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Using a tablet-mediated intervention for teaching pre-addition skills to children with autism

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ABSTRACT

Nowadays, tablets and their applications are part of the children's daily lives. These digital educational activities can become a potent educational tool for efficient and effective in neurotypical as well as children with autism spectrum disorder (ASD). Tablets and their applications allow children to take advantage of new learning platforms and effectively learning through activities in learning domains, such as mathematics. In the present study representational-abstract sequencing instruction in the form of explicit instruction used with the help of mobile technologies. The aim of this study is to match the semi-concrete visual drawings with the correct abstract mathematical pre-addition expressions. Findings suggest using a tablet mediated intervention is effective teaching to match the semi-concrete visual drawing with the correct abstract mathematical expression. Implications for practice and future research are discussed.

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1. INTRODUCTION

Students with autism spectrum disorder (ASD) are known primarily as having inappropriate or inadequate social skills, challenges with communication, behavioral concerns like obsessions, aggression, tantrums, repetitive behavior, and restricted interests [1] variability in academic performance [2], [3] including in the academic area of mathematics [4]. Although ASD may be associated with mathematics strengths [5] research on the academic abilities underlines the importance of mathematics interventions especially around 25% of individuals with ASD that may have a mathematics learning disability [6]–[8]. Teachers and special education teachers often consider mathematics as one of the difficult subject matters [9]–[11] for children with ASD.

Because mathematics performance in early mathematical concepts has correlation to later mathematics performance [12] generally low-performers in early mathematics education tend to remain low-performers if they do not receive appropriate support including explicit instruction [6], [13]–[15]. Sayers *et al.* [16] implies that correlation and underscore that certain basic mathematics skills can predict later arithmetical competence. Counting is thus a method of deciding which number word should be used to describe a particular cardinal, Thus, counting is a way to choose which numeral to use to express a given cardinal, which is a change in perspective on the same thing [17].

It might be challenging for chidren to use the changing order of number words as they count. The sequence evolved from being a mechanical list of words and objects to becoming a flexible representational tool for addition problems. Children's abilities to associate counting, cardinality, and other concepts to counting changed as a result of this alteration. Additionally, in order for youngsters to learn about cardinality through counting, cardinality has to first be related to them. Number words themselves cannot serve as the "objects" that represented the addition scenario if object counting cannot be condensed and abstracted from the objects.

It's known that, the knowledge of formal mathematical concepts may differ considerably even from a typical child to another. In the case of ASD around 25% of individuals that may have a mathematics learning disability [6]. However, since the software programs are based on children with typical development, intermediate software is needed for children with different developmental level and developmental sequences, such as ASD. It is important to provide additional support for children with ASD in their future acquisition of basic math skills. For this purpose, it is a smart alternative to use more up-to-date technological tools instead of classical pencil and paper activities during the teaching phase.

Children with ASD are sensitive to affective, visual and auditory stimuli in terms of learning characteristics [1]. Today, tablet computer applications make a big difference in addressing the different learning characteristics of children with ASD compared to other learning environments [18]. In the literature, it is seen that mobile technologies are effective in creating personalized learning environments by taking into account the individual differences of children with ASD, and it is recommended to use mobile technologies and student-oriented applications to provide these individuals with many skills.

As these technologies are used in many fields of education, including special education. Individuals with ASD provide the opportunity to learn at the desired place and time with many different devices. Among these technologies, the most widely used ones have been the new generation tablet computers [19]. These gadgets are typically selected since they support both technologies and are both lighter and larger than laptops and cellphones. Tablets are becoming more and more popular as one of the six new emerging technologies that may have a significant impact on teaching and learning in the educational sector [20]. The learning process has many benefits, including stimulation, motivation, usability, accessibility, and connectedness, among others [21]. Students' active participation in mathematics learning domains on tablets enables youngsters to efficiently access new learning platforms and acquire new knowledge. Additionally, beautiful surroundings are thought to be important learning enhancers for kids and students with ASD [22]–[27].

Digital media may expose kids to abstract ideas that were previously thought to be too sophisticated for their age [28] or for their way of thinking in the case of kids with ASD. Because sophisticated learning settings like digital media can offer children differentiated instruction, enabling them to take an active role in their education and activating diverse parts of their brains, leading to better intellectual growth [29]. By integrating digital technologies into current classroom practices, digital technologies have the potential to completely change how mathematics is taught and learned. They also establish a connection between mathematical skills and knowledge that may be enhanced in learning environments that effectively utilize technology and software designed with development in mind [30]. Math may be made more interesting, useful, and relevant by the use of digital activities in the right instructional context [31]. Digital exercises that investigate a particular issue or impart a certain ability, like Cardinal principles, are extremely successful. The Cardinal Principle—which states that the final number tallied is the count of a set—can be taught to children by asking them for both the tangible amount and the abstract number [32]—and Cardinality are reinforced. The idea that numbers can be used to count everything, including discrete things and sections of objects, is encouraged by the use of multiple representations [32], [33]. Manipulatives are used for counting and can represent a physical quantity. In arithmetic instruction, they have typically been considered to be helpful. Concrete manipulatives increased recall, problem-solving, transfer, and justification of solutions when compared to abstract symbols, according to research comparing the impact of education with both [34]. However, the effect sizes for the more sophisticated abilities were modest, maybe as a result of the inconsistent quality and complexity of manipulatives. Keeping two representations of the same thing, as both a sign for something else and something in and of itself, may be challenging for children with ASD. Objects designed to represent abstract ideas are called manipulatives. Children's capacity to learn the symbolic meanings is hampered if their object meaning is salient to them.

The transition from utilizing concrete manipulatives for multi-digit numbers to only using numerals needs to be made more clearly for children with ASD. This can be accomplished by employing vibrant little circles, or "dots," as a counting tool for digital activities. These vibrant little circles can be visualized as semi-abstract ideas that help people understand numbers and give them a plan of action. Given the chance to first develop a tangible understanding of the math concept or talent, children with arithmetic learning difficulties, such as those with ASD, are far more likely to be able to perform that math ability and genuinely appreciate abstract mathematical concepts.

To ensure that students fully understand the arithmetic concepts and skills they are learning, a concrete-to-representational-to-abstract teaching process is implemented. When kids use different forms of expression, they can learn from each other's views and ideas and discover other types of thinking [35]. Children can learn to reason about the similarity of concepts and to recognize similarities in things (representations) that have radically distinct appearances [36]. With the use of semi-concrete-colored circles, teachers provide students numerous chances to practice and show that they have mastered a skill. At the representational (semi-concrete) level, the math concept or skill is modeled using circles that imprint pictures for counting. At the abstract level, the mathematical concept of addition is eventually depicted (using only numbers and mathematical symbols).

Educators can utilize an educational framework called concrete-representational-abstract (CRA) sequencing instruction, which is an evidence-based practice (EBP), to teach mathematics in sequential fashion. Concrete manipulations, visual representations, and abstract notations are the three learning stages of CRA. For pupils with disabilities, using explicit instruction is advised [37]. In explicit instruction, the teacher first demonstrates the concept to the class, then prompts or cues them as they move on to answering the topic on their own. The first stage of CRA involves presenting mathematical ideas to children in a practical or concrete way so they may interact with the manipulatives. In the following phase, the mathematical concepts are presented at a semi-concrete or representational level, and in the last stage of CRA, the mathematical concepts are presented at an abstract level using numbers and symbols rather than visuals. Students are expected to grasp the mathematics at each level by moving from concrete to representational to abstract stages and making connections between them, which is a fundamental part of CRA. However, it could be challenging for kids with ASD to retain two representations of the same thing—one as a sign for another thing and the other as something distinct. Objects designed to represent abstract ideas are called manipulatives. Children's capacity to learn the symbolic meanings is hampered if their object meaning is salient to them. The transition from utilizing concrete manipulatives for multi-digit numbers to only using numerals needs to be made more clearly for children with ASD. For children with ASD, the three stages of CRA can be modified, and the concrete manipulation stage can be changed to semi-concrete-representational-abstract, which includes a graphical representation and abstract notations. Because students with ASD learn differently from their peers [2], [38] individualizing the intervention for these individuals through adaptations is a potential approach. Additionally, CRA has been shown to be successful in teaching math skills in recent studies of students with ASD [39]–[41].

The aim of this research is to determine the effectiveness of the applications offered with tablet-mediated intervention in learning pre addition skills of students with ASD. What is the continuity and generalization of the pre-addition applications offered with the tablet-mediated intervention? Questions will also be answered. In addition, what is the social validity of the family's study in learning the pre-addition skills of students with ASD through the applications offered with the tablet-mediated intervention? question will be answered.

2. RESEARCH METHOD

2.1. Participants and setting

Three male students with ASD in the Turkish Republic of Northern Cyprus participated in the research. Special education teachers were interviewed to determine the participants included in the study, and three participants were determined to do one-to-one education at home, with the permission of the parents of the students with ASD who could not achieve success in counting objects and simple addition skills in more than a year. All three participants ca not perform one-to-one correspondence; the ability to count objects by assigning a specific number to each object where no items are counted more than once or skipped.

The evaluation and determination of the levels of the participants and the reinforcement choices were carried out in the presence of the parents. Attention was paid to ensure that the prerequisite features were met in the participants who will be included in the study. These features are: i) They can be summarized as having a mean length of utterance of 1.7; ii) Having the ability to count rhythmically to 10, having the ability to focus on the tablet for 10 minutes; and iii) Having the concept of seven basic colors. Accordingly, three male students with ASD and prerequisite qualifications were determined as participants. Additionally, the reason why the education is carried out at home is that special education schools are closed during the pandemic.

The first participant, Doğa, is seven years old and attends a public school in the Turkish Republic of Northern Cyprus (TRNC) as an inclusion student. He is also attending part-time at a special education institution. Doğa has been receiving various special education supports since he was four years old. When he first started special education, he had many stereotypic and challenging behaviors and could communicate with three two-syllable words. Doğa continues to a private education institution after school on weekdays. However, due to the closure of schools due to the pandemic that started in 2019, the participant's education had to be interrupted. For this reason, the research was carried out at home and one-to-one during the period when the participants' schools were closed. Doğa has a playmate and they play games together every time he comes from school. He can perform self-care skills such as dressing, brushing teeth, and eating. He can fulfill the short instructions within the two performances given to him in a row and can count up to 20 rhythmically. However, when each number starts to count, it tends to complete the number to 10. When being asked to stop at a certain number while counting, Doğa finds it difficult to stop.

The second participant, Mehmet, is eight years old and attends a special education institution in the TRNC. Mehmet has been attending inclusive education and special education school from an early age. With the pandemic that started in 2019, Mehmet faced problems in continuing to a special education institution: while his parents are at work, Mehmet stayed at home alone. In mathematical skills, he can count up to 20 rhythmically and can read and write his name. The mean length of utterance in communication is 1.5. Mehmet can follow three-step instructions. He can use tablet computers comfortably. Mehmet has difficulty in maintaining his attention while studying with his special education teacher, but when he gets support for his attention, he can take part in the education practice for 12 minutes.

The third participant Ahmet is eight years old and attends a public school in the TRNC as an inclusion student. At the same time, Ahmet attends a special education institution part-time. Ahmet could not continue his education since all special education schools were closed during the pandemic. Ahmet continued his school with distance education. Ahmet can count up to 20 rhythmically in his mathematics skills and he is at the end of the first grade first semester in his literacy skills. The mean length of utterance in communication is 2. Able to follow three-step instructions. Ahmet can use tablets and phones effectively. In terms of attention span, Ahmet was able to stay active in the activity for 20 minutes.

2.2. Preparation of teaching material

The teaching material was created using Vegas pro 15 layer-based working media program. Vegas pro 15 offers a platform where audio editing can be done as well as various visual arrangements. Although the program is generally used for video editing, it allows editing in photos by using program's layered structure. Another program used in the preparation of teaching material is "Adobe Animate". Adobe Animate is a software/animation program based on Adobe Flash. The program is in Turkish and has a visualized interface. Using Adobe Flash infrastructure makes the program integrated into Android and IOS mobile operating systems. Therefore, an application developed here is suitable to work in all digital ecosystems. In addition, with the ready-made code sequences that the program contains, whatever action is desired can be selected and applied without the need for coding knowledge. In this way, the desired application can be carried out as planned.

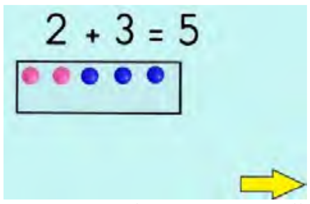
2.3. Experimental design

A therapy choice based on a sample of many participants may not be valid when applied to individuals who have a specific diagnosis like ASD, despite the fact that group comparison study with a bigger number of participants is quite helpful. This case report approach does not allow conclusions to be drawn about the efficacy of interventions because it is challenging to gather large homogeneous samples or conduct case reports. Single subject designs enable comparisons between participants, behaviors, or environments, and the intervention is methodically managed via repeatable data collection. Single-subject designs repeated data points (typically taken prior to intervention to establish a baseline) are followed by a series taken during intervention, and in the final phase generalization and maintenance may provide more appropriate conclusions to particular types of questions in special and inclusive education [42]. To strengthen internal and external validity, the study must be duplicated across people, behaviors, and contexts (one of these three things) if a meaningful change results from the intervention. Multiple-probe design, which combines multiple-baseline and probe [43] methods across patients, was employed in this study. To measure the effect of the intervention on participants' ability to choose the appropriate pictorial representation for the provided arithmetic notation skills, we used a multiple probe across participant design in this study. We included baseline, intervention, maintenance, and generalization conditions.

2.4. Intervention processes

The practice sessions were started after the baseline data of three sessions had been collected from the first participant. Then intervention sessions were performed after getting baseline probes. Intervention sessions were performed with each target stimulus or skill in the study sets which contains 10 trials. The training sessions were finalized when the participant performed desired skill which is matching the correct referent of semi-abstract sample with the correct mathematical process. For this step participant has to select the correct sample among two. If the participant selects the wrong sample by touching the screen, the sample disappears from the screen. This way tablet screen contains only the correct sample. If this is the case practitioner gives feedback and explains the whole process all over again. Then practitioner moves to the next sample. The data on effectiveness were collected and the effectiveness data of this study were recorded as the correct reactions given by the participants. Since the skill instructions do not give information to the participant about how to perform the skill, but only indicate what to do, the practitioner included the teaching process of presenting the hint starting from the maximum hint and gradually decreasing during the teaching phase. The controlling hint consists of presenting the simplest and shortest answer to the aforementioned questions by showing them on the figure. The researcher supported the participants to perform the skill independently by withdrawing the controlling prompt in accordance with their own learning speed, taking care to use the same group of clues throughout the entire application process. The desired response interval was determined as an average of three seconds. The responses of the participant were handled as correct response, incorrect response and no response. In order to help the student to have the desired reaction between the landscaping procedures, the environment around the individual was arranged. One-on-one training was carried out by placing the activity material in front of the table, which was placed away from the window. Each session is planned to be 14-17 minutes. The practitioner used the video recording method to collect the data more accurately, then marked the data of the teaching process on the "data collection form" after watching the videos.

Table 1. Intervention steps developed by the first author

Intervention steps	Step explanation	Step example
Step 1	Went to table with only the tablet on the table	Made sure there were no items on the table
Step 2	Participant showed same colored circle images (semi-concrete) on the tablet	
Step 3	Participant determined the (same colored) number of circle images (semi-concrete) and showed the associated number (abstract) in the addition sentence on the tablet	Took the participant's hand and helped them select a response.
Step 4	Participant determined the (next same colored) number of circle images (semi-concrete) and showed the associated number (abstract) in the addition sentence on the tablet	Took the participant's hand and helped them select a response.
Step 5	Participant determined the (same colored) number of circle images then count on next same colored circle images and said the final added number (sum) and showed it in the addition sentence on the tablet If the participant points to the wrong one of the two addition sentences and taps on it, this wrong answer is automatically deleted and only the correct addition sentence is left on the screen. Then the practitioner gave feedback by re-teaching the correct operational procedure by using the correct addition sentence on screen.	The practitioner explains "Symbol used to indicate Addition is + (plus symbol)". The practitioner became a model for the participant and read the math sentence. 
Step 6	The process continued until the participant performed the skill in a way that was independent with the help of reinforces.	Reinforcer; "You know very well, well done"Sound; "Clapping hends" 

2.4.1. Dependent variable

Data collection occurred six days a week, immediately after the tablet-based questioning during baseline, after instruction during intervention and after intervention generalization and maintenance. The dependent variable was the number of correct answers in determining the right pictorial representation to the given arithmetic notation skills within average three for the response to be considered correct.

2.4.2. Inter-observer reliability

Since the practitioner could monitor whether the instructions collected for internal validity were followed as intended by watching the video recordings, all sessions were primarily videotaped for coding purposes. The first author then educated two coders with prior knowledge of ASD (for example, two doctorate students), and training went on until coders obtained 85% agreement on two consecutive movies, which we reached after watching three videos. Then, for each participant, we chose 80% of the sessions from each condition at random. By dividing the number of agreements by the total number of items and multiplying by 100, inter-observer dependability was computed [44]. IOA (interobserver agreement) ranged from (91.2 to 94.1%) at baseline to (90.3 to 92.1%) during the intervention.

3. RESULTS AND DISCUSSION

3.1. Data analysis

In order to perform formative visual analysis within and between circumstances, we examined the data. Changes in level, trend, and variability are features that are given for conditions. Changes in data patterns, the speed of change, and overlap are characteristics for adjacent conditions. Figure 1 Number of correct responses in determining the right pictorial representation to the given arithmetic notation skills; we included baseline, intervention, maintenance and generalization conditions.

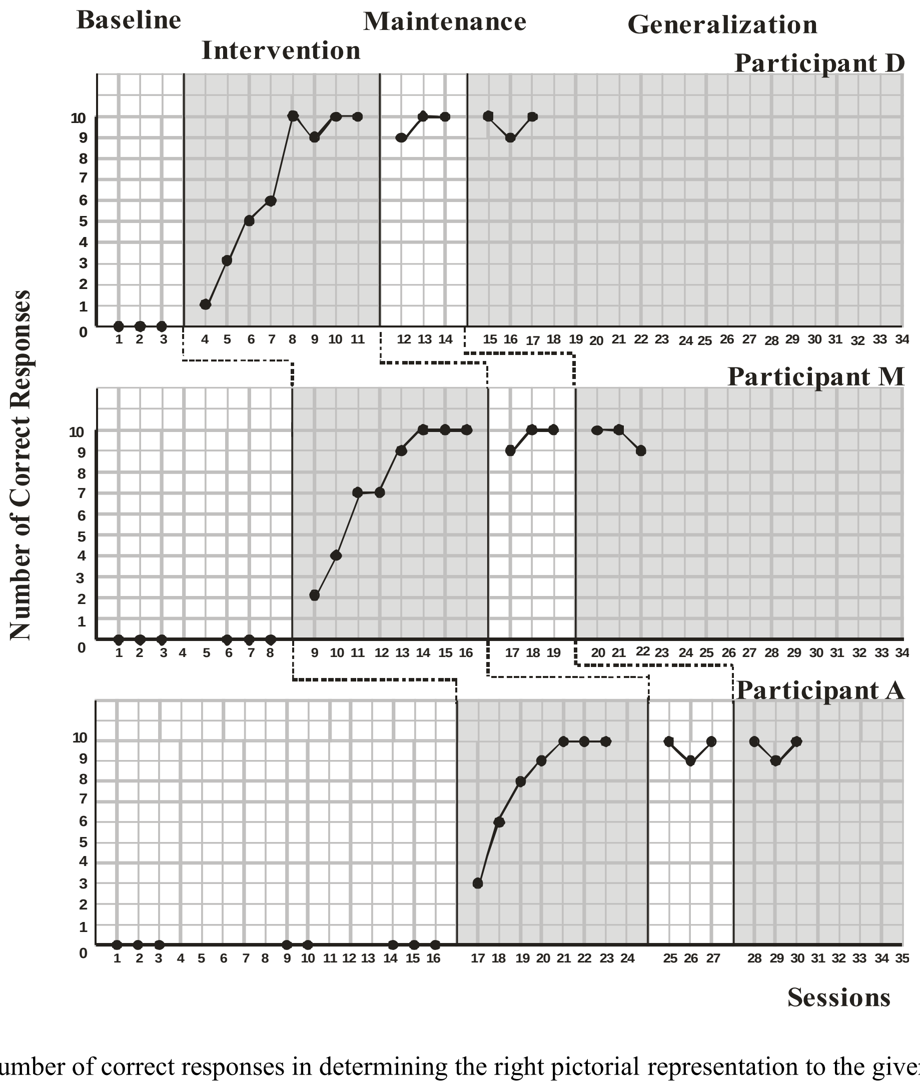


Figure 1. Number of correct responses in determining the right pictorial representation to the given arithmetic notation skills; including baseline, intervention, maintenance and generalization phases.

3.2. Effectiveness

Effectiveness data were collected for the baseline, intervention, maintenance, and generalization sessions. Figure 1 shows that all the participants' baseline data is at a level of 0 before intervention. During intervention phase all the participants are showing a positive slope which resembles increased skill performance. There is one-point drop in intervention phase for participant D and it is seen that the participants achieve independence in skills with 5-6 intervention sessions. It is possible to see similar positive results in maintenance and generalization sessions. Moreover, there is no overlapping data in the graphic Figure 1. Additionally, the social validity scores determined by the classical social validity questions and family views were obtained to be high. Depending on these view families questioned why their children had not learned the related skill for more than a year if results could be obtained so quickly.

3.3. Limitations and future research

This study has some restrictions that must be taken into account. External validity, internal validity, data processing by visual inspection, and most notably the small number of participants, are some of these drawbacks. Internal validity can be strengthened by replicating relevant studies, and design controls for frequent challenges to internal validity can be carried out. We used design controls with an additional check list and collected intraobserver data as before in order to boost internal validity. In this study, inter-observer reliability and procedural integrity were two forms of reliability data that were gathered. The research's inter-observer reliability was found to be 100% for the study's first participant, 95% for its second, and 89% for its third. While the research's procedural integrity practice was estimated to be 98%. When analyzing data by visual examination, it is important to carefully consider the level, trend, variability, immediacy of the effect, overlap, and consistency of data patterns both within and between phases. We carry out the generalization phase to ensure an accurate external validity. For limited number of participants, this disadvantage can be improved through the replication of the study. The results of this study also suggested that future studies can examine how the pre addition activities can be effectively integrated into the math interventions for children with ASD.

4. DISCUSSION

The aim of this research is to determine the effectiveness of the applications offered with tablet-mediated intervention in learning pre addition skills of students with ASD. In the research, high level and stable data were obtained after 4-6 sessions. High-level and stable data were also preserved in the maintenance and generalization sessions as well. Moreover, the social validity data showed that the families were also satisfied with the application.

As a result, students with ASD could have trouble understanding abstract ideas like the mathematical symbols that are used so frequently. For certain students, the transition to symbolic and abstract representation may be mentally exhausting or developmentally difficult [39]–[41]. Therefore, before solving equations at the symbolic, abstract level, certain students may need additional scaffolder training [37]. Visual aids are helpful while studying math, and they can be utilized to promote pupil learning as they progress. As a result, visual aids are included in a variety of mathematics interventions for students with ASD, including presentations with tablet-mediated interventions. Concrete-representational-abstract (CRA) sequencing is used in tablet-mediated treatments to systematically enhance students' development from non-symbolic to abstract skills. The progressive transition from the concrete level to the abstract level encourages proficiency at each level, but it takes time to adjust to working with abstract numbers and symbols. Whereas the programs offered with tablet applications shorten the learning time considerably. In this study, the positive results that could not be achieved by teaching with pencil-paper studies in two semesters enabled the students to acquire pre-addition skills in a short time with tablet applications. Although it is known that the generalization in single-subject studies is quite limited, it gives the impression of a fun and successful method that teachers who teach children with ASD, that have difficulty in transitioning from concrete to abstract, can include tablet-mediated interventions in their practices.

Digital activities in mobile technologies have been said to increase children's opportunities to learn and practice skills in an active learning environment. It can make mathematics more meaningful, applicable, and interesting. Because of this, children's poor arithmetic performance globally demonstrates the need for a better method of teaching math ideas than the conventional method.

Children begin learning to count at age two, although they may not necessarily understand the cardinal meanings of the numbers until they are four or five years old [45]. Early childhood education pioneers such as Montessori, Plato, Pestalozzi, Froebel, Owen, and Dewey believed that young children should learn mathematics through play in light of this growth [46]. Many early educators and academics agree that using tangible objects is an important part of effective arithmetic instruction in the primary grades [47]. One of the evidence-based practices (EBP) that teachers can use to teach mathematics sequentially through the three phases of learning—concrete manipulations, pictorial representations, and abstract notations—is physical-representational abstract (CRA) sequencing instruction.

According to the neurodiversity-related uniqueness, certain ASD youngsters may find it difficult to draw links between object counting and cardinal processing. If this situation persists, kids run the risk of being unable to do basic math operations like addition and subtraction. The abstract nature of mathematics and the neurodiversity among students with ASD can be overcome with new methods and clear instructions. In this study, explicit instruction using mobile technology was used to replace concrete-representational-abstract (CRA) sequencing instruction with representational-abstract sequencing instruction.

Our representational-abstract sequencing instruction data results provide credence to the idea that tablet-based learning can improve pre-addition task performance (choosing the appropriate graphical representation for the given arithmetic notation skill). These results are in line with other research [41], [48] that argues that when mathematical activities are engaging and enable kids to learn about and explore mathematical ideas through a variety of stimuli, they can successfully aid in the development of their mathematical aptitude.

5. CONCLUSION

The learning of mathematics presents numerous difficulties for students with ASD, yet there is little research to support interventions in this area. It may be difficult for students with ASD to process mathematical language. Related research data reveal that tablet-mediated intervention is an effective method in teaching pre-addition skills. Looking at education from the framework of what the child needs to learn today for a skill that he or she should do in the future will support us to write meaningful behavioral goals while creating an individualized education plan. This is particularly the case for math skills, where the topics are woven together like a spiral. Even though we teach the subjects on discrete basis, at the end of the day, associating mathematics subjects with each other is one of the building blocks in the development of a rich understanding of mathematics. In this way, the way for deeper learning will be opened by supporting the establishment of weak connections between mathematical skills, which is the missing point of discrete applications.

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