ENHANCING MATHEMATICAL SKILLS IN STUDENTS WITH AUTISM SPECTRUM DISORDER (ASD): A CREATIVE ART APPROACH WITH CABAMATH MOBILE APPLICATION

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Abstract: Individuals with autism spectrum disorder (ASD) need personalized instruction in mathematics. Creative arts have the potential to foster cognitive development. Hence, a mobile application based on the creative art, CABAMath, was designed. In this study, the effectiveness of CABAMath in enhancing the mathematical skills among ASDs was evaluated. A one-group pre-test post-test quasi-experimental design was implemented with six ASD students with Level 1 severity (DSM-IV) to examine their mathematical and behavioral situation. The technical usability of CABAMath was also investigated. There were significant improvements in students' basic mathematical skills for understanding shapes ($t(5) = 7.319$, $p=0.001$) and numerical abilities ($t(5) = 5.937$, $p=0.002$), but less significant in understanding colors ($t(5) = 4.392$, $p=0.007$), size ($t(5) = 4.54$, $p = 0.006$), addition ($t(5) = 4.54$, $p=0.006$), and subtraction ($t(5) = 3.141$, $p=0.026$. This indicates that CABAMath may be effective in enhancing mathematical skills among ASD students. However, the study's limitations are the small sample size and limited practice time. This study may be useful to assist ASD students in learning mathematics and provide teachers, instructors, and parents with an educational tool for this purpose. Future research could expand CABAMath to include additional content and advanced mathematical skills.

Keywords: Autism spectrum disorder, mobile applications, education, creative art, mathematical skills.

INTRODUCTION

Autism spectrum disorder (ASD) constitutes a complex neurodevelopmental condition with a complicated etiology exerting significant effects on individuals throughout their lives (Beltrão-Braga & Muotri, 2017). Individuals with autism present unique challenges, influencing various domains of development, including socialization, adaptive skills, language and communication, and academic learning (Sengupta et al., 2015), as well as limited interests and repetitive behaviors (Roberts & Webster, 2020). Notably, in education, it is important to acknowledge that students diagnosed with autism may have distinct educational requirements that differ from those of their neurotypical peers (Sasson et al., 2017; Witzel et al., 2023).

Mathematics skills acquisition, in particular, plays a pivotal role in enhancing autistic students' life quality, necessitating its inclusion in their educational curriculum (Park et al., 2020). However, individuals with autism often encounter unique challenges in learning and applying mathematical concepts due to the complex cognitive requirements involved (Siregar et al., 2020). Approximately 25% of individuals with ASD struggle with learning mathematics (Gevarter et al., 2016; Mazon et al., 2022). Various factors contribute to the challenges faced by individuals with ASD in mathematics (Cox & Jimenez, 2020).

One challenge is the difficulty of abstract reasoning (Minshew et al., 2002), meaning ASD people may struggle with the cognitive flexibility needed for tasks that involve higher-level abstract reasoning, such as organizing and understanding complex information (Minshew et al., 2002). This cognitive impairment is observed in individuals across the entire spectrum of the disorder (Santos et al., 2017).

In addition, articulating mathematical symbols and understanding their meanings posed a challenge (Geary, 1993; Peklari, 2019). When students learn numbers, they should incorporate different ways of representing each number, such as quantity, word, and digit (Kim & Cameron, 2016).

ASD children face a big barrier when translating mathematical concepts into their understanding and applying them in problem-solving. Mental arithmetic is essential for children to learn, but the emphasis should focus on fostering higher-order thinking, reasoning, and critiquing skills, as well as the ability to understand numbers and number operations (Erdem et al., 2011; Pourdavood et al., 2020). Mental arithmetic and mental calculation have a relation with other math skills such as learning number line and their relation, conceptual understanding (Ruiz & Balbi, 2019), learning percentages (Lubis et al., 2017), number sense, problem-solving skills (Lemonidis, 2015) and calculation written skills (Pourdavood et al., 2020). Aagten-Murphy et al. (2015) indicate that 6% to 22% of these students experience difficulties with calculation and mental arithmetic. However, according to Mah Jabeen et al. (2021), approximately 11.4% of students in mainstream schools are identified as having difficulties with arithmetic calculation and mathematical techniques, with the breakdown being 10.5% for male students and 16.5% for female students.

Another challenge is the limited short-term working memory capacity (Tasha Oswald et al., 2016). Working memory, crucial for managing, arranging, and actively retaining relevant information for intricate cognitive activities such as mathematics (Fauziyah & Budayasa, 2022; Raghubar et al., 2010), seems limited. This exacerbates the challenges.

Additionally, children with ASD frequently encounter difficulties relating to attention, including a limited ability to sustain focus, problems with shifting attention, an intense concentration on particular tasks or subjects, and a decreased ability to ignore distractions (Ridderinkhof et al., 2020; Tan & Kastberg, 2017).

Moreover, the signs and behaviors exhibited by students with ASD, such as difficulties in engaging in reciprocal social and emotional connections, restricted eye contact, and struggles in non-verbal communication (Li, 2016; Sicile-Kira, 2014), worsen their difficulties in learning. There might also be various other difficulties that are highly individual among each student on the autism spectrum.

Furthermore, given the diverse learning requirements of students with ASD, adopting appropriate instructional strategies becomes imperative, according to Baglama et al. (2017). Technological advancements, such as mobile applications, are well-established strategies for improving individuals diagnosed with ASD, including their education (Kokkalia & Drigas, 2016; Vlachou & Drigas, 2017). Moreover, technology offers individualized instruction and differentiation opportunities, potentially revolutionizing special education (Arouri et al., 2020).

Mobile learning provides numerous benefits in educational environments due to its easy accessibility without requiring substantial technological expertise, non-threatening nature, and inconspicuous classroom presence (Criollo-C et al., 2021). Mobile learning is an approach that necessitates careful attention to several factors, such as developing customized educational materials for mobile devices and accommodating mobility while adhering to pedagogical principles (Kokkalia & Drigas, 2016).

Mobile applications are captivating, aesthetically pleasing, and have the ability to attract the attention of children with autism, which supports earlier research on the benefits of using mobile technology (Vlachou & Drigas, 2017).

Prior studies have shown that individuals with ASD demonstrate greater engagement with educational applications compared to regular classroom settings (Kbar et al., 2015; Sondhi & Devgan, 2013; Vlachou & Drigas, 2017). Hence, mobile applications hold promise in addressing the needs of individuals diagnosed with ASD (Mohamad et al., 2020). Prior research has primarily concentrated on creating mathematical tools for students with ASD, specifically targeting fundamental numerical abilities such as numbers below 100, addition, and subtraction (Abreu et al., 2017; Aburukba et al., 2017; Mazon et al., 2022; Mohamad et al., 2020; Mohd et al., 2020; Munoz et al., 2016; Satsangi & Bouck, 2015; Tabassum, 2020; Tashnim et al., 2017).

Customized mathematics training can enable individuals with ASD to attain performance levels that are comparable to those of their neurotypical peers (Thompson, 2018). This study focuses on implementing the CABAMath application for six students diagnosed with level 1 severity ASD according to DSM-IV to evaluate the usability and effectiveness of the CABAMath application with two objectives: 1) To evaluate the effectiveness of the CABAMath application in improving mathematical skills among ASD individuals, as measured by learning gain; 2) To assess the CABAMath application's usability from a technical perspective.

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CREATIVE ART INTEGRATION IN EDUCATION

The CABAMath application integrates creative art, leveraging individuals' visual processing strengths (Chung & Son, 2020) and enhancing their mathematical skills. Engagement in the creative arts has shown the potential to foster cognitive development and educational skills among individuals with ASD (Bawazir & Jones, 2017; Maykel & Kaufman, 2022).

Artistic activities can encompass numerous areas of intellect and have been linked to different brain regions (D'Amico et al., 2015). Based on the theory of multiple intelligences, creative arts can be seen as a useful approach to improving the learning abilities of individuals with ASD. This is achieved by actively stimulating their imagination through various mediums such as art, dance, dramatic play, puppetry, and music. As a result, individuals with autism are engaged in cognitive, language, social, emotional, and physical aspects of learning (Mills, 2014).

Utilizing symbols and signs in art activities enhances information retention and application for children with autism, emphasizing the significance of visual art in improving information retention for those on the autistic spectrum (Bawazir & Jones, 2017).

According to Chamberlain and Wagemans (2015), there is a connection between drawing skills and a decrease in perceptual constancy effects. Additionally, drawing skills are associated with improved visual encoding, selection, and local visual processing. Hence, the integration of visual art has emerged as a potential method for improving engagement and academic results among students with special needs (Bin et al., 2023), which can enhance students' self-assurance, motivation, involvement, and emotional and social well-being, fostering their ongoing development as lifelong learners (Saunders & Nicholas, 2021).

Integrating creative arts into different educational activities shows potential for individuals with autism improvement, as it allows them to express their ideas and thoughts creatively and offers opportunities to improve the overall quality of life, academic achievement, and social development (Khairuddin et al., 2023). Participating in artistic endeavors promotes the growth of problem-solving techniques, nurtures innovative thinking, and improves comprehension, cognition, and perceptual abilities in a supportive setting (Allahverdiyev et al., 2017; Lowe, 2016).

METHOD

This study is a quasi-experimental research design with one group pre-test and post-test study. A score sheet questionnaire was used as the pre-test and post-test were created to simulate a math assessment for the students who participated in this study. The researcher used a checklist to track any behavioral and mathematical advancements made during implementation.

After implementation, a semi-structured interview was administered with the teacher responsible for the math classes of the same ASD students. The objective was to ascertain the individual's perceptions of the application's usability, specifically its effectiveness for mathematical improvement.

The sample included in implementing the CABAMath application involved six ASD students in level 1 (require support) according to DSM-IV (1994), under the supervision of one special needs education teacher. Table 1 displays the profile of the ASD students who participated in this study.

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Table 1.
Profile of Students with ASD

Student	Severity	Gender	Age	Information
1	Level 1/Hyperactive	Male	11	Good communication, Low focus
2	Level 1	Male	14	Repetitive behavior, non-verbal communication
3	Level 1	Male	10	Repetitive behavior, non-verbal communication
4	Level 1	Male	9	Repetitive behavior, non-verbal communication
5	Level 1	Male	11	Shy, low confident, minimum communications
6	Level 1	Male	10	Good communication, average focus

Data Analysis
The first step involves conducting a normality distribution test to analyze the data based on a one-group pre-test/post-test design, ensuring a normal distribution of all data. The Shapiro-Wilk test was used for statistical normality tests as there were only six participants in this study. The Shapiro-Wilk test has more statistical power in small sample sizes (Mooi & Sarstedt, 2011). The subsequent null hypothesis was constructed to assess the normal distribution of the test scores:

Null Hypothesis (H_0): The pre-test and post-test scores exhibit a normal distribution.

The normality test and t-test were conducted separately for every lesson.

To ascertain whether there is a difference between the means of the two sets of data, the paired samples t-test was applied to check the improvement of students in each lesson under the CABAMath implementation. The paired samples t-test is a statistical analysis utilized to ascertain whether there exists a significant distinction between the means of two related groups (Hedberg & Ayers, 2015).

Comparing pre-test and post-test scores was used to determine the effectiveness of the CABAMath application. The null hypothesis (H_0) states that there is no significant difference between the means of the two groups. There is no significant difference between the pre-test and post-test scores concerning learning gain in this study.

CABAMath Lessons
The CABAMath application encompasses the following lessons: 1) understanding color, 2) understanding shapes, 3) understanding size, 4) numerical abilities, 5) addition, and 6) subtraction, as well as behavioral improvement. The curriculum in the CABAMath application is aligned with the Early Numeracy Curriculum (MOE, 2015) and the needs of special education students. The Early Numeracy Curriculum is outlined in the *Dokumen Standard Kurikulum dan Pentaksiran* (DSKP) by the Ministry of Education (MOE) Malaysia. Lessons progress from basic to advanced levels, catering to students' learning paths. Teachers can adjust the learning lessons flexibly based on each student's knowledge and readiness.

One of the lessons in the CABAMath application is learning basic colors initially for basic mathematical concepts before progressing to more complex concepts.

The introduction to colors, understanding of basic shapes, and understanding of size and quantity were included in this lesson. Students engage in drill and practice exercises across all steps until they master the aforementioned areas. Advancement to level one is based on teacher approval.

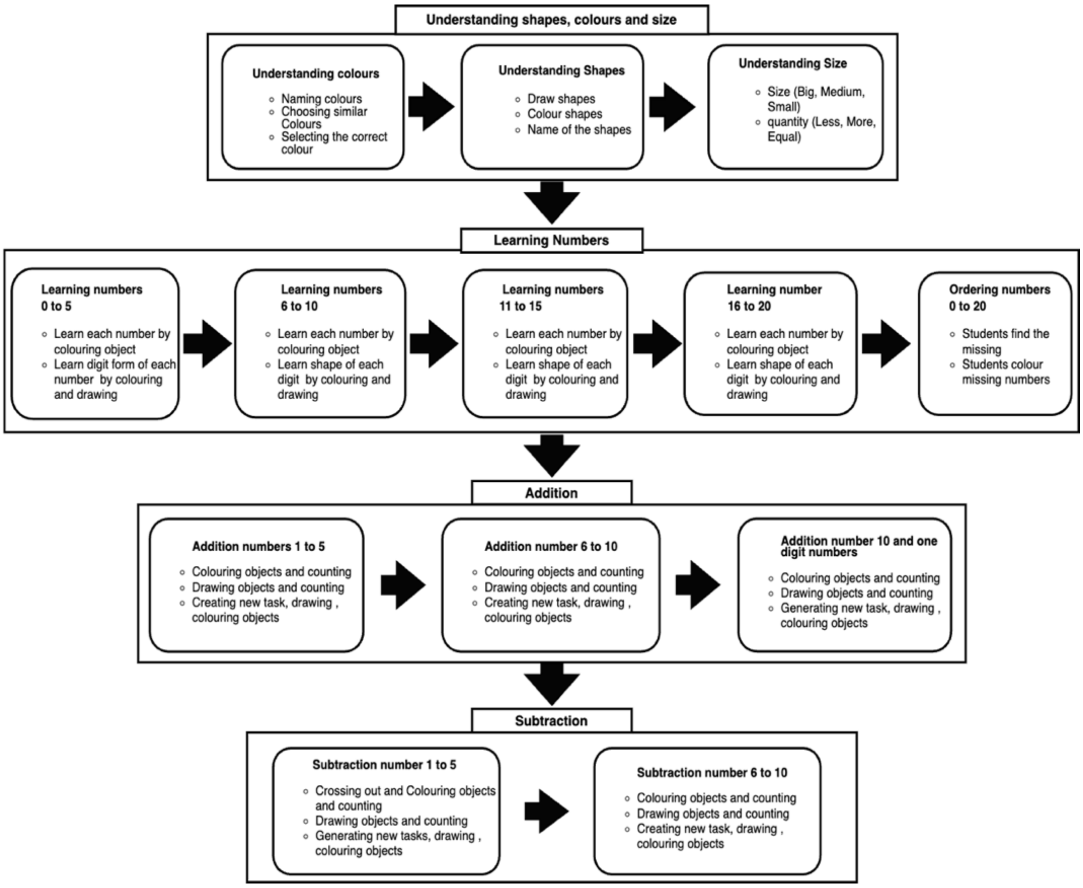
The numerical abilities are divided into five categorized activities to facilitate comprehension for students and streamline the application's developmental progress, as shown in Figure 1. Progression to subsequent lessons is contingent upon students completing the steps and proved by the teacher.

The CABAMath application adheres to a consistent structure throughout each learning number's steps. For instance, in the ordering the numbers level, students learn to sequence numbers by identifying and coloring the missing numbers sequentially. Once students have completed the number learning and verified their understanding by the teacher, they can progress to the next lesson.

The last lesson of the CABAMath application focuses on subtraction, which is accessible to students who have completed all previous lessons without errors, with their progress confirmed by the teacher (See Figure 1).

The CABAMath application interface was developed using the *Penpot* online platform, a tool for crafting visually appealing and user-friendly interfaces. *Penpot* was utilized for its cost-effectiveness and accessibility.

Figure 1.
The Framework of Lessons and Content in CABAMath Application



The User Interface of CABAMath

In designing the user interface for the CABAMath application, the researcher adheres to guidelines for creating applications tailored for individuals with ASD (Dattolo & Luccio, 2017; Jailani et al., 2015; Zamry et al., 2022). Figure 2 shows the sample of user interfaces of the CABAMath application.

Figure 2.
User Interface of the CABAMath

Structure of the CABAMath

The CABAMath incorporates Structures and options across different subjects. These structures cater to diverse learning styles and preferences, ensuring engagement and effectiveness in the learning process. The following actions are employed in each step:

1. Draw objects and count: Students draw objects and count them to reinforce numerical concepts.
2. Follow dotted lines and fill shapes: Students practice fine motor skills by tracing dotted lines and filling in shapes.
3. Color the objects: Students use colors to identify and differentiate objects, enhancing visual recognition skills.
4. Matching numbers and objects or words: Students match numerical or word representations with corresponding objects, reinforcing associations.
5. Painting: Students engage in creative expression through painting, fostering imagination and artistic abilities.

The CABAMath application features two types of tasks, including:

1. Direct structures: Provide clear instructions in tasks involving numbers and objects. Adhering to the prescribed structure by teachers' guidance.
2. Blanked canvas: With minimal information provided. Students are encouraged to explore and create their mathematical scenarios. Teachers guide students by assigning various tasks and challenges.

Additionally, all stages in CABAMath include options for repeating tasks multiple times. This flexibility allows students to reinforce learning and mastery at their own pace while teachers can tailor instruction to individual needs and provide ample practice opportunities.

The CABAMath employed instructional strategies including:

1. Drill and practice: This method involves disciplined and repetitive exercises aimed at teaching and perfecting a skill or procedure. Research has shown that students with ASD benefit from drill and training methods to enhance their understanding effectively (Lim et al., 2012).
2. Reinforcement: This plays a crucial role in classroom settings, with teacher attention being the most significant form. Other forms of reinforcement include praise, tokens, grades, and promotion, all of which serve as encouragement and motivation for students to achieve more. Research findings indicate that

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offering reinforcements following successful task completions can benefit individuals diagnosed with ASD (Maras et al., 2017).

Development of the CABAMath Application

After finalizing the user interface, the next step was developing the CABAMath application commenced using the *MIT App Inventor*. This platform offered a user-friendly interface for creating simple applications. Within the *MIT App Inventor* environment, an expert in Information technology (IT) with experience in app development closely monitored the researcher's design process, beginning with basic prototypes and gradually refining their projects with interactive elements and functional features.

Examples of the CABAMath application's development using *MIT App Inventor* are shown in Figure 3**Error! Reference source not found.Error! Reference source not found.**.

Figure 3.
MIT App Inventor in Development of CABAMath

Implementation of the CABAMath Application

The implementation of the CABAMath application employed tablets, offering one-to-one mathematics instruction. The intervention's duration is determined by the progression through the steps, with an estimated timeframe of approximately three months. Each session lasted around 20 minutes for each student and was conducted every weekday.

FINDINGS

The six students diagnosed with ASD participated in the pre-test and post-test. The study's normality measure was performed for the group. The normality test and t-test were conducted separately for every lesson.

Understanding Colors

In the lesson on understanding colors, the normality of the data was obtained from all six ASD students' performance. The pre-test and post-test were assessed using the Shapiro-Wilk normality test. The analysis revealed that the significant values for the pre-test ($p = 0.1542$) and post-test ($p = 0.1332$) conditions were greater than the conventional threshold of 0.05. Therefore, it can be concluded that both the pre-test and post-test data support the assumption of normality in subsequent statistical analyses.

The analysis of the findings indicates an increase in scores on the post-test compared to the pre-test among the students. The paired sample t-test was employed to evaluate the students' learning gains in the lesson on understanding color after implementing the CABAMath application. This analysis revealed a statistically significant difference in the scores obtained in the pre-test ($M = 5.833$, $SD = 2.639$) and post-test ($M = 7.333$, $SD = 2.338$) conditions ($t(5) = 4.392$, $p = 0.007$). It is important to acknowledge that the sample size was relatively small ($n = 6$), which may limit the generalizability of these findings. However, the results indicate that students who used the CABAMath application experienced significant gains in understanding color skills. Table 2 shows the result of the paired sample t-test.

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Understanding Shapes
Understanding shapes was the second lesson implemented for all six students with Autism. A Shapiro-Wilk test was conducted to assess the normality of the data for both the pre-test and post-test scores. With a significance level set at $\alpha = 0.05$, the pre-test ($p = 0.6139$) and post-test ($p = 0.2774$) yielded p-values greater than 0.05, indicating a failure to reject the null hypothesis. Thus, based on these results, it can be concluded that neither the pre-test data nor the post-test data appear to be normally distributed. The paired t-test was conducted to evaluate the students' learning gains in the lesson on understanding. The analysis revealed that the null hypothesis was rejected, indicating a statistically significant improvement in learning. The pre-test data showed a mean score of 5.5 ($SD = 2.345$, $n = 6$), while the post-test data had a mean score of 8.0 ($SD = 2.28$). The mean gain in understanding shapes was calculated as 2.5, while ($t(5) = 7.319$, $p = 0.001$), as shown in Table 2.

Understanding Size
In understanding size, the same analysis was applied to test for normality. The significance values for both the pre-test ($p = 0.3430$) and post-test ($p = 0.1264$) are greater than $\alpha = 0.05$, indicating that in both tests, the data are normally distributed.

The t-test conducted to compare the two tests reveals that the null hypothesis is rejected, indicating a statistically significant improvement in the lesson of understanding size scores after the implementation of the CABAMath application. The mean for the post-test ($M = 5.883$, Standard Deviation (SD) $= 2.297$) is higher than that of the pre-test ($M = 3.668$, $SD = 0.875$) and ($t(5) = 4.54$, $p = 0.006$). However, it is important to note that while the improvement is statistically significant, the magnitude of the gain may not be substantial. It suggests that although there was an increase in scores, students may require more practice and time to achieve more significant improvements.

Numerical Abilities
The test of normality was conducted for the lesson on numerical abilities. The results indicate that the pre-test ($p = 0.557$) and post-test ($p = 0.514$) significance values are greater than 0.05, suggesting normal distribution in both tests. The conducted t-test rejects the null hypothesis, with a pre-test mean of 4.333 and standard deviation of 1.966, and a post-test mean of 7.167 and standard deviation of 1.329, in addition ($t(5) = 5.937$, $p = 0.002$), indicating a statistically significant improvement in learning numerical abilities after implementation.

Addition
In addition, the results of the normality test indicate that the significance score for the pre-test is 0.4588 and for the post-test is 0.4206, both exceeding 0.05. Thus, the null hypothesis was rejected, indicating that the data are normally distributed in both tests.

Subsequently, to measure the improvement in addition among all six students, a t-test was conducted, with results displayed in Table 2. Based on the t-test findings, the mean for the post-test ($M = 5.5$, Standard Deviation (SD) $= 3.507$) is higher than that of the pre-test ($M = 3.333$, $SD = 2.503$), and ($t(5) = 4.54$, $p = 0.006$) there is a significant improvement in subject of addition. While the obtained outcomes show progress, it is important to acknowledge that the extent of this improvement may not be considerable. Students might need additional practice and time to make more significant advancements.

Subtraction
The normality of learning subtraction was examined. The significance scores for both the pre-tests ($p = 0.1011$) and the post-tests ($p = 0.8013$) are above 0.05, suggesting that the data appears normally distributed in both instances.

A t-test was performed to evaluate the progress of ASD students in subtraction. The pre-test mean ($M = 1.0$) and standard deviation ($SD = 0.837$) suggest ASD students had little previous knowledge of subtraction. However, in the post-test, the mean ($M = 3.5$) and standard deviation ($SD = 2.739$) and ($t(5) = 3.141$, $p = 0.026$) indicate a significant improvement in learning subtraction following the implementation of CABAMath (see Table 2).

Behavioral Assessments
The study not only assessed the learning progress in core mathematics lessons but also evaluated the behavioral improvements among ASD students toward learning math. The researcher prepared a checklist of behaviours and

assessed before and after the implementation for each student. The researcher observed the mathematics classroom during the pre-test and monitored implementation sessions for the post-test. The results show that the significance score for the pre-test is 0.1670 and for the post-test is 0.2117, both exceeding 0.05. This suggests that the data appears to be normally distributed in both instances.

The t-test was performed to assess the behavioral improvement of the six students following the implementation. As shown in Table 2, the pre-test means ($M = 3.0$) and standard deviation ($SD = 0.894$) compared to the post-test mean ($M = 5.167$) and standard deviation ($SD = 0.753$), and ($t\,(5) = 5.5$, $p = 0.0$), demonstrate an improvement across different aspects of student behavior observed during the implementation. However, most importantly, behavioral improvement would be related to engagement and later develop an interest in maths learning. **Error! Reference source not found.** illustrates the learning gain of ASD students in all lessons of the CABAMath.

Table 2.
Paired Samples T-Test for Lesson of CABAMath

Subject	**Test**	**mean**	**N**	**SD**	**T**	**dF**	**Sig.**
Understanding Colors	Pre-test	5.833	6	2.639	4.392	5	0.007
	Post-test	7.333		2.338			
	Gain	1.5					
Understanding Shapes	Pre-test	5.5	6	2.345	7.319	5	0.001
	Post-test	8.0		2.28			
	Gain	2.5					
Understanding Size	Pre-test	3.668	6	0.875	4.54	5	0.006
	Post-test	5.883		2.297			
	Gain	2.167					
Numerical abilities	Pre-test	4.333	6	1.966	5.937	5	0.002
	Post-test	7.167		1.329			
	Gain	2.833					
Addition	Pre-test	3.333	6	2.503	4.54	5	0.006
	Post-test	5.5		3.507			
	Gain	2.167					
Subtraction	Pre-test	1.0	6	0.837	3.141	5	0.026
	Post-test	3.5		2.739			
	Gain	2.5					
Behaiviural Improvement	Pre-test	3.0	6	0.894	5.5	5	0.0
	Post-test	5.167		0.753			
	Gain	2.167					

P<0-05

In assessing the behavioral improvement of students with ASD, various aspects were considered, such as one-to-one interaction, interest in tasks, engagement in tasks, students' focus, and students' motivation.

One-to-One Interaction with Teacher. Initially, establishing rapport with students posed challenges due to shyness and limited verbal expression. However, as sessions progressed, students became more comfortable, engaging in verbal communication and displaying positive nonverbal interactions.

Students' Interest. Students displayed genuine interest in using digital devices and exploring the features of the CABAMath. This autonomy in tablet usage contributed to an increased focus on ASD students during tasks.

Engagement with CABAMath Application. Students showed increased engagement and focus during sessions with the CABAMath. The tactile experience of using tablets and the interactive nature of the tasks kept students attentive and motivated throughout the sessions.

Student's Focus. During sessions, students demonstrated commendable focus levels, with minimal distractions or disruptions due to the tranquil atmosphere and engaging tasks within the CABAMath.

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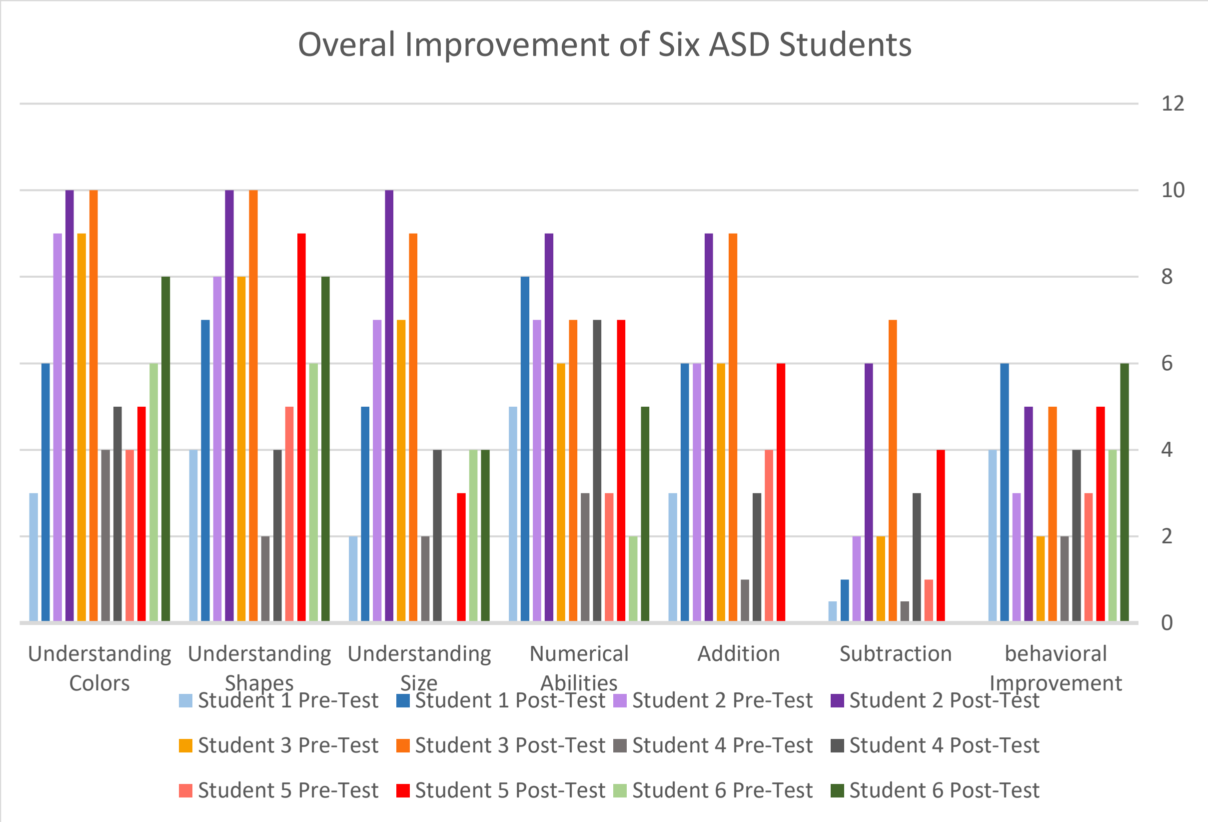
Students' Motivation. The CABAMath application significantly boosted student motivation and enthusiasm for learning math. Students eagerly anticipated sessions, actively participated in activities, and displayed excitement and joy during the learning process.

Figure 4.
Learning Gain of Students with ASD in Lessons of CABAMath



Usability Of the Cabamath Application

The study employed a comprehensive approach to ensure the robustness of the findings. This involved direct observations and semi-structured interviews with a teacher overseeing the student's progress with the application. By triangulating data from these diverse sources, we bolstered the credibility and depth of our evaluation process.

Pedagogical Usability. The teacher observed significant advancements in fundamental lessons such as colors, shapes, and sizes among the six students with ASD. Notable improvements were also noted in their numerical abilities, particularly in addition and subtraction. Three students, in particular, showed pronounced progress: “I noticed that the students who used the CABAMath application showed significant improvement in their understanding of colors, basic shapes, and understanding sizes. Some of the students can recognize shapes better than before. The visual and interactive nature of the app seemed to help them grasp these concepts more effectively”, and “The Numerical abilities of the students improved noticeably after implementation. The application's focus on number learning and engagement seemingly enhanced their numerical understanding, especially in numbers one to twenty. The two students can read and count numbers in order with no doubt. Another student can recognize numbers bigger than ten which couldn’t before”. “Also, I see improvement in the addition skills of the students. One of the students needed more guidance before compared to now. He can solve simple additions much easier than before. Another student seems to understand the concept better”, and “Similar addition, and subtraction also improved in three students”.

Behavioral Improvement. The teacher noted significant behavioral improvements in all six students with ASD after implementing the CABAMath application. The students displayed heightened interest, motivation, and active participation in math lessons, resulting in a more focused classroom environment. "I observed positive changes among the students. They seemed more engaged, attentive, and motivated during math lessons. There was a noticeable reduction in disruptive behaviour, and the classroom environment became more focused." "The students showed an increased interest in mathematical subjects during your work and after it. They appeared more eager to participate in math-related painting and drawing and seemed to genuinely enjoy learning math through drawing and painting. I saw they joined your class voluntarily and they were waiting for their turn to call them to learn math with CABAMath. I see motivation". "I do believe that using the app (CABAMath) had a positive impact on student motivation. The app's interactive and visually engaging nature seemed to motivate students to participate actively and take an interest in math specifically at the time they start painting for mathematical tasks".

Effect of Art in Learning Gain. The use of creative art within the CABAMath application significantly impacted the learning gain of students with ASD. According to the special needs teacher's opinion, she observed that the students demonstrated an increased interest in mathematical lessons both during and after the implementation. They showed greater enthusiasm to participate in math-related painting and drawing activities and genuinely enjoyed learning math creatively. Additionally, the teacher mentioned the application's interactiveness and visual appeal in motivating students to participate and take an interest in math. Moreover, the teacher mentioned that "using art painting in the app (CABAMath) makes students motivated".

Initially, the application encouraged students to engage in activities such as coloring, drawing, and painting to stimulate their creativity and provide reinforcement during tasks.

DISCUSSION

The effect of the CABAMath application in enhancing mathematical and behavioral skills was evident in pre-test/post-test data analysis and researcher observations during implementation. Additionally, the opinions of ASD teachers regarding student improvement in mathematical skills and behaviour supported these results. However, it was noted that students require more practice, particularly in lessening addition and subtraction.

Previous studies have developed mobile applications for teaching addition and subtraction to students with ASD, employing various approaches and strategies. For instance, Tashnim et al. (2017) utilized dotted line games for numeracy and operations, while Tabassum (2020) and Satsangi and Bouck (2015) implemented virtual reality for the same purpose. Mohd et al. (2020) utilized a series of 2D domination AI games, and Mohamad et al. (2020) employed puzzle games. These studies have shown significant improvement and promise in enhancing mathematical skills among students with ASD. However, only Kahveci et al. (2023) developed an application employing visual drawings with correct abstract math for pre-addition skills, demonstrating significant improvement among age 7 to 8 ASD children.

On the other hand, there are available studies on numerical abilities, including Karanfiller et al. (2018) with a pictorial application, Weng and Bouck (2019) with the number line approach, and Mohamad et al. (2020) with games for this purpose.

In the CABAMath application, creative art is an approach to teaching math lessons. Students displayed a keen interest in coloring and painting, demonstrating focused attention in selecting and matching colors, as well as meticulousness in drawing and coloring precision. The observed learning gains across all lessons, coupled with noted behavioral improvements in students' attitudes toward learning math, underscore the effectiveness of incorporating creative art. This approach motivates students, fostering genuine interest and heightened engagement in completing tasks within the CABAMath.

The literature provides numerous instances demonstrating the utilization of creative arts to assist persons with ASD. Drawing, for example, is a significant instrument for efficiently conveying the opinions of individuals with autism, surpassing the effectiveness of written text or spoken communication. Drawing, as a nonverbal mode of expression, allows children with autism to effectively convey their experiences (D'Amico et al., 2015).

The instructional strategies of CABAMath include drill and practice and reinforcement. Through the utilization of the CABAMath, students with ASD have the opportunity to engage in drill and practice strategies. Both students and teachers can repetitively go through each step of the application as needed, receiving progress reports after completing each step to compare and track students' progress.

Butler et al. (2001) conducted a review study synthesizing findings from the literature on math interventions for students with mild to moderate intellectual disabilities. They highlighted extensive drill and practice as a crucial component of effective math training programs. In the context of the CABAMath, implementing the drill and practice instructional approach has demonstrated the potential to enhance students' engagement and comprehension of mathematical concepts encapsulated within the application. This instructional strategy has yielded tangible benefits, manifesting in improved academic performance and enhanced proficiency in mathematical competencies among students.

Moreover, in CABAMath, internal reinforcement motivates students with ASD to complete all tasks. Additionally, teachers have opportunities to provide external reinforcement, such as words of encouragement, further motivating their students. The effectiveness was observed by the researcher during the implementation phase, where students made efforts to complete tasks correctly to receive in-app stickers as rewards.

Concerning learning gain among students with ASD in mathematical lessons, significant improvement was observed in lessons such as understanding colors and shapes and numerical abilities. However, lessons like understanding colors, size, addition, and subtraction showed less improvement than others. The study's limitations, including the small sample size and limited timing for practice, may have contributed to this lesson improvement. Nevertheless, although the improvement was seen in all lessons, the data may not be generalisable due to the limitations of this study. With continued practice, students may experience greater improvement in these lessons.

The behavioral improvement of ASD students also showed significant enhancement after the implementation of CABAMath. The study evaluated various aspects of behavioral improvement, such as *one-to-one, students' interest, engagement, and student focus.* Individuals with Autism have demonstrated a propensity for increased engagement with educational applications (Vlachou & Drigas, 2017). suggesting heightened interest and motivation when utilizing digital learning platforms. Additionally, incorporating creative arts into various learning activities has shown promise for individuals on the autism spectrum.

The literature suggests that creative arts interventions can effectively engage individuals with autism across diverse cognitive abilities, with drawing activities as a particularly motivating tool (Bawazir & Jones, 2017). Therefore, integrating creative arts into CABAMath may yield behavioral improvements among ASD students. This highlights the application's potential to create inclusive and stimulating learning environments for students with diverse learning needs.

CONCLUSIONS

The CABAMath was designed and developed, then implemented and evaluated with six students diagnosed with ASD at Level 1 severity according to DSM-IV (1994). The participants selected had voluntarily participated in this study with their parental consent. The study used the quasi-experimental method with pre-test and post-test to enhance mathematical skills among ASD students through utilizing creative art in CABAMath. The study assesses the educational usability and behavioral improvements of the CABAMath application.

The educational usability was evaluated in the basic mathematical lessons, including understanding colors, shapes, sizes, numerical abilities, addition, and subtraction. The behavioral assessment includes evaluation of *one-to-one Interaction with the Teacher, Students' Interest, Engagement with the CABAMath Application and Student Focus.*

The results showed that the CABAMath application was an effective and promising tool in both educational and behavioral aspects of ASD students toward learning mathematics, as the learning gains were significant. However, in some mathematical lessons, such as addition and understanding size, the learning gain was less than in other lessons. However, it was noted that variations in the personalities and attention levels of ASD students could have contributed to the differences in improvement levels observed among students. In addition, the limitation of the

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study was the small number of students involved. Thus, although implementing the CABAMath application with only six ASD students may not fully represent the diverse range of needs and responses within the ASD population, it could still indicate the potential for improving skills and behavior among ASD students. Hence, more investigations could be conducted.

Another limitation pertains to the development platform used for the CABAMath application. The chosen platform was suitable for basic app development but may have limited the application's features and user interface. Hence, future studies could investigate whether more powerful applications, especially those with artificial intelligence, could be used to develop even better designs.

The significance of this study is that individuals with ASD need to improve their methodical knowledge by using the CABAMath application and consequently improve their quality of life. Also, it is for teachers, instructors and parents to use the CABAMath application in mathematical education in the classroom or at home for their ASD children. For future studies, it is recommended to expand the scope of the CABAMath application to include other mathematical lessons, such as geometry or multiplication. This would provide a more comprehensive and holistic approach to mathematical learning for ASD students, potentially leading to further improvements in their skills and abilities.

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