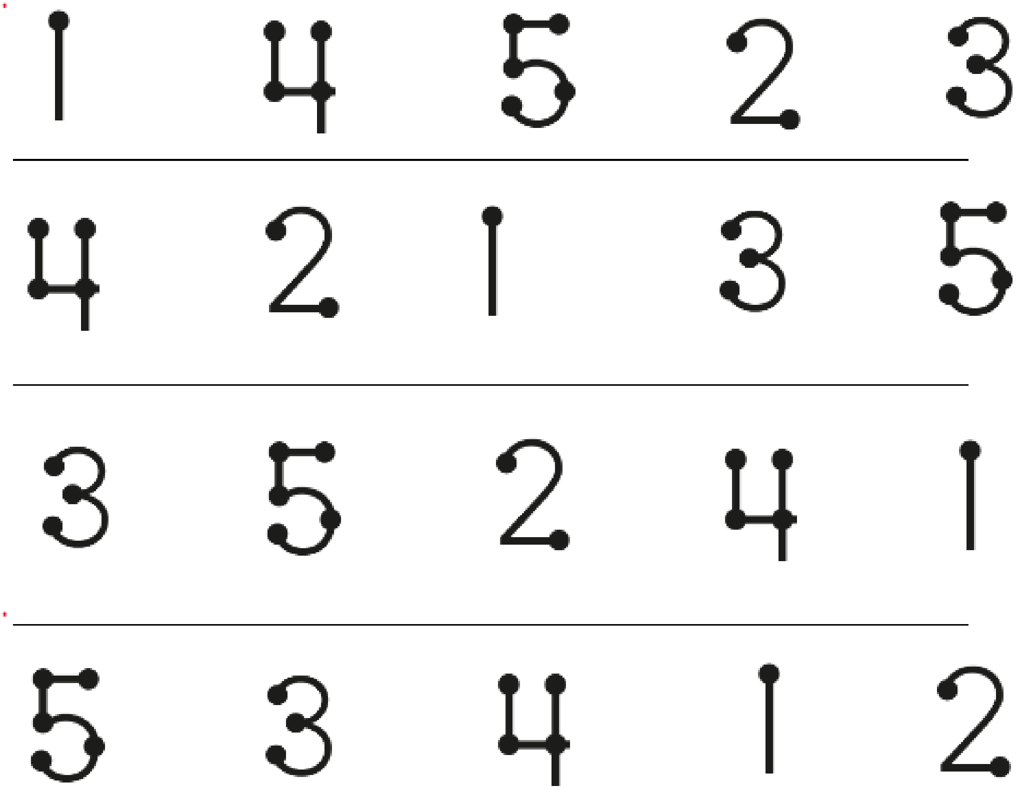
Touch and count the Touchpoints out loud for each number.



Appendix D

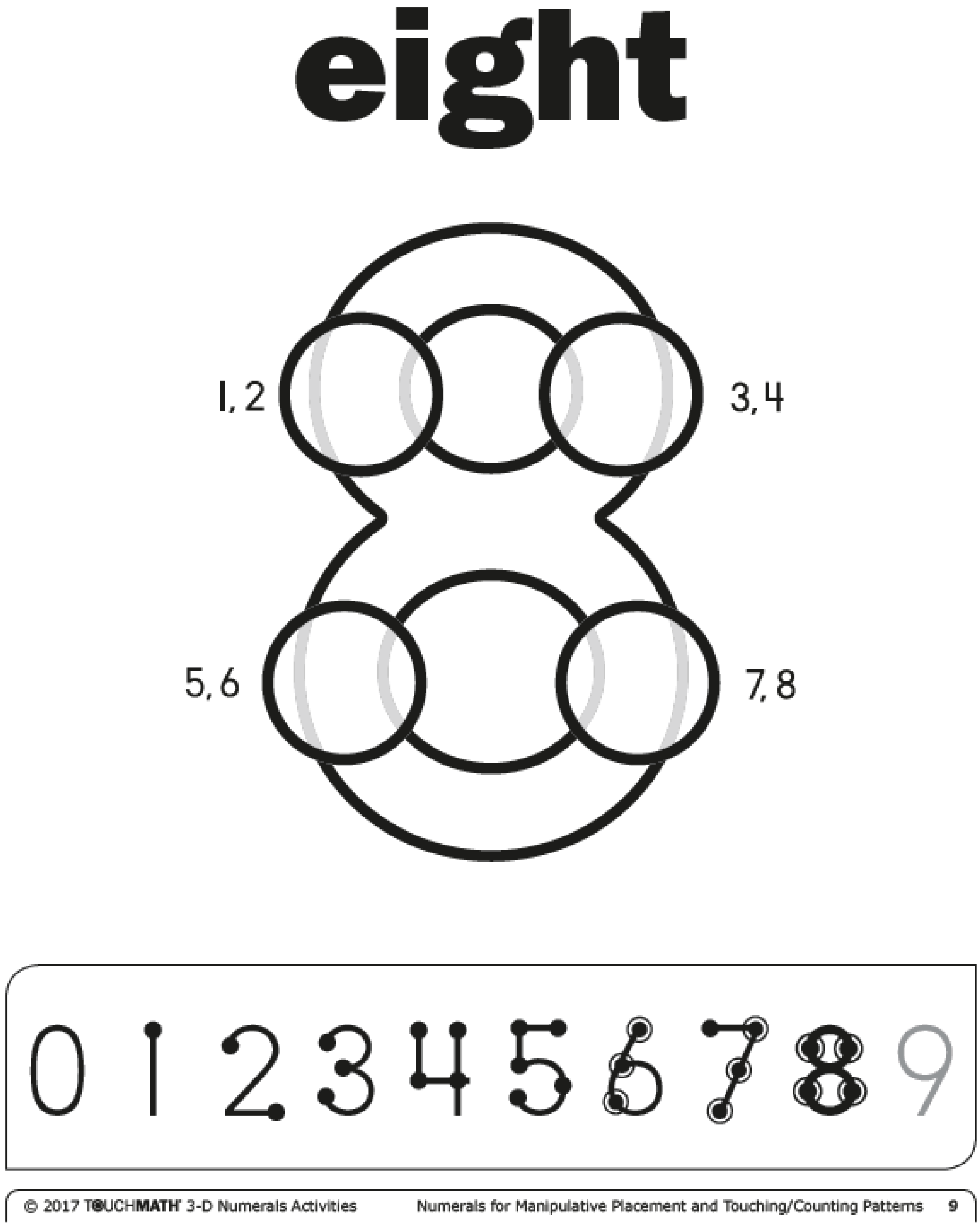
Criterion Data Collection – TouchPoints 1-5

Touch and count the Touchpoints out loud for each number.



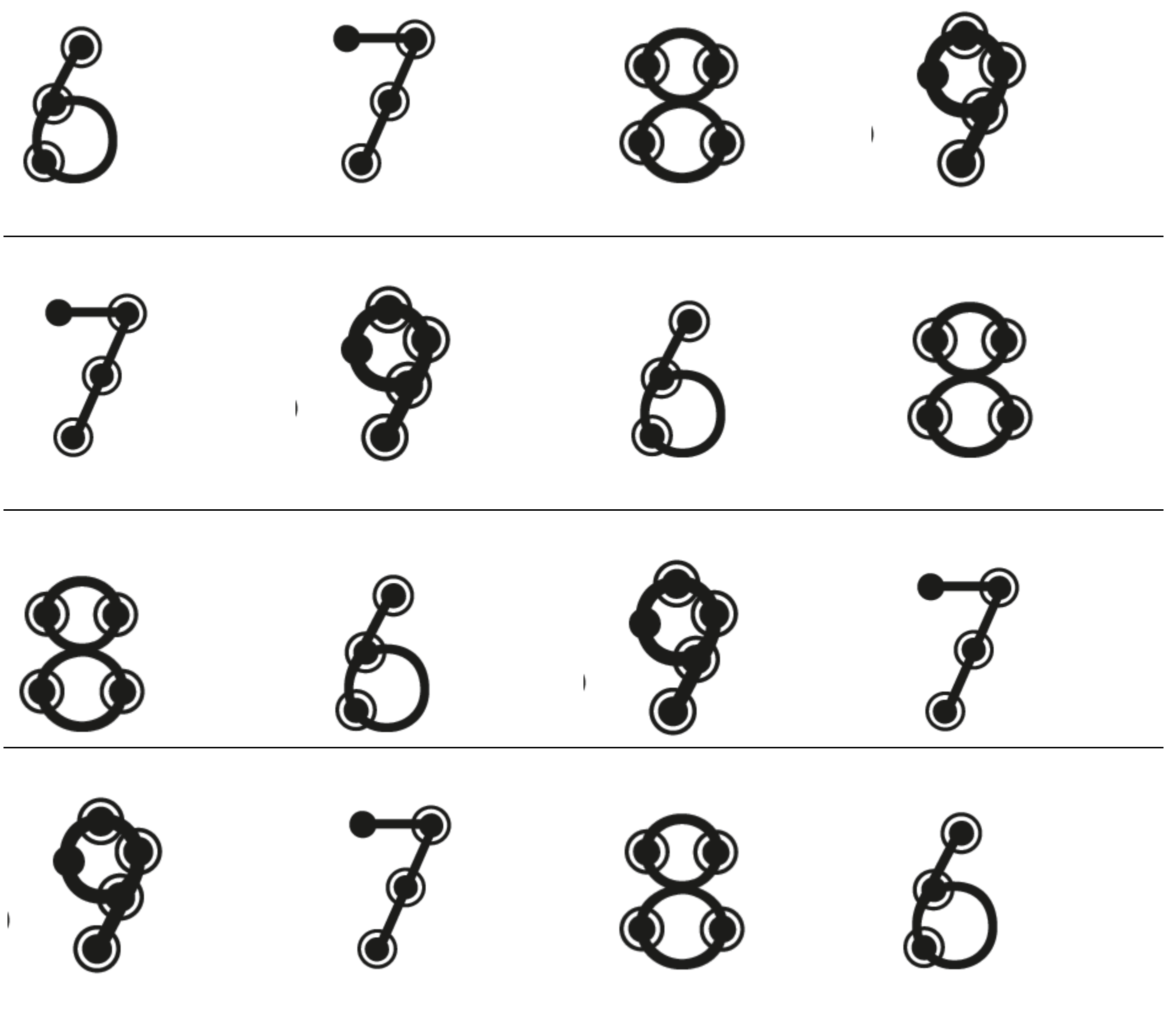
Touch & Count Correct: ______/20 x 100 = _______% correct

Appendix E
Teaching the TouchPoints 6-9



Appendix F
Practice with TouchPoints – 6-9

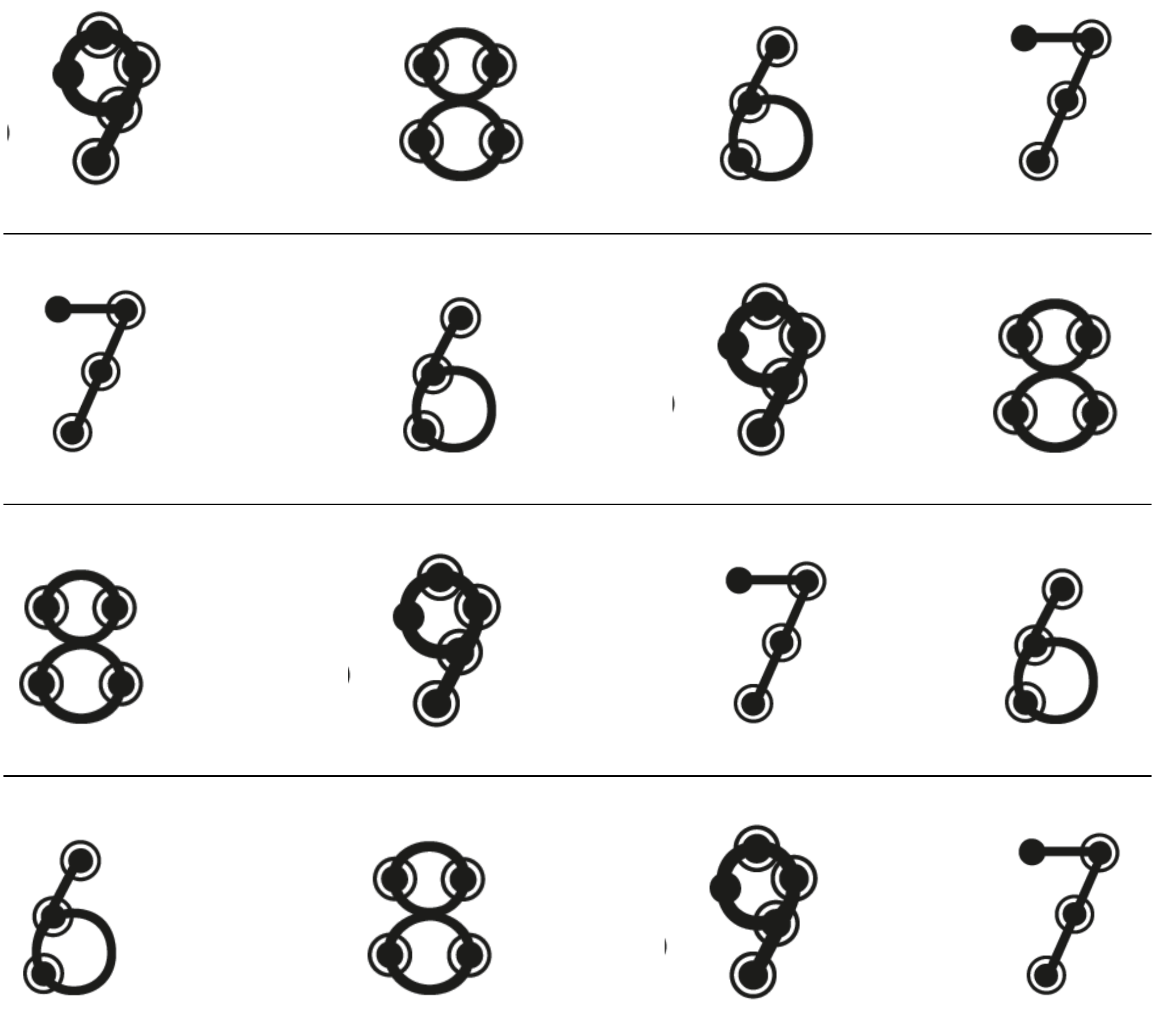
Touch and count the Touchpoints out loud for each number.



Appendix G

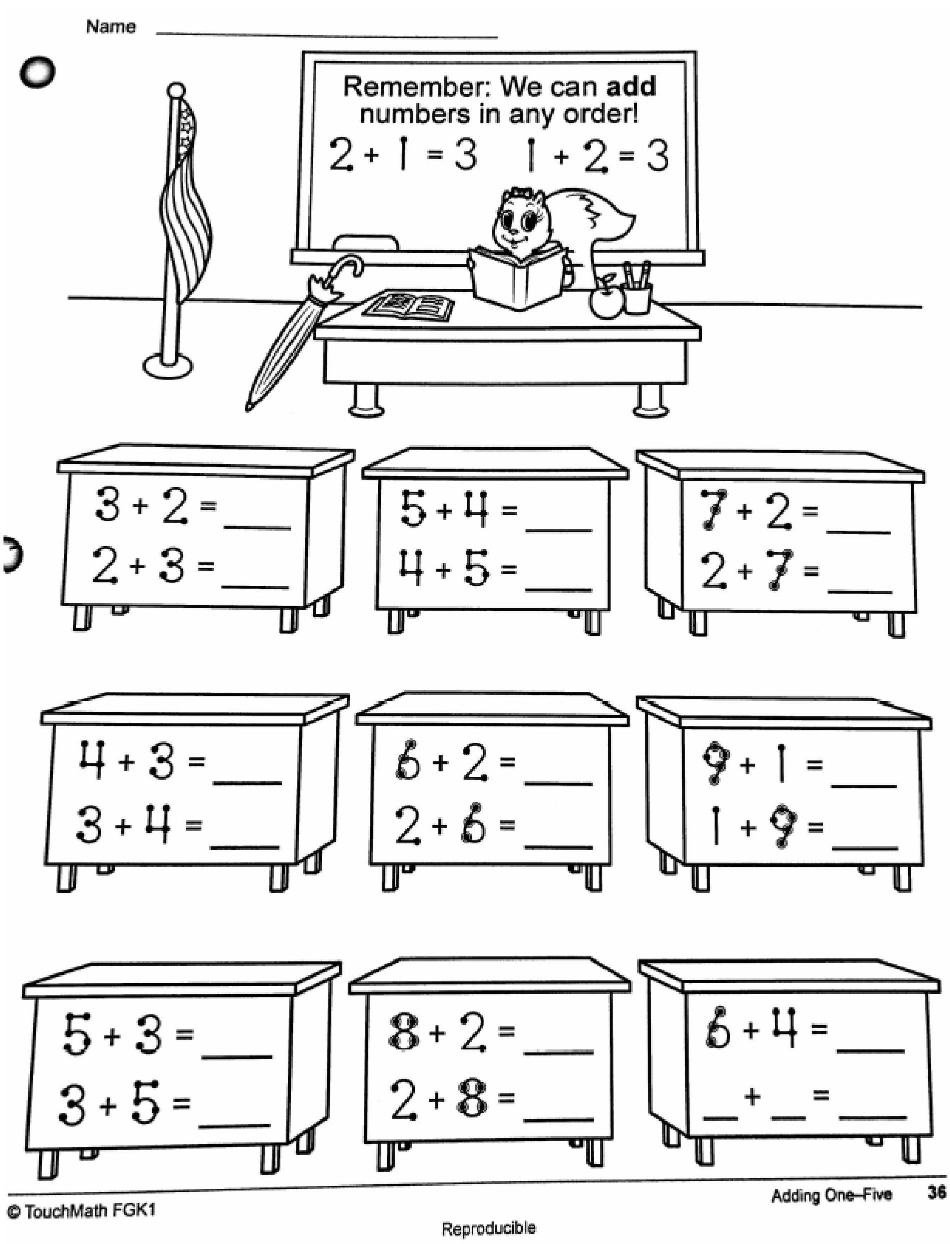
Criterion Data Collection – TouchPoints 6-9

Touch and count the Touchpoints out loud for each number.



Touch & Count Correct: ______/16 x 100 = _______% correct

Appendix H
Counting ALL Practice



Name ______________________

Remember: We can **add** numbers in any order!

2 + 1 = 3   1 + 2 = 3

3 + 2 = ___
2 + 3 = ___

5 + 4 = ___
4 + 5 = ___

7 + 2 = ___
2 + 7 = ___

4 + 3 = ___
3 + 4 = ___

6 + 2 = ___
2 + 6 = ___

9 + 1 = ___
1 + 9 = ___

5 + 3 = ___
3 + 5 = ___

8 + 2 = ___
2 + 8 = ___

6 + 4 = ___
__ + __ = ___

Adding One–Five 36

Appendix I

Criterion Data Collection – Counting ALL

Touch and count ALL TouchPoints to find the sum.

1) 5 + 0 =

2) 6 + 5 =

3) 3 + 8 =

4) 9 + 4 =

5) 6 + 7 =

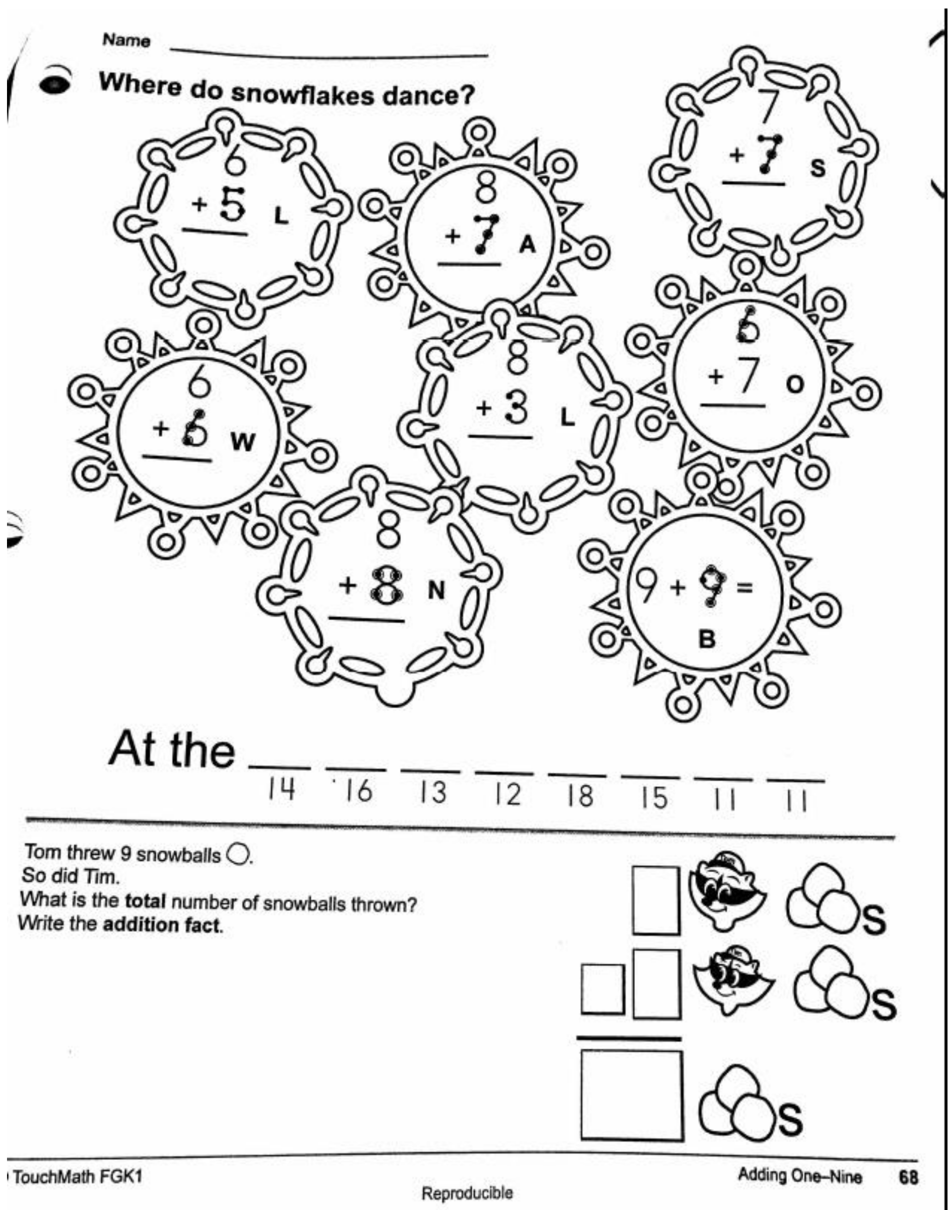
6) 1 + 8 =

7) 2 + 5 =

8) 7 + 3 =

______/8 x 100 = _______% correct

Appendix J
Counting ON Practice



Appendix K
Criterion Data Collection – Counting ON

Circle the largest number and continue counting the TouchPoints to solve the
problem.

1) 4 + 1 =

2) 2 + 3 =

3) 5 + 9 =

4) 8 + 4 =

5) 7 + 5 =

6) 2 + 6 =

7) 5 + 4 =

8) 8 + 6 =

______/8 x 100 = _______% correct

Appendix L
Counting ON with Faded TouchPoints Practice

Circle and SAY the largest number then continue counting the TouchPoints to solve the problem.

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

SAY the largest number then continue counting the TouchPoints to solve the problem.

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

Appendix M

Criterion Data Collection – Counting ON Faded

SAY the largest number then continue counting the TouchPoints to solve the problem.

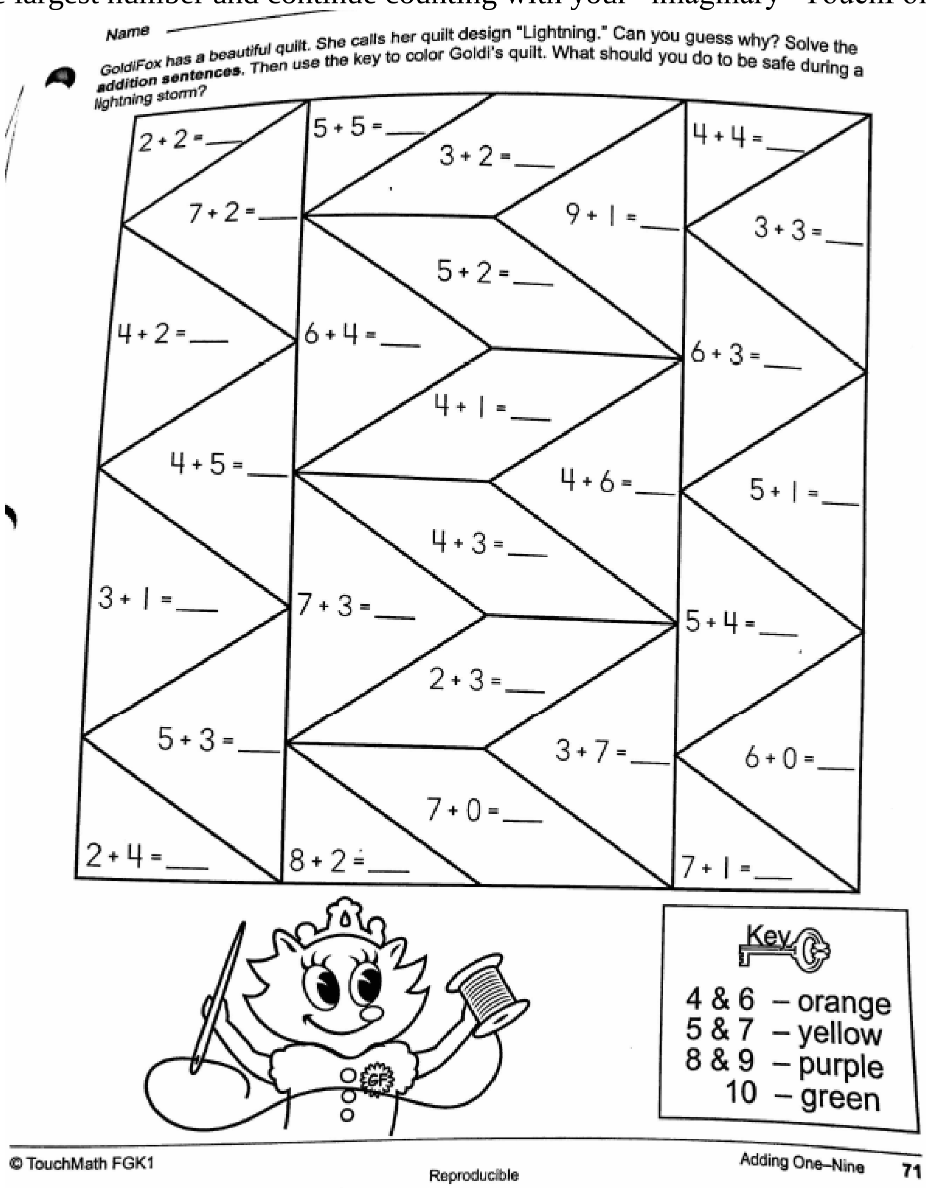
1) 5 + 6 =	2) 1 + 9 =
3) 8 + 4 =	4) 2 + 4 =
5) 7 + 3 =	6) 8 + 7 =
7) 4 + 6 =	8) 7 + 7 =

______/8 x 100 = _______% correct

Appendix N

Counting ON without TouchPoints Practice

SAY the largest number and continue counting with your "imaginary" TouchPoints.


Name

GoldiFox has a beautiful quilt. She calls her quilt design "Lightning." Can you guess why? Solve the **addition sentences**. Then use the key to color Goldi's quilt. What should you do to be safe during a lightning storm?

2 + 2 = ___
5 + 5 = ___
3 + 2 = ___
4 + 4 = ___
7 + 2 = ___
9 + 1 = ___
3 + 3 = ___
5 + 2 = ___
4 + 2 = ___
6 + 4 = ___
6 + 3 = ___
4 + 1 = ___
4 + 5 = ___
4 + 6 = ___
5 + 1 = ___
4 + 3 = ___
3 + 1 = ___
7 + 3 = ___
5 + 4 = ___
2 + 3 = ___
5 + 3 = ___
3 + 7 = ___
6 + 0 = ___
7 + 0 = ___
2 + 4 = ___
8 + 2 = ___
7 + 1 = ___

Key

4 & 6 – orange
5 & 7 – yellow
8 & 9 – purple
10 – green

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Appendix O
Criterion Data Collection – Counting ON without TouchPoints

SAY the largest number and continue counting with your "imaginary" TouchPoints.

1) 2 + 3 =

2) 6 + 8 =

3) 7 + 4 =

4) 9 + 9 =

5) 5 + 1 =

6) 5 + 6 =

7) 3 + 5 =

8) 4 + 8 =

______/8 x 100 = _______% correct

Appendix P
Generalization Assessment

Example:

Addition to 18

Name:________________ Date:___________________

Set	4
Probe	2

8 + 2	6 + 6	4 + 5	4 + 7	4 + 8	6 + 7	9 + 4	4 + 3
7 + 3	8 + 5	3 + 9	8 + 7	9 + 9	5 + 9	6 + 3	5 + 5
8 + 9	4 + 4	3 + 3	5 + 6	2 + 6	2 + 2	2 + 5	2 + 3
4 + 2	8 + 6	7 + 7	8 + 8	2 + 9	3 + 5	7 + 5	7 + 9
7 + 2	3 + 8	9 + 6	6 + 4	6 + 2	5 + 4	6 + 9	8 + 4
5 + 5	9 + 7	9 + 3	3 + 3	2 + 4	9 + 5	5 + 7	8 + 8
7 + 6	3 + 3	3 + 4	6 + 6	4 + 4	4 + 9	9 + 8	2 + 2
9 + 9	2 + 8	7 + 4	3 + 7	6 + 5	7 + 7	5 + 8	4 + 6
2 + 7	5 + 3	5 + 2	3 + 6	6 + 8	9 + 2	7 + 8	8 + 3

Appendix Q
Inter-rater Reliability Checklist

Procedural Checklist for session 1 - Teaching the TouchPoints 1-5		
1	2-minute Progress Monitoring Probe	√
	Participants complete progress monitoring probe with a 2-minute time limit	
2	Introduce TouchPoints with Counters on manipulative worksheets.	√
	- Participants place counters on circles of the worksheet	
	- Participants touch and count the counters out loud	
	- Participants touch and count the TouchPoints at the bottom of the worksheet	
3	Practice Counting TouchPoints on *Magnetic 3D Numerals*	√
	- Participants touch and count the TouchPoints out loud	
4	Practice worksheet	√
	- Participants practice touching and counting the TouchPoints out loud on the practice worksheet	
5	2-minute progress monitoring probe	√
	- Participants complete progress monitoring probe with a 2-minute time limit	

Procedural Checklist for session 2 - Teaching the TouchPoints 6-9		
1	Assessment Probes	√
	- 2-minute Progress Monitoring Probe - Participants complete progress monitoring probe with a 2-minute time limit	
	- Criterion assessment probe	
	- Score of < 80% Repeat Session 1	
	- Score of >80% Continue Session 2	
2	Introduce TouchPoints with Counters on manipulative worksheets.	√
	- Participants place counters on circles of the worksheet	

	- Participants touch and count the counters out loud	
	- Participants touch and count the TouchPoints at the bottom of the worksheet	
3	Practice Counting TouchPoints on *Magnetic 3D Numerals*	√
	- Participants touch and count the TouchPoints out loud	
4	Practice worksheet	√
	- Participants practice touching and counting the TouchPoints out loud on the practice worksheet	
5	2-minute progress monitoring probe	√
	- Participants complete progress monitoring probe with a 2-minute time limit	

Procedural Checklist for session 3 - Counting ALL – Single-digit plus Single-digit Addition Problems		
1	Assessment Probes	√
	- 2-minute Progress Monitoring Probe	
	- Participants complete progress monitoring probe with a 2-minute time limit	
	- Criterion assessment probe	
	- Score of < 80% Repeat Session 2	
	- Score of >80% Continue Session 3	
2	Review TouchPoints	√
	- Participants review TouchPoints on *Student Number Cards*	
3	Introduce Counting All Strategy on *Magnetic 3D Numerals*	√
	- Participants touch and count all TouchPoints out loud on *Magnetic 3D Numerals* for single-digit plus single digit sums (1+3=4; 6+2=8; 3+4=7; 7+2=9; 8+0=8)	
4	Practice worksheet	√
	- Participants practice touching and counting the TouchPoints out loud on the practice worksheet	

5	2-minute progress monitoring probe	√
	- Participants complete progress monitoring probe with a 2-minute time limit	

Procedural Checklist for session 4 - Counting ON with TouchPoints		
1	Assessment Probes	√
	- 2-minute Progress Monitoring Probe	
	- Participants complete progress monitoring probe with a 2-minute time limit	
	- Criterion assessment probe	
	- Score of < 80% Repeat Session 3	
	- Score of >80% Continue Session 4	
2	Review TouchPoints	√
	- Participants review TouchPoints on *Student Number Cards*	
3	Introduce the Counting ON Strategy	√
	- Participants identify and circle largest numeral in the problem	
	- Participants say the name of the number they circled	
	- Participants continue counting the TouchPoints to solve problem	
4	2-minute progress monitoring probe	√
	- Participants complete progress monitoring probe with a 2-minute time limit	

Procedural Checklist for session 5 - Counting ON with Faded TouchPoints		
1	Assessment Probes	√
	- 2-minute Progress Monitoring Probe	
	- Participants complete progress monitoring probe with a 2-minute time limit	
	- Criterion assessment probe	
	- Score of < 80% Repeat Session 4	
	- Score of >80% Continue Session 5	
2	Review TouchPoints	√
	- Participants review TouchPoints on *Student Number Cards*	

3	Practice the Counting ON Strategy with Faded TouchPoints Part 1	√
	- Participants identify and circle largest numeral in the problem	
	- Participants say the name of the number they circled	
	- Participants continue counting the TouchPoints to solve problem	
4	Practice the Counting ON Strategy with Faded TouchPoints Part 2	√
	- Participants identify and say the largest numeral in the problem	
	- Participants continue counting the Faded TouchPoints to solve problem	
5	2-minute progress monitoring probe	√
	- Participants complete progress monitoring probe with a 2-minute time limit	

Procedural Checklist for session 6 - Counting ON Strategy without TouchPoints		
1	Assessment Probes	√
	- 2-minute Progress Monitoring Probe	
	- Participants complete progress monitoring probe with a 2-minute time limit	
	- Criterion assessment probe	
	- Score of < 80% Repeat Session 5	
	- Score of >80% Continue Session 6	
2	Review TouchPoints	√
	- Participants review TouchPoints on *Student Number Cards*	
3	Practice the Counting ON Strategy without TouchPoints	√
	- Participants identify and say the largest numeral in the problem	
	- Participants continue counting the “imaginary” TouchPoints to solve problem	
4	2-minute progress monitoring probe	√
	- Participants complete progress monitoring probe with a 2-minute time limit	

Procedural Checklist for session 7 – Generalization Assessment		
1	Assessment Probes	√
	- 2-minute Progress Monitoring Probe	
	- Participants complete progress monitoring probe with a 2-minute time limit	
	- Criterion assessment probe	
	- Score of < 80% Repeat Session 6	
	- Score of >80% Continue Session 7	
2	Review TouchPoints	√
	- Participants review TouchPoints on *Student Number Cards*	
3	Generalization Assessment	√
	- Participants complete assessment probe with a 2-minute time limit	

Appendix R
Social Validity

Thesis Social Validity Survey for Participants

Participant ____________________ Date____________

For each statement, circle one number that best describes how you feel about the TouchMath intervention study you took part in.

1. I liked the study.

Strongly Disagree					Strongly Agree
1	2	3	4	5	6

2. I was able to understand the directions given by researcher.

Strongly Disagree					Strongly Agree
1	2	3	4	5	6

3. The TouchMath strategies were easy to use.

Strongly Disagree					Strongly Agree
1	2	3	4	5	6

4. I improved my math calculations with TouchMath.

Strongly Disagree					Strongly Agree
1	2	3	4	5	6

5. I will continue to use TouchMath over other strategies I have learned in the past.

Strongly Disagree					Strongly Agree
1	2	3	4	5	6

6. The study was helpful.

Strongly Disagree					Strongly Agree
1	2	3	4	5	6

Comments:____

VITA

April M.Huckaby completed her Bachelor of Science degree at Stephen F. Austin State University in the Spring of 2007. She obtained a teaching certificate and taught high school biology and chemistry for ten years at a rural school district in East Texas. When her oldest son was diagnosed with Autism, she became aware of the struggles that can occur between a special education student and a general education teacher. Mrs. Huckaby realized the importance of supporting not only the students in special education, but also the need to support teachers working with those students. In the fall of 2016, she entered the School Psychology program at Stephen F. Austin State University in hopes of making a greater impact for her students and their families.

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