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Evidence-based practices: using the touch points strategy to teach single-digit addition to students with ASD

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An ever-growing number of students are being diagnosed with Autism Spectrum Disorder (ASD) in Saudi Arabian schools, creating a need for highly effective, research-based strategies for teaching mathematics. However, current research on such strategies is limited. Nevertheless, several studies, including those by Wisniewski and Smith (2002) and Scott (1993), have found the touch-point strategy effective in developing and retaining single-digit addition and mathematical problem-solving skills in students with disabilities, as well as in retaining addition skills among students with ASD. The researchers conducted single-subject research using a reversal design (A-B-A-B) to determine the intervention's effect on three students with ASD as the main data source. Additionally, an interview with the math teacher of these participants was conducted to gather more in-depth data, which helped explore the effectiveness and challenges of using the touch-point strategy in teaching math addition facts to Saudi students with ASD. Significant improvements in computation and acquisition rate were noted among all participants when the strategy was used to solve single-digit addition problems. Two major themes emerged from the analysis of the interview data: the need for resources to teach the strategy and challenges in implementing the touch-point strategy across the whole class, given the individual needs of each student.

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Introduction

The Kingdom of Saudi Arabia is one of the leading countries in adopting modern educational practices for students with ASD and is taking advanced steps toward inclusive education for students receiving special education services. The Kingdom has partnered with organizations such as the Prince Salman Center for Disability Research and the Association for the Care of Children with Disabilities to support special education (Al-Mousa, 2010), as well as the Prince Sultan Bin Abdulaziz Charitable Foundation to assist teachers and share methods for teaching students with special needs. However, there is a need for evidence-based teaching practices, specifically in mathematics, for children with ASD. An evidence-based practice can be defined as an instructional teaching program designed by teachers that leads to positive results for students with disabilities and is supported by empirical research (Mohn, 2010). These students often lag behind their non-disabled peers. One possible reason for the gap between these students and their peers may be linked to the abstract thought processes required for problem-solving in mathematics at the elementary school level.

Mathematics becomes more applied and abstract in elementary school, requiring students to use higher-order thinking skills to solve problems, reason, and think critically. This is essential to understand the relationship between these concepts in the classroom and their real-world applications. Often, learners with ASD face difficulties in comprehending abstract concepts, such as organizing information, using place value, remembering operations, and understanding how to solve word problems. Additionally, many students with ASD have deficits in visual-spatial abilities, leading to challenges in conceptualizing and understanding representations in visual form. According to Mohn (2010), there is a widely recognized close relationship between visual-spatial capability and the conceptual and problem-solving skills needed for higher-level math. Therefore, the inability to perceive objects correctly often leads to difficulties in mathematics. Similarly, due to the organizational and perception problems these learners experience, it can be challenging for instructors in schools and private organizations to effectively teach math to these students. As a result, educators need effective, practical strategies to assist students with ASD (Mohn, 2010).

Research problem

Teaching mathematics to second-grade students with ASD in Saudi Arabia can indeed be challenging and overwhelming. In America, the Individuals with Disabilities Education Act (Smith, 2005) and the No Child Left Behind Act of 2001 (NCLB, 2008) mandate equal access to the general education curriculum and adherence to national and state standards for all students. Similarly, Saudi Arabian legislation, particularly the Regulation of Special Education Programs and Institutes (RESPI), outlines the rights and regulations for students with disabilities, modeled after the IDEA legislation (Alquraini, 2011). These mandates have set a global precedent for educating students with disabilities. All students, including those with ASD, are expected to meet annual yearly progress (AYP) on high-stakes tests and achieve educational standards comparable to their neurotypical peers.

The increasing number of students diagnosed with ASD each year in Saudi Arabia has created an immediate need to find or develop effective educational strategies. Wagner et al. (2003) found that in middle schools, the performance of students with ASD in mathematics is, on average, 5 years behind that of their neurotypical peers. However, reports from the and the National Research Council (2001) indicate a scarcity of evidence-based academic interventions for students with ASD. One of the few strategies found to be effective in the literature is the touch-point strategy.

Wisniewski and Smith (2002) reported that using the touch-point strategy has proven to have a positive impact on promoting the proper solving of single-digit addition problems for students with disabilities. This strategy has also been found effective in helping students with ASD maintain addition skills, as it employs visual aids (Scott, 1993). However, it is not known to what extent teachers use the touch-point strategy to teach math to students with ASD. With the increase in ASD diagnoses in Saudi Arabia, there is a need to explore the extent of its use by special education teachers. Historically, teachers have struggled to find and implement effective math practices with their special education students. Saudi Arabia has begun to widely implement teacher professional development focusing on new research-based teaching practices in both special and general education fields (Planning and Development Agency, 2018). Yet, there is limited research on effective practices specifically designed for teaching math to students with ASD. Scholarly research findings regarding math in special education are often limited to basic pedagogy and individual experiences (Kelly et al., 2016). Considering the increasing number of students with ASD, combined with Vision 2030 and the goal of productive education in Saudi Arabia, a qualitative research design could be identified as an effective way to research teaching math to students with ASD and the use of scientific practices (Alothaim, 2017). There has been an increase in the number of students with ASD receiving tutoring and being admitted to general classrooms, and these students can achieve success when provided with appropriate services (Bandura, 1977).

Research objectives

Using a single-subject design, researchers set out to determine if the touch-point strategy is an effective method for teaching single-digit addition to students with ASD. This was the primary objective of the research. The researchers examined whether customized instruction of math strategies in a small group setting could help students with ASD learn to solve single-digit addition problems more quickly. A secondary objective was to explore one special education teacher's experiences with implementing the touch-point strategy in the classroom.

The research questions were:

1. Does using the touch-point strategy affect the ability of students with ASD to solve single-digit addition problems?
2. Does the touch-point strategy increase the acquisition rate of basic math skills concepts for students with ASD?
3. What are the teacher's perceptions of using the touch-point strategy to teach single-digit addition in an ASD classroom?

Literature review

Vision 2030 is an ambitious plan in the Kingdom of Saudi Arabia (KSA), aiming to improve educational outcomes for all students, including those requiring special services (Planning and Development Agency, 2018). This improvement is to be achieved by modernizing teaching practices. In America, the Individuals with Disabilities Education Act (Smith, 2005) and the No Child Left Behind Act of 2001 (NCLB, 2008) mandate equal access to the general education curriculum and national and state standards for all students. Saudi Arabia has adopted similar legislation. With the increasing number of children diagnosed with ASD, these children are expected to achieve the same educational standards as their neurotypical peers. Therefore, there is a growing emphasis on developing efficient educational strategies for students with ASD. For instance, in middle schools, the performance

of students with ASD in mathematics is, on average, 5 years behind their neurotypical peers (Wagner et al., 2003). This literature review includes the most common studies involved in teaching mathematics to elementary students with ASD and other disabilities.

Elementary age

Number lines and touch points. A strategy used to teach elementary-age children, particularly those with ASD, involves the use of number lines and the touch-point strategy in teaching basic whole numbers, matching of numbers, and addition facts. Number lines aid in providing a visual representation of the number relationships, thus making the computation of mathematical problems easier for students with ASD. The touch-point strategy provides a representational method including drawings and pictures to assist students with ASD in solving addition problems. In this strategy, students are taught single-digit additions using drawings. They count the drawings in the sets provided when computing and solving the addition problems (Cihak and Foust, 2008). Both number lines and the touch-point strategy have been established as effective methods for teaching mathematical skills, such as addition, to students with ASD (Cihak and Foust, 2008).

Cihak and Foust (2008) conducted a study to compare the effectiveness of using number lines and the touch-point strategy to teach math to students with ASD. The study involved three elementary students with ASD and two special education teachers. Each student was diagnosed with ASD by two independent agencies. The school psychologist from the local educational agency and the developmental pediatricians of the students conducted formal assessments within the calendar year preceding the study. The requirement for the two special education teachers was to have at least three years of experience teaching students with severe disabilities, such as ASD and/or multiple disabilities. In the number line operations, students were provided with a number line from 0 to 20. Students were asked to point at the digit corresponding to question number one. During the exercise, participants learned to identify the numbers one to nine using dot positions on the numbers, and whenever they made significant progress in understanding, their instructors rewarded their efforts with extrinsic rewards.

According to Cihak and Foust (2008), the instructor correctly mimicked the structure and action in the two sessions. The two techniques were repeated each morning, as this was considered the ideal time for the tasks. A comparison was made between the effectiveness of the touch-point strategy and number lines in teaching single-digit addition. The study found that the touch-point strategy was more successful in teaching students with ASD single-digit addition problem-solving skills. The results clearly indicated that students preferred the touch-point strategy over number lines for acquiring single-digit addition skills. Cihak and Foust (2008) concluded that the touch-point strategy was more effective than the number line strategy. Furthermore, Cihak and Foust's findings (2008) support previous studies with similar results, suggesting that using touch points is a more viable method for teaching single-digit addition to students with ASD.

A similar study by Yikmis (2016) also found the touch-point strategy to be an effective method for teaching single-digit addition to students with ASD. This technique is based on the concrete-to-abstract instruction principle, which is crucial for teaching and learning mathematics. This study represents the most recent research found in the literature regarding the touch-point strategy in single-digit addition instruction for students with ASD. However, a meta-analysis conducted by Kot et al. (2018) further supports this finding. Through descriptive analysis and meta-analysis, they determined that the touch math technique (touch points) is effective in teaching the acquisition of addition skills to children with special needs.

Concrete–Representational–Abstract

The Concrete-Representational-Abstract (CRA) instructional sequence consists of three levels: learning through concrete objects (C), learning through pictorial representations (R), and learning through abstract notation (A). Students with learning disabilities (LD), especially those at the secondary level of education, often struggle to acquire mathematical concepts and skills. The CRA instructional approach, using the mnemonic CRA math, assists students with LD, including those with ASD, in understanding how to solve mathematical problems and improve their mathematical performance. The CRA approach aims to help these students acquire mathematical skills and enhance their secondary math performance, communication skills, and social skills through multimodal forms, including touch, hearing, seeing, and muscle movement. Although these students may have varied learning preferences, this strategy supports them to interact in numerous ways, thereby improving both their engagement and attitude toward mathematical concepts and content (Witzel et al., 2008).

Self-monitoring

Legge et al. (2010) examined the effects of self-monitoring on the on-task behavior of three male students with ASD from a local district school. While independently completing math problems, these students wore an electronic device called MotivAider®, which vibrated at preset intervals. This prompted the students to self-record whether they were on task. Self-monitoring, the act of observing and recording one's own behavior, is one of the few research-based effective methods for teaching students with learning disabilities, including those with ASD (Legge et al., 2010). The participants in the study were periodically monitored to ascertain task performance. Enabled by the MotivAider®, which vibrated at specific times during independent work, students were reminded to record their focus on the task. As the study progressed, the intervals for the MotivAider® were adjusted to occur four to ten minutes apart. Two of the three students had their devices set to vibrate at intervals measured in seconds. They also recorded their own progress by completing a personal progress form, marking either a plus or minus to indicate their on-task status. The study's results demonstrate a functional relationship between self-monitoring with a tactile prompt and increased on-task behavior.

TOUCHMATH

TOUCHMATH is a multi-sensory program developed in 1975 by elementary school teacher Janet Bullock as an experiment for struggling learners (Yikmis, 2016). It involves placing dots on numbers, which students touch while counting, allowing them to experience the numbers visually, auditorily, and tactilely. Many students, especially those with intellectual disabilities, face difficulties in meeting the curriculum demands of mathematics, including basic skills like addition. Students with intellectual disabilities tend to be less proficient in solving mathematical problems compared to their peers with other disabilities and often use fewer effective strategies in completing mathematical problems than their typically functioning peers (Fletcher et al., 2010). However, the ability to perform basic mathematical computations is essential for students' success and for fostering independent life skills. Due to these difficulties, students with intellectual disabilities often struggle with solving mathematical problems.

Fletcher et al. (2010) conducted a study to determine the effectiveness of using manipulatives to help students with moderate intellectual disabilities acquire skills and complete mathematical computations effectively. One of the most effective and widely used manipulatives in teaching mathematical computations to these students is the number line. The use of a number line is considered one of the best multi-sensory approaches for teaching addition, utilizing both 'count on' and 'count all' strategies (Fletcher et al., 2010). In the 'count all' strategy, students count all entities in a mathematical problem; for instance, they start at 'one' and continue counting up to '$m + n$.' Conversely, in the 'count on' strategy, students start counting from 'm' and then continue to '$m + n$.'

Another study by Fletcher et al. (2010) aimed to extend previous systematic studies on the TOUCHMATH program. The participants were three middle school students with multiple moderate disabilities. In this study, students were taught how to calculate single-digit math problems using both the number line technique and the TOUCHMATH technique. The effects of both strategies were evaluated, and the researchers found that participants showed more significant improvements using the TOUCHMATH approach compared to the number line approach. One limitation of this study was that it focused only on single-digit math problems for students with intellectual disabilities, limiting its generalizability to a larger population. A subsequent meta-analysis conducted by Kot et al. (2018) found through descriptive analysis and meta-analysis that the TOUCHMATH technique (touch-point strategy) is effective in teaching the acquisition of addition skills to children with special needs.

Methods

Selection of participants. The participants were three students attending an elementary school in Jeddah City, Saudi Arabia, which serves students with ASD. They were selected based on interviews with math teachers to assess their prerequisite skills, including the ability to write, focus on the board, identify the problem, and complete addition tasks. Other necessary skills included the ability to recall numbers, engage fully in activities for 5–15 min, and count from 1 to 15. Additionally, to further ascertain the participants' prerequisite skills, the students were observed during several math sessions at school, aiding the researchers in selecting appropriate candidates for the study. All selected students were in the second grade and had been identified as receiving services under the disability category of ASD, as per an initial special education evaluation in accordance with the DSM-5 standards (American Psychiatric Association, 2013). Based on this evaluation, it was determined that each student would receive special education support or services in math. These subjects were students who struggled with acquiring and retaining basic math skills, particularly the concept of single-digit addition. According to grade-level mathematics standards, by the end of the second grade, students should be able to read, write, compare, and represent whole numbers up to 1000 including applying these skills to subtraction and addition facts.

Observer. To ensure intervention reliability and interobserver reliability, a 35-year-old special education teacher with experience in using the touch-point strategy for teaching addition to students with ASD was selected as an observer. This teacher underwent a 2-h orientation about the study. The orientation involved three steps. First, the researcher explained the touch-point strategy to ensure the teacher was ready to implement it. Second, the teacher was shown several videos of other educators using the touch-point strategy to model the approach that would be used. Finally, the teacher engaged in a demonstration of the procedure to address any further questions. Before each task, the observer received specific instructions about the task requirements. After completing the tasks, each paper note was reviewed and discussed with the researcher to ensure task reliability.

Design. A multiple baseline design was utilized to assess changes and evaluate the participants' progress in using touch points to solve single-digit addition problems. The design consisted of four phases, denoted as A–B–A–B, structured as follows: (A) baseline phase, (B) intervention phase, (A) return to baseline, and (B) return to intervention. All conditions are needed to reach stability before progressing to the next phase (Kratochwill et al., 2012).

Baseline data were collected before initiating the intervention. The participants with ASD were assessed for their knowledge of single-digit addition math skills in a small group setting. Over three consecutive sessions, the teacher asked the three participants to complete worksheets containing ten single-digit math facts. These sessions were conducted three times per week and lasted ~10–15 min each.

Once the baseline was established, the intervention phase commenced. The study encompassed two primary stages: first, a multiple baseline design was employed to assess changes in teaching single-digit addition skills and the impact of the touch-point intervention on these skills. Second, after establishing the baseline, the touch-point strategy was implemented with the participants. Teaching sessions occurred three times per week, and assessment data were collected at the conclusion of each session to evaluate learning. This design entailed establishing a baseline for 2 weeks, implementing an intervention for 2 weeks with a 1-week maintenance phase, followed by comparing the intervention data with the baseline data to determine the intervention's effect on the student's skills. Throughout each phase, the participants were taught and assessed in the same environment to ensure data stability for the study.

Variables. In this intervention, the independent variable was the touch-point strategy, while the dependent variable was the test scores related to basic single-digit addition problems. The dependent variable of this study pertained to the process of combining single-digit numbers to arrive at a single-digit result. The operation of employing a two-step approach to solve mathematical problems and determine the solution for the task was crucial for the dependent variable in this study. Conversely, the use of the touch-point strategy to solve addition problems in mathematics was regarded as the independent variable. Prior to the implementation phase of the study, all steps involved in math problem-solving were carefully organized and structured to ensure clarity regarding the variables and to facilitate participants' understanding of the process.

Instructional setting. The study was conducted at an elementary school in Saudi Arabia, with all meetings taking place in a resource classroom within the school compound. The classroom was equipped with a kidney-shaped table positioned in front of a whiteboard, which served as the instructional area. During each session, only the researcher, the observer, and the three participants were allowed in the room to maintain a quiet and focused learning environment. Additionally, all teaching sessions were recorded to enable the researcher to revisit the collected data as needed.

The researcher opted to work with a small group of students with ASD, limiting the number of students in each instructional session to three. This small group size ensured personalized attention and meaningful interaction between the participants

and the instructor, guaranteeing that each student received the necessary support and guidance. To maintain a favorable instructor-to-student ratio, one trained instructor was assigned to each group of three students. This arrangement facilitated individualized instruction, progress monitoring, and timely feedback for every participant.

The researcher's objective was to establish a supportive and effective learning environment that maximized each student's opportunity to acquire and master single-digit addition-fact problem-solving skills using the touch-point intervention. Some participants required more assistance and scaffolding, while others displayed greater independence in applying the touch-point strategy.

Procedures. At the beginning of the first phase (baseline A), the objective was to determine the dependent variable and the participant's level of engagement without any treatment. During this phase, a baseline was established for the dependent variable. This is the level of response before any treatment is introduced; therefore, the baseline phase is similar to a control condition.

The baseline was established by evaluating participants' existing knowledge of single-digit addition-fact math skills. This phase was designed to provide a stable reference point for the participants' abilities before the intervention commenced. Data were collected during this phase over an appropriate duration to ensure data stability and consistency. When all participants had completed the first session, phase B began, and a treatment was introduced.

The researcher introduced the touch-point intervention (phase B). This intervention aimed to improve participants' problem-solving skills in the context of single-digit addition facts. During this phase, participants were actively engaged in using the touch-point strategy to solve problems. The researcher conducted regular meetings to assess their progress and learning of the intended skills. The treatment was later removed to ensure that the dependent variable achieved a steady state. After two weeks, the stated process was implemented again to evaluate the influence of the treatment on participants' ability to complete single-digit addition problems.

Return to Baseline (A): After completing the intervention phase (B), The researcher returned to the baseline (phase A) to observe any potential changes or retention of the skills acquired during the intervention. This phase allowed the researcher to determine whether the improvements were sustained or whether participants reverted to their previous performance levels.

Return to Intervention (B): Subsequently, the researcher reintroduced the intervention (phase B) to further evaluate the effectiveness of the touch-point strategy in enhancing problem-solving skills. The goal was to assess whether participants could once again improve their performance following a second round of intervention.

Each phase continued until the researcher observed stability in the data, ensuring there was sufficient information to make meaningful comparisons. The researcher then transitioned from baseline (A) to intervention (B) when he felt confident that the baseline data provided a clear reference point for the participants' initial abilities. The researcher then moved from intervention (B) back to baseline (A) and then to the second intervention (B) phase following similar criteria, ensuring that each phase was well-documented and consistent.

Materials. Once the participants were selected, the researcher had to determine reinforcers to ensure that the student's responses were correct. Accordingly, the parents of each participant were asked to fill out a preferred reinforcement form for their child. The reinforcers were then prepared for the experiment in order to keep the participant engaged in each required task. All teaching sessions were recorded using an FDR-AX100E video-recording camera.

Students were provided with their own set of instructional materials, including worksheets containing single-digit addition problems and touch-point prompts. This ensured that each participant had access to the necessary resources during the instructional sessions. The materials also included two worksheets based on the touch-point strategy, marked as worksheet one and worksheet two, for the assessment sessions. Each of the worksheets contained five single-digit addition problems written in a different order. For instance, if worksheet one had a problem written as "2 + 3," it would be written as "3 + 2" in worksheet two, with touch points represented on the worksheets used during the teaching sessions. During preparation, all the teaching worksheets had additional facts with dots placed on each number from top to bottom.

This was done to represent the total dots for each number. For instance, for the question "4 + 2 =?", an identical number of dots were placed on all numbers "4" and "2." On the other hand, during the second addend, which in the generalization phase dots were. For example, in the problem "3 + 2 =?", the dots on the first addend were faded for the participant to generalize the addition problem.

Intervention. At the outset of the experiment, participants were presented with two worksheets, each featuring pictures of touchpoints. Both worksheets contained five single-digit addition problems, with the only difference being that the addends were in reverse order on the second sheet. Participants were instructed to complete each of the problems on both worksheets.

The instructional sessions followed a structured format that incorporated a combination of direct instruction, guided practice, and independent problem-solving. Initially, the instructor introduced the touch-point strategy, explained its application, and provided guidance by working through sample problems with the students. Subsequently, participants were given opportunities to practice the strategy with support and assistance from the instructor. The participants were taught the dot positions for the numbers 1 through 9 and were then instructed to count the dots aloud using the "count all strategy." The teacher demonstrated how to touch the points while counting aloud, and students were given time to count aloud and then write down the last number they had stated. If there was no response within 3 min, the teacher would repeat the dot positions instruction to the student. When a student-produced an appropriate response by counting aloud and writing the last number they had said, they received verbal reinforcement for their response.

Similar baseline procedures were employed to assess the effectiveness of the touch-point strategy. The participants were seated at a kidney-shaped table in front of the teacher at the beginning of every session, with the table positioned in front of a whiteboard. The touch-point strategy was introduced in the first session, encompassing the demonstration of how to count the dot positions on the numbers and correctly apply the "count all strategy" for the numbers 1 through 9.

The demonstration was conducted on the whiteboard. In the subsequent step, participants were given the opportunity to practice solving an addition problem using the "count all strategy" alongside the teacher. During the second session, the teacher demonstrated the proper steps and provided verbal instructions for solving an addition problem. In this step, all participants were required to add two numbers by counting the dots on both numbers. Emphasis was placed on the process of

starting with the larger number and then counting forward using the touch points on the smaller number. Each participant was then asked to perform the task as demonstrated. During this stage, verbal corrective feedback was provided to help participants correct their errors and improve their performance through at least three practice trials.

Clear and precise instructions on using the touch-point strategy to solve problems were given in all four sessions. Practice sessions included a minimum of 10 problems based on single-digit addition. For the first five practice problems, the teacher re-taught any operational mistakes made by the students. Subsequently, the students were required to independently solve at least four problems on their own worksheets using the touch-point strategy, without any assistance from the teacher.

In the maintenance stage, no visual assistance or verbal instruction was provided to the students from the touch-point materials when solving addition-based problems. The problems were presented on worksheets, but this time, there were no touch-point pictures on the worksheets, and the students were expected to apply the last two intervention steps. Each student received at least one maintenance probe every day for four days. The maintenance phase utilized an assessment worksheet similar to that used in the baseline phase, and it included a complete probe similar to the baseline process. The duration of each problem-solving session during the maintenance phase ranged from 12 to 16 min.

Data collection. Data were collected after the conclusion of each intervention session. Just before the session ended, the participants were given a worksheet containing five problems that represented the strategy demonstrated and practiced during that day's session. The students were required to work independently for 20 min to solve these problems. Once the allotted time had passed, the teacher instructed the students to stop and collected their completed worksheets. Data was then collected on each student's performance, including the accuracy and efficiency of their problem-solving using touch points. This data provided valuable insights into individual progress and informed decision-making regarding the effectiveness of the intervention.

Interview Protocol. An interview with the teacher was conducted to gain insights into their perspective on using the touch-point strategy for teaching math. This qualitative approach, rooted in the human experience, adds depth to the understanding of the data collected during each teaching session (Nowell et al., 2017). The interview was semi-structured and conducted face-to-face in a predetermined setting agreed upon with the participating teacher. The interview protocol was developed based on the intervention results, serving as a guide for the interview process. The duration of the interview fell within the expected range of 30–40 min and was recorded for future reference.

Thematic analysis was employed to analyze the interview data, following an inductive approach to delve deeper into the experiment's details (Saldana, 2014). This method aided in identifying recurring themes and patterns within the data, enriching the overall understanding of the study (Patton, 1990; Nowell et al., 2017).

Results

The A-B-A-B reversal design was employed over a period of 5 weeks, with 40-min sessions conducted twice a day for 2 days a week. The study utilized a multiple baseline design across the targeted skills. The research commenced with the collection of baseline data, and the intervention phase began once the baseline phase had been completed and reached stability. To assess intervention effectiveness, the study was designed to temporarily remove the intervention after 2 weeks and return to the baseline stage. After confirming the effectiveness of this removal, the intervention was reintroduced once more. The study closely monitored any potential increases in participants' abilities in math problem-solving and implemented a probe session to explore potential correlations between variables.

The touch-point strategy was implemented in each intervention session, resulting in a noticeable increase in correct responses among the participants. It became evident that the independent variable positively influenced the dependent variable. While some participants exhibited a temporary decrease in correct responses during the second baseline in comparison to the first, the data indicated that the mastery rate of all participants increased after the introduction of the touch-point strategy, and students readily engaged with the strategy during its second implementation. The results demonstrated an increase in the number of correct answers, highlighting the positive impact of the strategy on the learning process for all participants.

The following figures illustrate the means and standard deviations of the participants' scores during the baseline and intervention sessions. Variations in participants' scores were observed, particularly in the task of solving single-digit addition problems. All participants demonstrated improved performance, achieving significant success during the intervention sessions compared to the baseline sessions. In both instructional time periods, participants scored higher when solving math problems using the touch-point strategy during the intervention compared to the baseline approach. Prior to the intervention, success rates were very low during the pre-test session. However, after the intervention was implemented, participants' performance levels in successfully solving single-digit addition problems increased. Furthermore, participants retained these skills and consistently used the touch-point strategy throughout all sessions, as documented.

Participant one. As depicted in Fig. 1, the first participant exhibited significant improvement when employing the touch-point strategy compared to the first baseline in solving single-digit addition problems. The results also indicated that the first participant was able to solve math problems more quickly using the touch-point method. During the initial baseline phase, the first participant's average correct responses in accurately solving single-digit addition problems stood at 2 out of 10 questions. The participant was unable to accurately compute more than 4 correct single-digit addition problems during this phase. Upon the application of the touch-point intervention, a gradual increase in the number of correct responses was observed, exceeding 5 correct answers for the first participant. The data initially started at 2 correct responses out of 10 in solving single-digit addition problems, but this increased to 9 out of 10 correct responses when employing the touch-point strategy during the intervention. Upon returning to the baseline stage, the results indicated stability and a continued positive impact of the intervention. A positive change was noted in the level of correct responses when reverting to the baseline phase, highlighting the effectiveness of the touch-point intervention (Figs. 2 and 3).

Participant two. The second participant initially completed only 1 single-digit math problem correctly during the baseline phase. However, there was a noticeable improvement when the touch-point strategy was introduced for solving math problems. During the intervention phase, the second participant's correct responses increased to 5 out of 10 math questions. Upon returning to the baseline stage, the participant continued to correctly solve 5 math

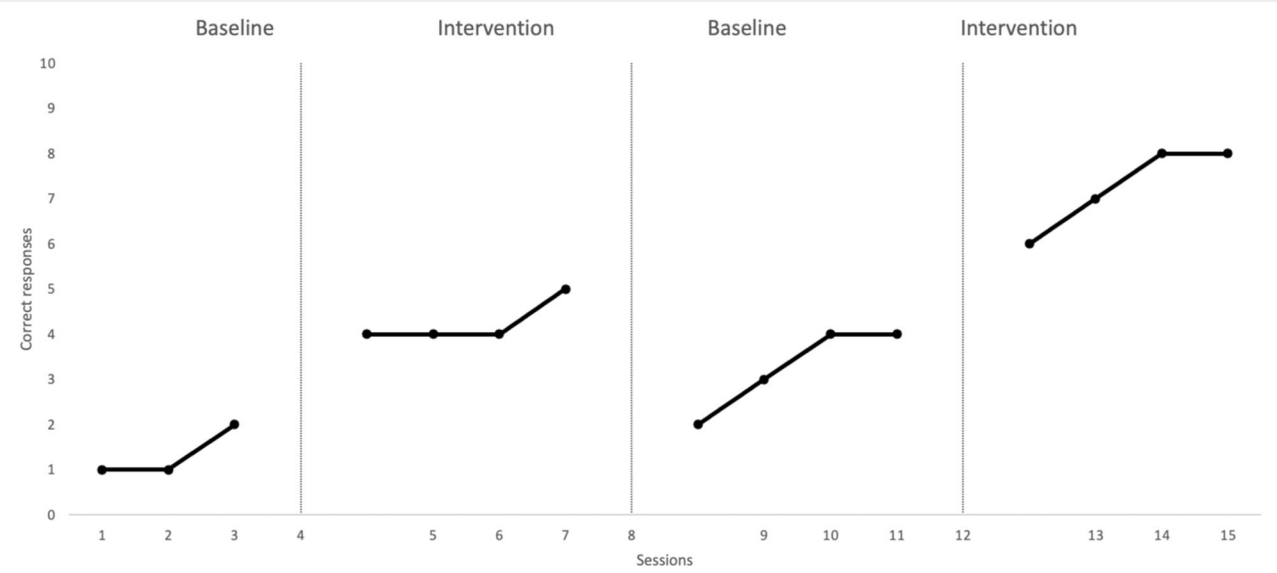

Fig. 1 The number of correct responses. This graph illustrates the remarkable progress of the first participant in solving single-digit addition problems. Initially, the participant could solve only 2 out of 10 problems correctly. However, with the introduction of the touch-point method, their accuracy soared to 9 out of 10 correct answers. The graph highlights this significant leap in performance, showcasing the touch-point strategy's effectiveness.

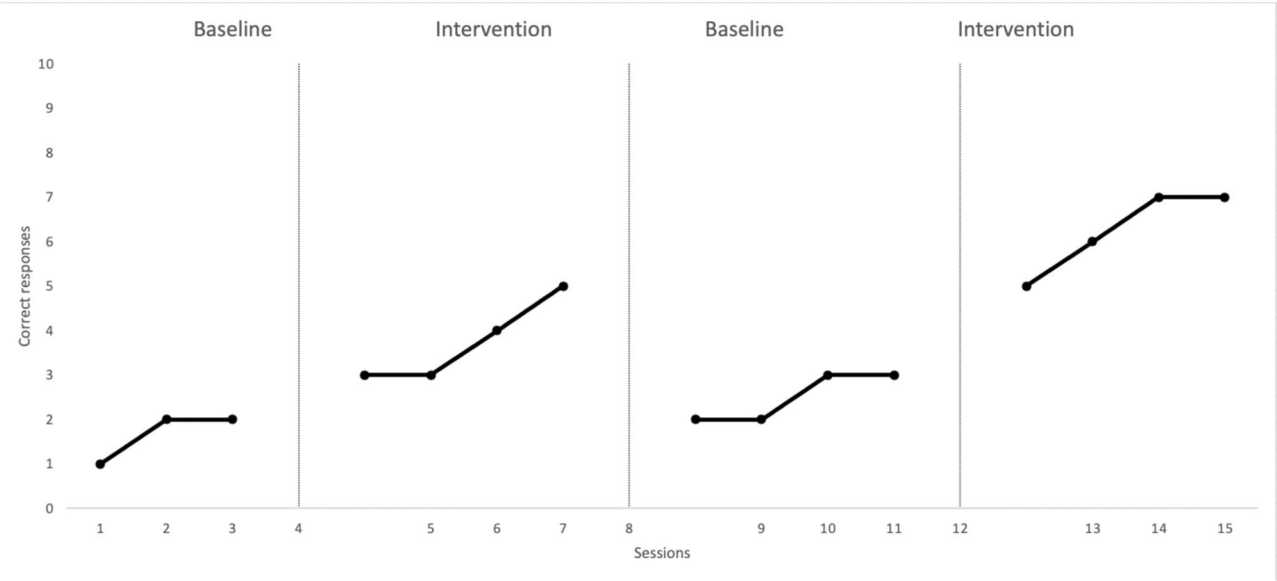

Fig. 2 The number of correct responses. This graph the increased speed of solving problems using the touch-point method. The data reflect a notable decrease in the time taken to arrive at correct answers, emphasizing the method's efficiency in enhancing mathematical problem-solving skills.

problems out of 10, indicating a slight positive change between these stages. Notably, a significant and immediate improvement in correct responses to single-digit addition problems was observed when the touch-point strategy was reintroduced. In other words, there was a substantial increase in correct responses compared to the baseline phase, with the participant achieving correct responses in 8 out of 10 questions by the end of the last intervention stage.

Participant three. The third participant began with only 1 correct answer out of 10 during the first baseline phase. When the intervention phase began, this participant was able to record 3 correct responses. The data indicates a fast response from baseline to intervention with an average of 4 correct responses. In the second baseline stage, a change was recorded as compared to the previous baseline. When returning to the baseline stage, the touch-point intervention enabled the participant to complete 4 single-digit addition problems out of 10 correctly in the final intervention phase.

Interview with the math teacher. At the conclusion of this experimental design, researchers conducted an interview with the math teacher who participated in this study to gain a comprehensive perspective on the treatment employed (Tashakkori and Teddlie, 1998; Nowell et al., 2017). The study aimed to explore the barriers that hindered teachers from implementing the touch-point strategy when teaching math facts to students with ASD.

One prominent theme that emerged from the interview data was the presence of two barriers to the strategy's implementation. The teacher highlighted the challenges related to the amount of

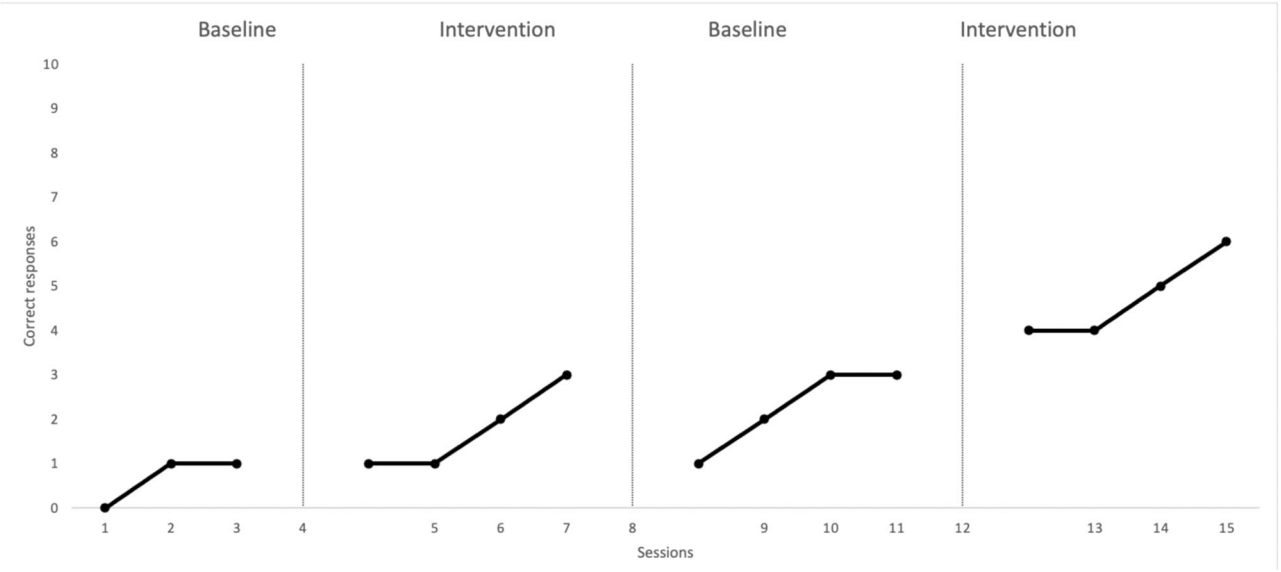

Fig. 3 The number of correct responses. This final graph focuses on the long-term effects of the touch-point intervention. Even after reverting to the baseline stage, the participant maintained high accuracy levels, indicating the enduring impact of the touch-point strategy in improving mathematical proficiency.

time and attention required to teach students how to use the touch-point strategy effectively in a classroom setting. For instance, the teacher mentioned that a large number of students in the class posed difficulties in the learning process. Additionally, the varying degrees of severity of ASD among students in the same classroom made it challenging to implement the touch-point strategy uniformly.

Another obstacle to implementation was the absence of a teacher's assistant (TA) to observe the progress of each student. According to the teacher, managing the behavior of other students while working one-on-one with a student necessitated the presence of another person in the room. Another issue raised by the teacher was the simultaneous instruction of one student while others were expected to use the touch-point strategy at the same time, leading to a lack of available support for all students. Finally, there appeared to be a shortage of funding for resources needed to teach the students this strategy. According to the teacher:

> I teach six students with ASD, who are between high functioning and severe in their disability. So, I cannot use the same practice with all students due to their learning ability. As you know, using touch-point strategy takes so much time and effort. In addition, I have a number of students in my class, and most of them have ADHD. I just can't work with all of them at the same time by myself with no TA. I can easily work with one or two students in implementing this practice. However, because of the large number of students I have, it is very difficult to use the touch-point strategy in my classroom. In addition, due to the complexity of implementing this strategy, in my opinion, it should be implemented individually, not in a classroom full of students. If I'm going to use touch points, I will have to ignore the rest of the students and make the learning process unfair for the rest.

He continued:

> Honestly, in our school, we don't seek to teach students with ASD any advanced academic skill. Our target is to develop students' behavior, such as social and communication skills. Sometimes, we use modeling in teaching literacy for some students who are capable. I know this practice we have been using is beneficial for the students with ASD, as I saw. However, this practice needs materials every time I use it. As teachers in this school, we need more support on materials to teach our students, and I buy all materials at my own expense.

In summary, the teacher who participated in this study stated that he found the touch-point strategy to be a valuable method. He acknowledged that the strategy was effective for students and helped them to learn the process of solving math problems. The barrier to using such a practice in a classroom environment is the number of students in one class. As the teacher stated, "Compared to traditional teaching strategies, with touch point, I could easily observe positive changes in the students' ability and learning progress. However, it is hard to use with more than one student, and if I do, I will take away the curriculum from the rest of his classmates."

Implications and suggestions for future research

A positive impact was observed in the students' performance when comparing pre- and post-test scores after implementing the touch-point strategy with participants with ASD. The strategy aided the participants in solving single-digit addition problems. During the second post-test phase, the researcher noted that participants were using their fingers to count invisible dots on the numbers while solving single-digit addition problems. This has implications for educators working with students with ASD, who need to find ways to teach the strategy while managing the classroom environment.

Another implication is the need for school districts to review their funding allocation for schools and classrooms to ensure there are adequate resources and personnel to teach evidence-based programs to students with ASD. Equitable funding is essential to provide a free and appropriate education to all students, regardless of their disability. The touch-point intervention was conducted in a small group setting with three students with ASD, resulting in a small sample size. To facilitate multiple classroom comparisons, further research could be conducted in larger settings. The current study offers valuable insights into how the strategy can effectively teach basic addition skills to

elementary students with ASD, demonstrating positive outcomes. Teaching younger students such an effective strategy at an early age may facilitate skill automatization. Additionally, future research could extend both the number of sessions and the duration of each session to promote skill generalization.

Most of the literature related to the present study suggests that students with ASD can benefit from the touch-point strategy or any highly systematic and structured program (Jarrett and Vinson, 2005; Wisniewski and Smith, 2002). The gap in current literature for Saudi schools pertains to how to implement such a practice in a classroom setting for a group of students with ASD. There is a need to investigate how the touch-point strategy can be taught effectively and manageably. Larger-scale studies could provide support for arguments advocating the generalization of the touch-point strategy for all elementary school students.

Limitations

The following limitations need to be considered to understand the probable outcomes of the study. First, the touch-point strategy was examined in three students who were diagnosed with mild ASD. The other limitation of the study is that it covered only one specific target skill (single-digit addition), which limits the ability to generalize the findings to other mathematical skills or groups of students.

There were only five weeks of study; because of the time frame, the researcher was not able to determine whether the students would retain the skills that they had learned long term.

Ethical considerations

It is the researcher's obligation to respect all participants' values and rights. All the participants were treated in accordance with the Institutional Review Board (IRB) standards to ensure the protection of individuals' confidentiality. The researcher also ensured that each participant understood the entire interview process and the purpose of the study. The informed consent procedures were completed individually with each participant's parent before the interview began. In addition, this procedure allowed for the provision of other details, such as the disclosure of potential risks/benefits, participants' right to stop the interview at any time, and participants' right to ask questions about the interviewing process as necessary.

Discussion

The study yielded several positive findings. Firstly, the touch-point strategy was found to enhance students' ability to address mathematical questions by promoting the processing of both linguistic and numerical information through visual aids. This strategy proved valuable for students with ASD, assisting in bridging the gap between concrete numerical representations and the development of visual-spatial, conceptual, and problem-solving skills necessary for higher-level mathematics (Mohn, 2010).

Secondly, the simplicity and ease of use of the touch-point strategy make it a readily adoptable tool for teachers within the classroom environment. Furthermore, its potential extends beyond students with ASD, benefiting other students, both with and without special needs. This approach offers a novel way for all students to learn math facts through the use of touch-points, enhancing their ability to work with problems visually and aiding in the long-term retention of acquired skills. The importance of utilizing multiple forms of data assessment to gain insights into student performance was emphasized throughout this study, suggesting that students can retain and apply the skills learned in various settings.

This study holds significance as it illustrates how the touch-point strategy enables students with ASD to grasp math concepts initially at the concrete level, progressing to the representational level. This sequential approach prepares students with ASD for higher levels of cognitive thinking required for abstract math and memorization skills. It is noteworthy that the touch-point strategy allows students to engage with numbers on concrete, pictorial, and abstract levels concurrently. This aligns with the learning preferences of students with ASD, who benefit from educational approaches that incorporate concrete objects and visual stimuli, as well as systematic and structured methods. These approaches have been shown to be more effective for children with ASD than traditional stimuli (Berry, 2007; Simon and Hanrahan, 2004). Therefore, the use of the touch-point strategy serves as an effective scaffold for teaching single-digit addition to students with ASD.

The teacher provided valuable insights into his perception of implementing the touch-points strategy in his classroom. He acknowledged the value of the strategy but expressed concerns that the time and effort required outweighed the benefits. There may be resistance stemming from the belief that other students might be adversely affected while he focuses on teaching a small group. Addressing this issue may necessitate providing professional development and coaching on effectively managing small groups while others are engaged in different activities. Additionally, the school should consider offering support to the teacher to ensure that all students receive a free and appropriate public education.

The teacher's perspective may also be influenced by the school's focus primarily on behavioral and social aspects of education, as indicated by his remarks. Unfortunately, he may not fully recognize the connection between academic frustration and behavioral issues. It could be beneficial to initiate efforts to shift the school's paradigm regarding the education of students with ASD, emphasizing the importance of addressing academic challenges alongside behavioral and social development.

Data availability

All relevant data are fully shared in the results section of this paper. Additionally, for comprehensive access and analysis, all associated data files have been uploaded as separate supplementary files in the submission. Access to video recordings from the research cannot be provided due to strict adherence to the confidentiality agreements signed by participants at the beginning of the study. These agreements ensure the privacy and protection of participant data, a priority that necessitates the restriction of video data sharing.

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Author contributions

This manuscript was authored solely by ASA.

Competing interests

The author declares no competing interests.

Ethical approval

All procedures performed in this study were conducted in accordance with the ethical standards of the institution. The approval number is D31/456.

Informed consent

Informed consent was obtained from all participants and their legal guardians prior to the commencement of this study.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1057/s41599-023-02460-w.

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