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Nur Amira Yusaini, Siti Mistima Maat, Roslinda Rosli

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Touch-Point Mathematics Instruction for Children with Autism Spectrum Disorder: A Systematic Literature Review

Nur Amira Yusaini, Siti Mistima Maat, Roslinda Rosli

Faculty of Education, National University of Malaysia

Email: P89375@siswa.ukm.edu.my, sitimistima@ukm.edu.my, roslinda@ukm.edu.my

ABSTRACT

Children with Autism Spectrum Disorder (ASD) often face some problems in mastering basic numeracy skills. A touch point is a multisensory method that has been introduced especially for children with ASD as it is one of a proven way of improving their achievement in mathematics. Thus, this systematic literature review is conducted (a) to identify the characteristics of participants and suitability of touch points interventions based on the characteristics of children with ASD and (b) to evaluate the effectiveness of touch point interventions in improving the achievement of children with ASD. Overall, the empirical studies indicated that the touch point mathematics instruction commonly used in teaching primary school students on basic mathematical knowledge such as numbers and arithmetical operation skills. Hence, the touch point was effective in helping teachers to help children with ASD in learning basic mathematics. Implications are discussed.

Keywords: Autism Spectrum Disorder (Asd), Mathematics Interventions, Numeracy, Hands-On Approach.

INTRODUCTION

Autism Spectrum Disorder (ASD) is defined as a lifelong disability that has been characterized by impairments in communication, social interaction as well as limited and repetitive behaviors and interests (American Psychological Association [APA], 2013). According to Schmidt and Bonds-Raacke (2013), ASD is a type of disorder that includes individuals with autism and Asperger syndrome also extensive of a developmental disorder. Individuals with autism often experienced three types of impairments wherein includes verbal and non-verbal communication, socialization, and distraction to environmental changes (Burney, 2015; McCrimmon & Yule, 2017; O'Malley et al., 2014; Schmidt & Bonds-Raacke, 2013; Su et al., 2012).

The disability of ASD can adversely affect the education performance of children with autism (Burney, 2015; O'Malley et al., 2014; Schmidt & Bonds-Raacke, 2013) which in turn will cause them to be left behind by their peers. The problems that enormously affect children with autism are mastering in basic mathematical skills (Burney, 2015; O'Malley et al., 2014), reading, writing, speaking and also their ability in completing tasks individually (Burton et al.,

2013; Holifield et al., 2010; O'Malley et al., 2014). This education and skills are an essential element for them to live life and to build the foundation for more complex numeracy skills (Jowett et al., 2012; O'Malley et al., 2014). The mastery of basic skills in mathematics is a part of critical skills that can determine the individuals' achievement in mathematics (Royer, 1999). Basic skills in mathematics include number identification, addition, subtraction, multiplication, and division involving single digit number, problem-solving, learning about money and time units (Berry, 2012; Yıkmiş, 2016).

According to Yıkmiş (2016), the addition process involving single-digit numbers and obtaining two digit numbers also known as essential mathematical skill. However, if children's early understanding of mathematical concepts is not well developed, they will have difficulty in understanding the next level of mathematics in primary school. This will lead most of ASD's children with average and inferior intellectual development struggle in order to understand the basic mathematical skills (Burney, 2015) yet showing continuous difficulty in basic calculation and problem solving which in turns give low standards of mathematics achievement (Browder et al., 2012; O'Malley et al., 2014; Spooner et al., 2018).

Numeracy skills for children with ASD

Numeracy can be defined as the efficiency in performing basic mathematical operations and the ability to apply such knowledge in the context of real life (NCTM 2012; KPM 2010). Siti Rahaimah (2014) states numeracy is an essential topic of mathematics in primary and secondary school. Numeracy is the basis for the continuation of mathematical learning at the next level. Apart from that, numeracy is also more geared towards the ability to use mathematical knowledge and skills in solving problems (Asiahwati, 2015; Geary, 2011; Geiger et al., 2013; Jordan et al., 2009; Sarama & Clements, 2008). The significance of numeracy should be given attention to the early stages of learning, especially for the basic skills that the children should be required in mathematics (Siti Rahaimah, 2014).

Therefore, various forms of early mathematical interventions are often carried out to aim in helping the mathematics achievement of children with ASD at all levels and to avoid them having problems in learning mathematics (Shanley et al., 2013). Several practical teaching skills showed to be highly effective for children with ASD. Among them are the delivery of systematic and explicit directions, peer-to-peer learning and visual display (Besler & Kurt, 2016; O'Malley et al., 2014). Besler and Kurt (2016) also point out that one of the most effective teaching methods is to show how the skills are demonstrated. Nevertheless, the rapid adoption of computer-based technology in the classroom today makes concrete materials as teaching aids less used although, for decades, these materials are believed to help students with learning disabilities (Cihak & Foust, 2008; Satsangi et al., 2016). As a result, children with ASD often make writing skills as a challenging skill (Zajic et al., 2016). Still, Burney (2015) and Cihak and Foust (2008) affirmed that students could even develop basic mathematical concepts using concrete materials.

Touchpoints intervention facilitates children with ASD in mastering numeracy skill

Behind the use of rapid technology as a teaching aid tools (Satsangi et al., 2016), more and more studies have been made on new and innovative interventions such as TouchMath programme (Bullock et al., 1989) also known as a touch point. Touchpoint is a multisensory method that involves visual, auditory and tactile learning (Calik & Kargin, 2010) especially for

children with disabilities and had ASD (Calik & Kargin, 2010; Cihak & Foust, 2008; Simon & Hanrahan, 2004; Waters & Boon, 2011).

This method use dot-notation to teach mathematical skills (Cihak & Foust, 2008; Simon & Hanrahan 2004; Waters & Boon 2011) which the children mark the points that appear on the numbers and dots in the circle while looking at the number (visual) and calculate the amount (auditory) using a pencil (tactile). The children are taught to count the points found on each number representing the actual quantity of the number (Berry, 2012; Waters & Boon, 2011) as shown in Figure 1.

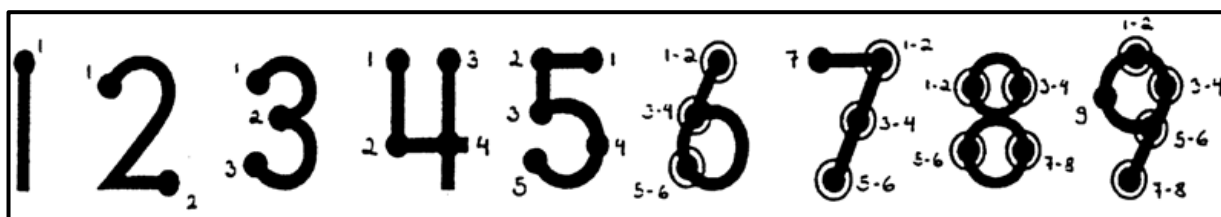


Figure 1. Touchpoints system representation developed by Bullock et al. (1989)

This method has showed a few results with positive effects in improving the student's performance with or without problems in understanding the basic concepts of mathematics (Waters & Boon 2011). It has been proven successful in solving addition and subtraction problems with single digit (Avant & Heller, 2011; Berry, 2012; Cihak & Foust, 2008; Rudolph, 2008; Wisniewski & Smith, 2002) and two digits (Calik & Kargin 2010; Simon & Hanrahan, 2004; Waters & Boon, 2011; Yıkımsı, 2016) specifically for children with ASD who confront with problems in learning basic numeracy skills.

The necessity of early intervention was to address the learning problems they faced. Ping Yee and Mohd Ali (2008) states that one of the purposes of early intervention is to enhance the confidence level of children with ASD to apply basic numeracy skills in everyday life. Therefore, to ensure their basic mathematical knowledge is at the finest level, interventions need to be carried out to ascertain the rationality of teaching methods. Furthermore, the best way to help children with learning disabilities is by using concrete materials (Berry, 2012; Calik & Kargin, 2010; Cihak & Foust, 2008; Simon & Hanrahan, 2004; Yıkımsı, 2016) considering the instructions given with the use of concrete materials as manipulative tools facilitate the children with ASD to understand the concepts of mathematical skills learned. Thus, a touch point is chosen as an intervention as it is a multisensory method that applies to children with ASD.

There are three recent literature syntheses have reviewed on mathematics intervention for the same population. First, Cindy et al. (2016) discussed mathematics intervention that focused on students with ASD and the studies are within the area. Thirty studies for the academic content area that have been published between the year of 1987 and 2015 were included as studies that meet research criteria. Second, King et al. (2016) have reviewed on mathematics intervention studies which also focused on children with ASD and intellectual disabilities involving 14 academic studies that were published around 1988 until 2014. Third, Lemons et al. (2015) have reviewed mathematics intervention for both children and adult with ASD and down syndrome. Lemons et al. (2015) studies involved nine academic studies between the years of 1989 and 2012. This present study is emphasized on the review on mathematics intervention using touch points, determine additional studies, classify touch

points according to the characteristics of the study participants to identify the suitability of interventions and the effectiveness in improving the achievement of children with ASD.

Research questions

The research questions that guided this systematic literature review are: What kind of studies published in journals that engaged touch points intervention to assess children with ASD? Specifically, the aims of this study are:

- (a) to identify the characteristics of participants, findings and suitability of touch point intervention based on the characteristics of children with ASD and;
- (b) to assess the effectiveness of touch point intervention in improving the mathematics achievement of children with ASD.

METHODOLOGY

The method used to conduct this review is PRISMA (*Preferred Reporting Items for Systematic Review and Meta-Analyses*). In short, PRISMA is a form of reporting for systematic review and meta-analysis that focus on reporting survey to assess random trials but also used as a basis for reporting systematic review, particularly for intervention assessment.

Inclusion Criteria

Studies with the following criteria are included: (a) touch point intervention with at least one dependent measure of mathematics-related outcomes is evaluated, (b) involved at least one participant with ASD by assessing the effectiveness of touch point intervention on the experimental group or single-subject design and (c) used an experimental design. The findings with a focus of mathematical accuracy are accepted (e.g., the percentage of correct responses).

Search Procedures

We identified the relevant articles through search procedures consisting of four phases (see Figure 2). Specifically, we conducted (1) electronics database search, (2) a review of recent systematics journals, (3) a hand search of relevant journals and (4) an ancestral search of identified articles.

First, three searches of databases are used, Educational Resources in Education Clearinghouse (ERIC), SAGE Journals dan Google Scholar. The first search used the terms ("autism" OR "autism*") AND ("intervention" OR "mathematics" OR "math" OR "numeracy" OR "arithmetic" OR "addition" OR "subtraction" OR "algebra" OR "count"). While the other search replaced the second set of terms with "Touch-Points" OR "TouchMath" OR "multisensory approach." At this phase, the search is limited to the first ten years of publishing which is from 2008 to 2018. All of the reviewed article journals yield 527 records and 12 articles with full text. Five of these met the inclusion criteria.

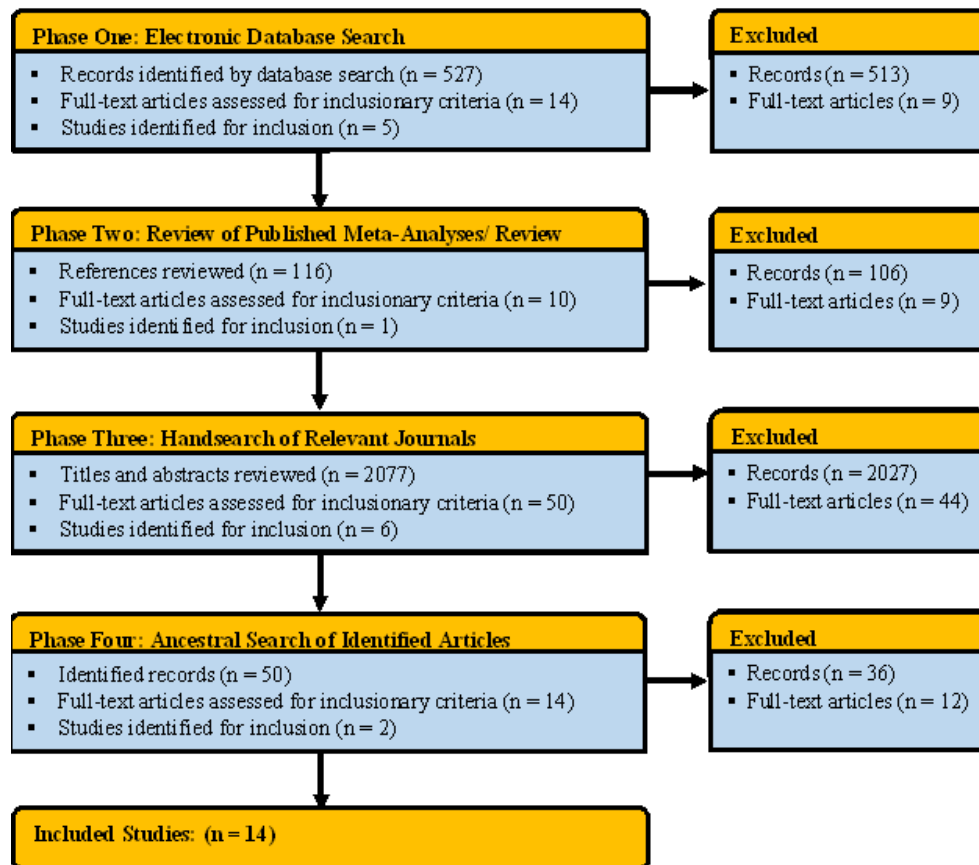


Figure 2 Study identification procedures

Second, the list of seven published recent reviews related to mathematics intervention for children with ASD is reviewed (Aydemir, 2015; Burney, 2015; Cihak & Foust, 2008; Gevarter et al., 2016; Lemons et al., 2015; Spooner et al., 2018; Whalon et al., 2015). From the search of 116 journal articles, ten articles with full text covering technology-based interventions, concrete materials, and touch points methods are chosen. One of these met the inclusion criteria.

Third, a hand search of relevant journal articles according to the year published between 1980 to 2018 is conducted for the following journals: *American Journal of Intellectual and Developmental Disabilities*, *Education and Treatment of Children*, *Developmental Neuropsychology*, *International Journal of Special Education*, *Journal of Intellectual Disability Research*, *Journal of Special Education*, *Exceptional Children*, *Remedial and Special Education*, *Journal on Developmental Disabilities*, *Research and Practice for Person with Severe Disabilities* dan *Research in Developmental Disabilities*. At this stage, the search is broadened to the year of 1980 until 2018. The year 1980 was used because that was the first year autism was a separate diagnostic category in the *Diagnostic and Statistical Manual of Mental Disorder* (Gevarter et al., 2016). The search at this phase yield 2,077 journal articles and 50 articles with full text are identified. Two of these met the inclusion criteria. Fourth, an ancestral search by reviewing the references of articles were identified up to this point of search. From the pursuit of 50 journal articles, 14 articles were identified that focused

on mathematical interventions using the touch point method for children with ASD. All of these nine articles are published between the year of 1983 and 2016 identified for inclusion.

Coding Procedures

The information for each of the study has been categorized based on the variables: participants, setting, instrument, mathematical skills focused and the findings. The coding procedures for participants of the study are based on items: age, gender, ASD level and level of mathematical performance. While the coding procedures for setting include the location of research has been conducted in general (e.g., school) or specific (e.g., classroom in a school) and the intervention situation (e.g., group or study). Instrument encoding includes all manipulative materials used such as touch point worksheets and additional equipment as complementary to convey instructions. Mathematical skills focused are a mathematical skill developed using intervention to improve students' mathematical performance (e.g., addition, subtraction, multiplication, and money). The coding procedures for findings are to measure the mathematical accuracy (e.g., percentages of correct responses).

FINDINGS AND DISCUSSION

In the following section, the discussion of the research findings focused on the previous research that has been included in Table 1 for answering the research question.

Characteristics of participants and suitability of touch point interventions

Fourteen intervention studies using touchpoint have been selected meet the inclusion criteria are between the years of 1983 and 2016 sorted descending by year as shown in Table 1. All of the studies involved 239 participants with ASD with a mean age of 7 (from 5 years old to 9 years old). Among the 14 studies selected, ten journal articles conducted a single-subject design with 41 participants in total (24 males, 17 females) and the rest were held using group experimental design with 198 participants in total. All of these studies with the single-subject design carried out intervention for 15 to 180 minutes individually. While group experimental design was conducting group intervention sessions either with 3 to 4 participants in a group or whole-class involvement. Most of the interventions sessions take place in a class or separate room to prevent any interference.

All the studies used intervention focused on improving the basic mathematical skills of children with ASD on addition and subtraction. Ten studies focused on addition skills in which eight studies (Akmanoglu & Batu, 2004; Avant & Heller, 2011; Calik & Kargin, 2010; Cihak & Foust, 2008; Fletcher et al., 2010; Rudolph, 2008; Wisniewski & Smith, 2002; Yıkmış, 2016) investigated addition with one digit and two studies were in addition with single and double-digits (Simon & Hanrahan, 2004; Strand, 2003). On the other hand, there is a study (Waters & Boon, 2011) used touch points intervention to focus on subtraction skill to learn about money. The remaining three studies focused on both addition and subtraction skills with two studies conducted single digit addition and subtraction (Berry, 2012; Thornton et al., 1983), and one study conducted the single and double-digit addition and subtraction (Scott 1993). Based on the characteristics of the participants involved in this study, it can be seen that the primary school students were the most participants involved. This finding suggested that the touch point method was used in teaching the basic mathematical knowledge to primary school students. However, due to the limited number of high-quality studies, we have not been able to identify the suitability of touch point intervention based on the

characteristics of ASD's children and evaluate the effectiveness of touch point intervention in improving mathematical achievement for them accurately.

Table 1. Descriptions of participants, settings, focused skills, instruments, and findings

Researcher (s)	Participants	Settings	Focused skills	Instruments	Findings
Yikmis (2016)	Three males (8 – 10), diagnosed with ASD.	Intervention held in a class (4 x 3 m) individually. Practitioner and participant sat face to face. There was no other person in the classroom except the practitioner and participant.	Single-digit addition that has a single-digit sum.	A video camera was used to record and worksheets with ten addition questions with touchpoint strategy.	Emrah, Doruk, and Seyit showed a success rate from 0% to 100% at the end of 12 intervention sessions and managed to maintain the performance at the end of 14 sessions.
Berry (2012)	Ten males, diagnosed with ASD.	Intervention sessions held in the class individually. Instructions begin with one to one training areas.	Single-digit addition and subtraction.	Pen, pencil and three worksheets of addition and subtraction problems with touchpoint strategy. Every sheet has the same difficulty level.	8 out of 10 participants showed the ability and effectiveness of using touch-point and able to maintain the performance. 2 out of 10 were not capable of using touchpoint strategy and require calculator as additional support.
Waters & Boon (2011)	Three males (14 - 16), secondary school students, diagnosed with ASD and mild intellectual disabilities.	Intervention sessions held in a special education class (3 x 6.5 m) individually. Teacher and participants are sat face to face during the intervention sessions	Subtraction for the topic of money.	A poster contains numbers 1 to 9 with touch points are used and pasted on the walls for instructions. Worksheets of subtraction problems are used.	The trend showed an increase from 6.66% to 75.55% (increased by 68.88%), Michael showed a rise from 5% to 88% (increased by 83%), and Alex showed an increase from 2.22% to 76% (increased by 73.77%).

Avant & Heller (2011)	Two males and one female (7 – 9), diagnosed with autism and physical disabilities.		Basic addition problems up to 20.	<i>TouchMath</i> number kit produced by the Innovative Learning Concept (Bullock, 1999).	Amy showed an increase from 33% to 100%, Bob showed a rise from 42% to 100%, Connor showed an increase from 17% to 100%.
Fletcher, Boon & Cihak (2010)	Two males and one female (13 – 14), diagnosed with ASD and mild intellectual disabilities.	Intervention sessions held in a self-contained classroom with each of the participants individually.	Addition	Two types of worksheets, A and B with different addition problems but at the same level of difficulty. Worksheet A used a touch point strategy to solve problems. Worksheet B used a number line strategy to solve problems.	Ashley showed 30% of increment using the number line and 98% using the touch point. Robert showed 100% of increase using both number line and touch point. Ken showed 40% of increase using a number line and 100% using the touch point.
Calik & Kargin (2010)	One male and two females (8) diagnosed with ASD and mild physical disabilities.	Intervention sessions held in a classroom at the participant's school. Table and chairs are provided for the teacher and participants. A set of recordings is installed for data collection purposes and intervention reliability.	Basic addition	Worksheets contain a different kind of addition problems at the same level.	At the end of 9 sessions, Participant A showed an increase from 30% to 100%, Participant B showed an increase from 40% to 100%, Participant C showed an increase from 30% to 100%. All of the participants were able to maintain performance until the control sessions were conducted.

Cihak & Foust (2008)	One male and two females (7 – 8), diagnosed with autism and mild intellectual disabilities.	All of the intervention sessions were conducted in a classroom at the school of participants and free from any interruption.	Single-digit basic addition.	Two types of worksheets with touch point and number line strategies for each sheet with different addition problems but at the same level of difficulty.	Travis showed an increase from 2% to 74% after 12 sessions. Ivy showed an increase from 0% to 70% after 12 sessions. Gina showed an increase from 0% to 71% after 16 sessions.
Rudolph (2008)	A whole class with 17 students. 5% with Academically Intellectual Gifted (AIG), 35% are Exceptional Children (EC), 60% are Attention Deficit Hyperactivity Disorder ADHD.	Intervention sessions conducted in a classroom equipped with math manipulative technology and materials.	Basic mathematics addition		Sixteen participants showed up to 25% increment. While 1 participant was not able to use the touch point strategy has decreased by 32%.
Akmanoglu & Batu (2004)	Two males and one female (6 -17), diagnosed with ASD.	Intervention sessions for Omer and Baris held in a classroom at their school. Intervention sessions for Serap held in a school at a university. Each class provided a table and chairs for the practitioner and participants.	Addition	White cards (10 x 15 cm) and black numerals written on the card. Video and stopwatch to control intervention sessions.	Baris showed an increase from 89% to 100%. Omer showed an increase from 84% to 100%. Serap showed 100% of increment.

Simon & Hanrahan (2004)	One male and two females (10), diagnosed with ASD and low intellectual disabilities	Intervention sessions held in a private room on Tuesday, Wednesday and Friday, and free from interruption	Single and double-digits additional problems	Worksheets with 12 single and double-digit addition problems sorted according to the difficulty level.	Participant A showed an increase from 47.2% to 81.9%. Participant B showed an increase from 1.4% to 92.56%. Participant C showed an increase from 74% to 97.2%.
Strand (2003)	Involved two groups of students at the same level, Group I (treatment), Group II (control). Group I consists of 59 students from two schools (A: 37, B: 22). Group II consists of 61 students from the same school.	Intervention sessions held in each class.	Single and double-digit addition	Worksheets were containing 16 math problems with different difficulty levels.	Group I showed the ability to answer additional problems with 80% of correct responses, while Group II showed the ability to solve the additional problems with 40% of correct responses.
Wisniewski & Smith (2002)	Four participants (3 – 4) received special education within 3 to 3 hours and a half daily.	Intervention session held in the participant's classroom.	Addition	A poster contains numbers one to nine with touch point are pasted in front of the class as students' references. Worksheets contain touch-point are used. The video recorder was set to record intervention sessions.	Participant 1 showed an increase of 85% to 100%. Participant 2 showed a decrease of 98% to 95%. Participant 3 showed the same achievement (100%) before and after the intervention. Participant 4 showed an improvement of 23% to 93%.

Scott (1993)	Three participants (8) diagnosed with ASD and mild intellectual disabilities.	Intervention sessions held in a library's class. Each session runs for 2 hours per day.	Single, double and triple digit addition and subtraction.	Twenty-four worksheets (single digit: 8; double-digits: 8; triple-digits: 8), a poster of touch points posted on the wall for participants' references.	Participant 1 showed an increment of 96% within three days of intervention sessions. Participant 2 showed an increase of 100% within two days of intervention sessions. Participant 3 showed an increment of 94% within one day of intervention session.
Thornton, Jones & Toohey (1983)	Sixty-one participants (Grade 2 -6).	Intervention session held in a group of 10 students for each group.	Single-digit addition and subtraction problems.		

The effectiveness of touch points intervention in improving ASD's student mathematical achievement

There are numerous researches on new and innovative interventions such as the TouchMath (Bullock et al., 1989), also known as touch points. Among them are the studies conducted by Avant and Heller (2011), Berry (2012), Calik and Kargin (2010), Cihak and Foust (2008), Rudolph (2008), Simon and Hanrahan (2004), Waters and Boon (2011), Wisniewski and Smith (2002), and Yıkmiş (2016) which aims to examine the effectiveness of touch points intervention for children with ASD in solving fundamental mathematical problems for addition and subtraction topics. These studies showed that touch point techniques were an effective strategy in helping children with ASD to build and improve basic mathematical problem-solving skills. While Rudolph (2008) suggested, touch points intervention continues to be carried out in helping to address the problem of students with low capability in mastering numeracy basis.

The previous studies showed the touch point method have focused on addition and subtraction with one and two digits only. Thus, there has been limited research using the touch point method to develop addition and subtraction for three digits and above. The method also has not been conducted to build multiplication and division skills. With the effectiveness of mathematical intervention using touchpoint method in enhancing the addition and subtraction skills as evidenced Table 1, it is recommended that this touchpoint method should be utilized in multiplication and division too.

CONCLUSION

The purposes of this systematic literature review are to identify the characteristics of participants, findings, and suitability of touch point intervention based on the characteristics of children with ASD. All of the included studies used touchpoint strategy to children with ASD that focused on basic mathematical skills such as one and two digits addition and subtraction. The findings expanded the literature by evaluating the quality of the studies, identifying participants' characteristics, findings and suitability of touch point intervention based on the characteristics of children with ASD. By all counts and with proven research findings, touchpoints method is considered by many educators to have been among the excellent teaching aid to help students in progressing number skills.

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