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Design of the CABAMath Application based on Fuzzy Delphi Method: Enhancing Mathematical Skills among Students with Autism Spectrum Disorder

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ABSTRACT

Individuals with autism spectrum disorder (ASD) can enhance their educational experiences with mobile applications. Furthermore, previous studies indicate that utilising creative art has a positive impact on Autism spectrum disorder students' (ASDs) educational performance as well as behaviour and attention. This study aimed to design a creative arts-based mobile application (CABAMath) to improve mathematical skills for ASDs with level 1 severity based on DSM-IV. By utilising the Fuzzy Delphi Method (FDM), the study seeks to determine consensus among experts on appropriate elements for CABAMath's design. Key findings include consensus on the CABAMath app's objectives and content, including numerical abilities and understanding shapes and sizes. The instructional strategies for the app include simple games and reinforcement, as well as features for customizable skills and progress reports. The CABAMath approach based on creative arts include colouring, drawing, and painting. Future research may explore the implementation and evaluation of CABAMath to determine its usability and effectiveness.

Keywords: Autism spectrum disorder, creative art, educational technology, Fuzzy Delphi method, mobile applications

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INTRODUCTION

Autism, a neurodevelopmental disorder with symptoms that occur across a spectrum, has a global prevalence rate of 0.72%, representing approximately 79 million individuals worldwide (Talantseva et al., 2023). Access to high-quality education is critical to enhance the life experience

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for ASD individuals (Asahar et al., 2021). However, developing independent living skills encompasses proficiency in practical academic skills such as mathematics (World Health Organisation, 2023). Nevertheless, over 25% of students diagnosed with ASD experience notable difficulties with the abstract concepts in mathematics (Siregar et al., 2020). Additionally, ASD students exhibit characteristic difficulties, which vary across a spectrum, such as short attention span and limited cognitive capacity (Peklari, 2019). For the effective teaching of academic skills to individuals with ASD, instructional approaches need to be tailored to their needs (Tan & Kastberg, 2017). This is to organise students' thought processes, thereby enhancing their cognitive development (Siregar et al., 2020).

Research indicates that ASD children tend to prefer technology-based learning methods over traditional approaches (Tashnim et al., 2017). Hence, by developing user-friendly mobile applications with pedagogical purposes for ASD individuals, there is the potential to enhance their mathematical skills (Munoz et al., 2018). Further, the literature suggests that the creative arts can develop ASD individuals across multiple intelligences (Maykel & Kaufman, 2022). Despite this, creative art for educational purposes has received limited attention in the literature. While numerous studies have explored the development of mobile applications with a variety of strategies in mathematics for individuals with ASD (Hassan, 2020), there is little research on creative arts. Hence, it is critical to determine whether a creative arts-based application could be designed for teaching mathematical skills to ASD students. The potential of creative art integrated in mobile applications for mathematics education needs to be considered. The lack of utilisation of creative arts in mathematical learning applications represents a notable gap in the existing literature, warranting further investigation and exploration. Hence, this study aims to gather experts' consensus to identify the appropriate elements of a creative arts-based application (CABAMath), to enhance mathematical skills among ASD students who exhibit level one severity according to the DSM-IV criteria.

LITERATURE REVIEW

Mathematics Applications for ASD Children

Previous studies have predominantly focussed on developing mathematical applications for ASD children, covering foundational numerical skills such as numbers below 100, addition, and subtraction (Che Ku Mohd et al., 2020; Tashnim et al., 2017), with limited attention to multiplication, division (Che Ku Mohd et al., 2020) and calculation with money (Ntalindwa et al., 2021). Moreover, a few studies have addressed basic topics such as size, shapes, and colours (Winoto et al., 2018).

The strategies employed in previous studies predominantly involve interactive games (Che Ku Mohd et al., 2020;

Winoto et al., 2018), supplemented by visual images (Karanfiller et al., 2018), quizzes (Sweidan et al., 2022), dotted lines (Tashnim et al., 2017), and semi-concrete visual drawings (Kahveci et al., 2023). However, some studies have highlighted the lack of comprehensive instructional approaches that effectively engage and motivate individuals with ASD (Fernández-Batanero et al., 2024).

Creative Arts for Learning among ASD Students

Creative arts utilised alongside various learning activities have shown promise for ASD individuals (Bawazir & Jones, 2017; Famildardashti et al., 2024). Art activities help develop problem-solving strategies, fosters creative thinking in a secure environment, promotes focussed engagement (Lowe, 2016), and enhances ASD individuals' understanding and perception abilities (Allahverdiyev et al., 2017).

Art integration is recognised for its role in facilitating the effective transfer of knowledge and skills across various domains, encouraging students to make connections between different disciplines (Hardiman et al., 2019). Engaging students with art promotes their confidence, enjoyment, motivation and engagement in learning and participation in classroom activities, fostering connections and understanding of curriculum content (Papachrysanthaki, 2022; Saunders, 2021). Furthermore, art integration enables visual representations that empower ASD students to take a more active role in their education (Papachrysanthaki, 2022). According to Bin et al. (2023), visual arts integration has emerged as a promising approach to enhancing engagement and academic outcomes for students with special needs.

Existing research has explored the effects of art integration in various subjects, such as science (Hardiman et al., 2019), social-emotional skills (Anderson & Valero, 2020), ASD students' academic achievement (Navei et al., 2022), language development (Spence, 2014), STEM (Butera et al., 2016) and geometry (Bin et al., 2023). However, art integration in teaching mathematics to ASD students has received little attention.

Theoretical Framework

There are two theories that are related to the current study. 1) Piaget's Theory of Cognitive Development ; and 2) Mayer's Cognitive Theory of Multimedia Learning (CTML).

Jean Piaget's theory of cognitive development delineates stages of intellectual maturation in children. This theory underscores the significance of play, exploration, and hands-on experiences as fundamental components of learning (Pakpahan & Saragih, 2022). According to Piaget's theory, students require a curriculum that supports their cognitive development by helping them acquire concepts and progress logically (Lefa, 2014). Therefore, CABAMath needs to accommodate differences in thinking quality. Piaget emphasises the importance of active learner engagement in the learning process. By incorporating a creative art approach into CABAMath, learners take an active role in tasks.

Piaget's theory acknowledges individual variations in cognitive development (Lefa, 2014), and hence, the CABAMath application organises one-to-one activities. By understanding ASD students' cognitive levels, teachers should adjust their teaching methods accordingly.

Mayer's Cognitive Theory of Multimedia Learning (CTML) holds particular significance in the field of education, focussing on problem-solving and the creation of educational multimedia. According to this theory, the concurrent presentation of visual and verbal information maximises learning effectiveness (Mayer & Moreno, 2003). CTML emphasises the importance of designing multimedia materials that align with cognitive processes to optimise learning outcomes (Mayer, 2005). Learning occurs through the internal processing and transformation of data into long-term memory, often facilitated by experiential learning. Applying Mayer's theory to the development of CABAMath's user interface and content is geared towards optimising the mathematical learning outcomes of ASD students.

To facilitate students' construction of mental images and improve cognitive and long-term memory, CABAMath will incorporate creative art, including drawing and painting, into its design. This approach aligns with cognitive learning principles, which emphasise the importance of engaging learners through visual and experiential means.

METHODS

Research Design

The study employed the Fuzzy Delphi Method (FDM), which is an objective and time-efficient approach to securing consensus (Murray et al., 1985). FDM uses expert consensus to identify the most suitable elements for the design of CABAMath, addresses uncertainties using linguistic variables (Abdullah & Yusof, 2018), and has been used to garner consensus in generating ideas for designing innovative curricula, modules and solutions (Awang et al., 2016). There are two rounds in the FDM. The first round entailed semi-structured interviews with six experts to identify potential elements of CABAMath related to the mathematical content within the application, the instructional strategies, the technical features, and the user interface considerations. In the second round, the experts were asked to rank their agreement with the sub-elements of CABAMath. The expert consensus on the primary constructs required within the application was determined.

Round 1 of the FDM

Semi-structured interviews were conducted with each of the six experts to gather their opinions on potential elements for CABAMath related to the mathematical content. The experts were asked about the instructional strategies, the technical features, and the user interface considerations in the application. The data from the semi-structured interview were transcribed and analysed thematically. The themes that emerged were structured according to the main elements in the following domains: objectives, mathematical content, instructional strategy, user interface, and features and options. Specifically, six sub-elements were identified for the learning objectives of the CABAMath, while there were twenty-one sub-elements for content. There were eleven sub-elements for instructional strategy, which would outline the suggested curriculum for CABAMath. Similarly, the user interface, features, and options sections each contained eleven and nine sub-elements, respectively.

Experts underscored the importance of incorporating creative art forms such as drawing, painting, and colouring within the application. As expressed by one expert, "This app has to be visual (and) can be helpful for any ASD child. They are concrete learners, and drawing gives them stimulation" (Expert 1). Another expert emphasised the value of art, stating, "Definitely use art, using colours, drawing and painting " (Expert 2). Similarly, another expert highlighted, "They (ASD students) love art very much, use drawing, painting , and colouring'" (Expert 3).

Based on expert insights, the study recognised limitations in using various art forms in a mobile application, opting for digital painting in CABAMath. Aligned with CTML colouring, which emphasises multimedia education, CABAMath incorporates familiar or student-created images for colouring. The structure focusses on drawing, painting, and colouring activities. Music and narration were also considered and included in the FDM instrument to determine expert consensus.

Round 2 of the FDM

This inclusive approach aimed to enrich the process of issue identification, a crucial aspect achievable through the application of FDM (Glumac et al., 2011). In this study, experts were carefully diversified to ensure comprehensive coverage of relevant domains. In the second round of the FDM, 19 experts agreed to provide responses to the instrument. The profile of the experts is shown in Table 1.

Table 1
Profile of experts

Area of expertise	Sex	Position	Experience (years)
Special Needs Education	F	Practitioner	18
	F	Academic	21
	F	Academic	14
	F	Academic	7
	F	Academic	15
Creative Art	F	Academic	+20
	F	Practitioner	17
	F	Academic	15
	F	Academic	13
Information technology (IT) with experience in development of mobile applications	M	Academic	21
	F	Academic	+20
	F	Academic	12
	F	Academic	+20
	F	Academic	13
	M	Academic	+20
	M	Trainer	18
	M	Trainer	15
	F	Trainer	12
	F	Trainer	+20

Source: Famildardashti (2025)

Data Collection and Analysis

The transcripts of the semi-structured interviews of the first round were analysed to identify the key elements and sub-elements, which were subsequently used to form the items in the FDM instrument. The instrument employed a 5-point Likert scale. The FDM instrument was distributed to the panel of 19 experts who had consented to participate in the study. Data from the experts were converted using the linguistic scale shown in Table 2. A systematic analysis was conducted using the FDM formula to determine the level of expert consensus and prioritise the elements to be integrated into the CABAMath, and was computed in Microsoft Excel software, as recommended by Jamil and Noh (2020).

The FDM analysis involved the use of triangular fuzzy numbers and the defuzzification process. The process of the FDM analysis consisted of six steps:

Step 1: Determining the linguistic Likert scale with fuzzy numbers (Saido et al., 2018). To accommodate the inherent fuzziness among experts' responses, each response is assigned three fuzzy values, forming a triangular fuzzy number. Within this structure, m_1 represents the minimum value, m_2 denotes the median value, and m_3 signifies the maximum value. These values, m_1, m_2, and m_3, exist as fuzzy numbers within the range of 0 to 1. Consequently, for every response on the Likert scale, three values are assigned, allowing for a nuanced understanding of expert opinions.

In step 2, The computation of the average fuzzy number entails determining the average responses for each fuzzy number (Abdullah & Yusof, 2018). Step 3 involves identifying the threshold value 'd', which plays a crucial role in determining the consensus level among experts. This was calculated using the following formula:

$$d(\bar{M},\bar{m}) = \sqrt{\frac{1}{3}(M1-m_1)^2+(M2-m_2)^2+(M3-m_3)^2}$$

The acceptance of an element in the triangular fuzzy number stage is determined by two conditions: Firstly, the percentage of expert consensus for an element must be equal to or more than 75.0%, and secondly, the threshold value (d), for each component and/or element must be less than or equal to 0.2.

Step 4 involves identifying the alpha-cut level, which is commonly set at 0.5

Table 2
Linguistic scale

Level of Agreement	Likert Scale	Fuzzy Scale		
Strongly Agree	5	0.6	0.8	1
Agree	4	0.4	0.6	0.8
Neutral	3	0.2	0.4	0.6
Disagree	2	0.1	0.2	0.4
Strongly Disagree	1	0	0.1	0.2

Source: Famildardashti (2025)

due to the range of the fuzzy number being between 0 and 1. Elements with values above 0.5 are accepted, while those below 0.5 are rejected (Saido et al., 2018).

Step 5 involves the defuzzification process. The term "defuzzification process" refers to the method used to rank each construct, component, element, problem, variable, and sub-variable identified in the study. This process aids researchers in determining the importance and ranking of each component under consideration. It involves determining the fuzzy score value (A) based on the alpha-cut value of 0.5 (Rahman et al., 2021). If A is equal to or greater than 0.5, the measured elements are accepted; if it is less than 0.5, the measured elements are rejected.

The defuzzification value (DV) for each element used the following formula to calculate and determine the ranking:

$$DV = \frac{1}{3} \times (m1 + m2 + m3)$$

Step 6 involves ranking the phases and sub-phases (elements) of the model. This ranking is crucial for prioritising the elements based on their defuzzification values (DV) in the model for implementing instruction in the science class. The element with the highest DV is assigned the highest priority, following the principles outlined by Fortemps and Roubens (1996).

RESULTS AND DISCUSSION

In this study, FDM was employed not only to select the elements of the CABAMath application but also to ascertain the importance of each element by ranking them.

Objectives of CABAMath

For the objectives of the CABAMath application, only three of the six sub-elements proposed to delineate the learning objectives achieved sufficient consensus (above 75.0%) and were accepted. The analysis of the defuzzification values to rank the sub-elements, according to experts' consensus is shown in Table 3. Results showed that being able to do simple addition and subtraction achieved the highest ranking (defuzzification value=0. 725), followed by writing and counting numbers in the second rank (defuzzification value=0.688), and understanding shapes and sizes in the third rank (defuzzification value=0. 675).

Content of CABAMath

In content of CABAMath, five main elements with twenty sub-elements were proposed. However, only four of the main elements comprising ten sub-elements were accepted, as shown in Table 3.

The understanding of subtraction secured the top rank (defuzzification value=0.750), followed by five sub-elements tied for second place with an equal defuzzification value of 0.738. These elements include understanding the concept of addition, addition for numbers below 20, subtraction for numbers below 10, ordering numbers, and practicing the concept of bigger, and smaller. The third rank was obtained by writing and counting numbers 0 to 10, with a d value of 0.725.

Table 3
Experts' consensus on elements of CABAMath

Objectives	Fuzzy evaluation			Defuzzification	Ranking
1. Understanding shapes and size	0.475	0.675	0.875	0.675	3
2. Write and count numbers	0.488	0.688	0.888	0.688	2
3. Write and read mathematical words	0.425	0.625	0.825	0.625	Rejected
4. Able to do simple addition and subtraction	0.525	0.725	0.925	0.725	1
5. Understand Malaysian currency	0.375	0.563	0.763	0.567	Rejected
6. Able to proceed with a simple purchase	0.419	0.613	0.813	0.615	Rejected
Content	**Fuzzy evaluation**			**Defuzzification**	**Ranking**
Understanding shapes, size					
1. Drawing basic shapes: square, triangle	0.513	0.713	0.913	0.713	4
2. learning basic colours: red, green	0.463	0.663	0.863	0.663	Rejected
3. Practicing concept of bigger, smaller	0.538	0.738	0.938	0.738	2
Learning Numbers					
4. Writing and counting numbers 0 to 10	0.525	0.725	0.925	0.725	3
5. Writing and counting numbers 11 to 20	0.488	0.688	0.888	0.688	5
6. Writing and counting numbers 21 to 50	0.419	0.613	0.813	0.615	Rejected
7. Ordering Numbers	0.538	0.738	0.938	0.738	2
Write and read alphabetical form of:					
8. Numbers 0 to 10	0.475	0.675	0.875	0.675	6
9. Numbers 11 to 20	0.450	0.650	0.850	0.650	Rejected
10. Numbers 21 to 50	0.400	0.600	0.800	0.600	Rejected
11. Learning about mathematical signs	0.425	0.625	0.825	0.625	Rejected
Simple Addition and Subtraction					
12. Understanding concept of addition	0.538	0.738	0.938	0.738	2
13. Understanding concept of subtraction	0.550	0.750	0.950	0.750	1
14. Addition number below 10	0.538	0.738	0.938	0.738	2
15. Subtraction number below 10	0.538	0.738	0.938	0.738	2
16. Addition numbers below 50	0.431	0.625	0.825	0.627	Rejected
17. Subtraction numbers below 50	0.431	0.625	0.825	0.627	Rejected
Understand Malaysian currency					
18. Knowing Malaysian money (coins)	0.444	0.638	0.838	0.640	Rejected
19. Knowing Malaysian money (paper note)	0.469	0.663	0.863	0.665	Rejected
20. Practicing counting money	0.431	0.625	0.825	0.627	Rejected
Instructional Strategies	**Fuzzy evaluation**			**Defuzzification**	**Ranking**
1. Drill and practice	0.488	0.688	0.888	0.688	3
2. System of least prompts	0.425	0.613	0.813	0.617	Rejected
3. Constant time delay	0.400	0.588	0.788	0.592	Rejected
4. Simultaneous prompting	0.413	0.613	0.813	0.613	Rejected
5. Reinforcement	0.500	0.700	0.900	0.700	2
6. Simple math game	0.550	0.750	0.950	0.750	1

Table 3 *(continue)*

	Fuzzy evaluation			Defuzzification	Ranking
7. Touch math	0.438	0.625	0.825	0.629	Rejected
8. Task analysis	0.444	0.638	0.838	0.640	Rejected
Curriculum					
9. Early numeracy curriculum	0.500	0.700	0.900	0.700	2
10. Malaysian Curriculum for special students.	0.438	0.638	0.838	0.638	Rejected
11. Standard Malaysian curriculum	0.338	0.506	0.700	0.515	Rejected
User Interface	**Fuzzy evaluation**			**Defuzzification**	**Ranking**
Background colours and font size					
1. Soft and light colours to use in background	0.444	0.638	0.838	0.640	Rejected
2. Avoiding overly bright colours in background	0.463	0.663	0.863	0.663	Rejected
3. Changeable theme of colour	0.425	0.625	0.825	0.625	Rejected
4. Using a readable font in a standard size	0.525	0.725	0.925	0.725	1
5. Use one touch selecting to choose letters for alphabetical writing	0.456	0.650	0.850	0.652	Rejected
6. Using cartoon characters in user interface	0.381	0.575	0.775	0.577	Rejected
Sound and music					
7. Narration in some steps (learning numbers)	0.450	0.650	0.850	0.650	Rejected
8. Playing background music during tasks	0.344	0.538	0.738	0.540	Rejected
9. Playing background music before starting tasks	0.413	0.613	0.813	0.613	Rejected
10. Sound effects in solving tasks	0.463	0.663	0.863	0.663	Rejected
11. Capability of voice over	0.369	0.563	0.763	0.565	Rejected
Features and Option	**Fuzzy evaluation**			**Defuzzification**	**Ranking**
1. Available for both mobile phone and tablet	0.500	0.700	0.900	0.700	Rejected
2. Customisable mathematical Subjects	0.469	0.663	0.863	0.665	2
3. Report on each student's progress	0.525	0.725	0.925	0.725	1
4. Option to disable the narration	0.438	0.638	0.838	0.638	Rejected
5. Usable for multiple users	0.419	0.613	0.813	0.615	Rejected
6. Hints and solutions available for all steps	0.438	0.638	0.838	0.638	Rejected
7. Option to skip steps by student	0.400	0.588	0.788	0.592	Rejected
8. Option to disable sound / music	0.425	0.619	0.813	0.619	Rejected
9. Showing dashboard for progress of each kid	0.463	0.656	0.850	0.656	3

Source: Famildardashti (2025)

Drawing basic shapes: square, triangle attained the fourth rank, with a d value of 0.713. Writing and counting numbers 11 to 20 were placed fifth (defuzzification value=0.688) while learning numbers 0 to 10 received the sixth rank (defuzzification value=0.675) among all the sub-elements. The remaining sub-elements did not garner consensus among the experts and were consequently rejected.

Instructional Strategies and Curriculum of CABAMath

For the Instructional Strategies, eleven sub-elements were suggested. The findings, as depicted in Table 3, revealed that a simple math game (defuzzification value=750), merged as the highest-ranked item, garnering significant consensus among experts. In mathematics education, game-based learning offers numerous advantages that enhance the teaching and learning experience as it motivates students to learn mathematical concepts subconsciously, fostering the development of strong foundational mathematical skills (Ramli et al., 2023).

Sub-elements for reinforcement and early numeracy curriculum (MOE, 2015) equally obtained the second rank. The early numeracy curriculum, *Dokumen Standard Kurikulum dan Pentaksiran* (DSKP), is designed by the Malaysian Ministry of Education (MOE) under the Curriculum Development Division (CDD).

The sub-element drill and practice achieved the third rank (defuzzification value =0.688). Drill and practice is an instructional approach that involves repeating exercises that are utilised to develop and perfect a skill or method (Lim et al., 2012). The remaining elements failed to meet the threshold for consensus, leading to their rejection in the instructional strategies section.

The User Interface of CABAMath

Concerning the user interface of CABAMath, eleven sub-elements were suggested but only one sub-element, using a readable font in a standard size (defuzzification value=725), was accepted as the highest rank (see Table 3). Based on the CTML theory, individuals tend to acquire a deeper level of understanding when exposed to a combination of textual and visual information, as opposed to textual or pictorial information alone. Therefore, it is imperative to consider the use of readable fonts alongside images in the application.

The rejection of sub-element involving cartoon characters in the user interface is rooted in the ASD child's short attention span (May et al., 2013). Children with autism often exhibit difficulties in disengaging and orienting their attention, heightened focus on specific tasks or topics, and a reduced capacity to filter out distractions (Ridderinkhof et al., 2020). It's important to eliminate secondary content that could distract the user. Limiting the number of features at one time is essential to optimising children's concentration, and learning outcomes (Aguiar et al., 2022). In this study, the term "cartoon characters" referred to superheroes and famous personas from the world of children's entertainment. For children with developmental delays, it's crucial to avoid using pictures that are non-relevant or overly abstract (Dattolo & Luccio, 2017).

The changeable theme and colours are another rejected sub-element. The guidelines suggested by Aguiar et al. (2022) emphasised minimising ASD students' distraction in the application design and keeping it simple. On the other hand, children with ASD do not like changes and often thrive in environments with established routines and may become upset, distressed or frustrated when changes are introduced (Rehman et al., 2021). Hence, CABAMath design incorporated only one colour theme.

Sub-elements with overly bright colours or too soft colours were rejected by experts. According to Rehman et al. (2021), the main navigation and pages should utilise simple colours rather than bright ones. Contrast in user interface colours is a critical consideration (Aguiar et al., 2022). CABAMath employs simple colours with medium radiance and brightness to ensure contrast without excessive brightness or softness.

The remaining sub-elements regarding sound effects, background music, narration, and voice-over were rejected based on expert consensus (Table 3). Experts have indicated that auditory sub-elements may be distracting for ASD students. As one expert quoted "children with autism are highly sensitive to sensory overload and are easily distracted. So, using sounds or music may not be a good choice". Furthermore, according to guidelines from Dattolo and Luccio (2017), background sounds, moving text, and blinking images should be avoided, as they can be distracting and overwhelming for ASD individuals. Aguiar et al. (2022) also advised to "avoiding the use of disturbing sounds". Consequently, the CABAMath design avoids any type of music and sound entirely.

Students with ASD have limited capacity to tolerate noise (Scheerer et al., 2022), Instead, in CABAMath, teacher-led instruction involving reading and writing will be employed for dual-channel processing. In alignment with the CTML theory, particularly the dual-channel assumption. According to this theory, humans process information through separate channels for visual/spatial and auditory/verbal representations as well as the concept of active learning, where individuals attend to relevant information, organise it into coherent mental representations, and integrate it with existing knowledge (Mayer, 2005).

Features and Options of CABAMath

Regarding the features and options for CABAMath, nine sub-elements were suggested (Table 3). Each of these sub-elements was carefully evaluated. The findings revealed that the report on each of the student's progress (Defuzzification value=0.725), ranked highest, followed by the customisable mathematical subjects in second rank with d value 0.665, and showing dashboard for the progress of each kid (Defuzzification value=0.656) secured the third position. The sub-element report on each student's progress ranked first due to its crucial role in monitoring the educational progress of ASD individuals. According to Deno (1985), progress monitoring can be defined as "the simple repeated measurement of student performance toward a long-range goal".

The customisation of mathematical subjects for each student is due to the fact that ASD students exhibit a diverse range of disabilities, varying from case to case (Hodges et al., 2020). Additionally, they may possess differing levels of mathematical knowledge, cognitive abilities (Peklari, 2019) , and conceptual understanding (Siregar et al., 2020).

The rejected sub-elements, include music and narration features, which were mainly rejected in the previous section (see Table 3) . The availability of both mobile phones and tablets is another rejected sub-element. Although designing for mobile devices could include handphones and tablets, in this study, experts' consensus rejected developing the CABAMath for both types of devices. Experts recommended focusing solely on designing CABAMath for one type of device at this stage. According to Aguiar et al. (2022), tablets offer advantages for individuals with ASD due to their large screens, which facilitate easy selection of icons or menu items, data input, and other interactions. Hence, the design of this study prioritised measurements suitable for use on tablets in the first stage.

The sub-element hints and answers in all steps rejection, experts suggested making hints available for some steps only to engage the cognitive thinking and memory working of ASD students. As for the sub-element option to skip steps by the student, experts mentioned that these actions should be available exclusively for teachers and not for students. As one expert quoted" If the mobile app aims to ensure the learning process is completed by the student, then options to skip steps should be avoided or solely under the control of the instructor."

The need for customisation and individualisation of the application for each ASD user led to the rejection of the sub-element that could serve multiple users. Opting for single-user optimisation enhances progress monitoring and improvement tracking, thus better meeting the needs of individual users.

The Framework of the CABAMath Design

The app's structural framework prioritises painting, drawing, and colouring as primary activities. These tasks engage students in mathematical concepts by involving counting, colouring objects, drawing shapes, and painting objects according to mathematical tasks.

The visual representation of the framework of CABAMath is demonstrated in Figure 1. The study implements CABAMath by offering versions in both English and Bahasa Melayu, catering to a wider user base in Malaysia. According to Dattolo and Luccio (2017), "language is a key issue when dealing with impaired users".

Based on the experts' consensus and ranking achieved through FDM analysis, among the elements of the objectives in CABAMath, the priority element was simple addition and subtraction. Regarding the content of CABAMath, the sub-element of understanding subtraction received highest rank. Consequently, applying simple addition and subtraction both ranked second, equally. The foundational skills include number recognition, basic operations like addition, subtraction, multiplication,

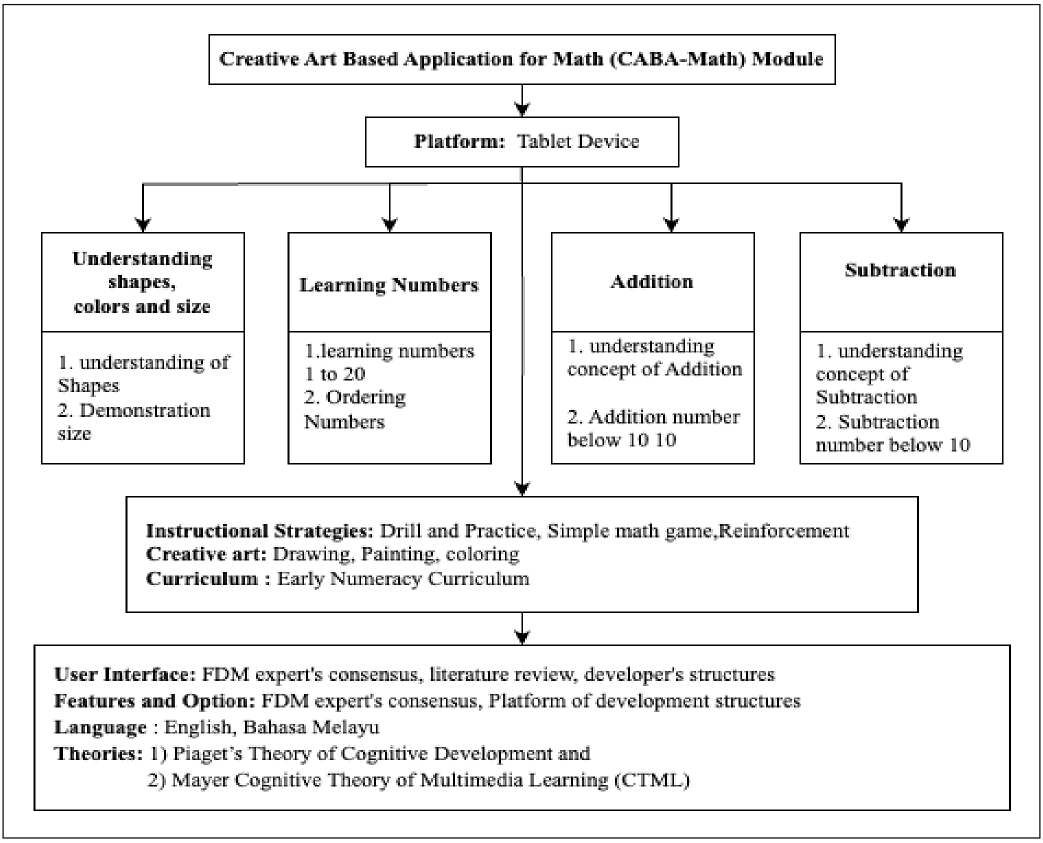

Figure 1. The framework of CABAMath design
Source: Famildardashti (2025)

and problem-solving abilities (Yusaini et al., 2019). Proficiency in fundamental mathematical operations is imperative for effectively resolving problems in daily life as indicated by Park et al. (2020). In the literature, various studies have explored teaching operations in mobile applications for individuals with ASD, employing diverse instructional strategies and approaches. These include game-based learning (Che Ku Mohd et al., 2020). It is important to note that these approaches differ from the primary approach of CABAMath, which employs creative art.

The writing and counting of numbers were ranked second among objectives and third rank for content of CABAMath. Numeracy serves as the fundamental subject for the progression of mathematical education to subsequent levels (Aunio et al., 2021). According to Yusaini et al. (2019), numeracy is primarily focussed on the application of mathematical knowledge and skills for problem-solving purposes. In this regard, most of the available mathematical applications in the body of literature target numerical abilities (Karanfiller et al., 2018; Ntalindwa et al., 2021; Winoto et al., 2018).

According to Peklari (2019), children must learn to associate numbers as represented by value, auditory verbal, and visual English codes. Hence, in this study, numerical abilities include learning numbers from zero to twenty in counting, writing, reading, and ordering based on the experts' consensus. The sub-element of ordering numbers zero to ten was ranked sixth based on experts' consensus.

In the objectives the third rank was for the understanding of shapes and sizes, but it ranked fourth among the contents sub-element. There are few studies available with the aim of teaching shapes and colours to ASD students (Winoto et al., 2018). The CABAMath application focuses on familiarizing ASD students with essential shapes and understanding the concept of size. In terms of instructional strategies, simple math games are ranked first. Research by Sousa and Costa (2018) suggests that learning strategies focussed on digital games have shown more significant effects compared to traditional approaches in general interventions. Research has demonstrated that a game-based intervention for ASD students enhances their motivation, participation, and engagement in math learning (Pradiante, 2022). Nonetheless, CABAMath is designed to utilise creative art in the form of a simple math game.

Reinforcement received the second rank among the instructional strategies. Teachers can effectively foster students' enthusiasm for learning mathematics by providing positive reinforcement. This can take the form of verbal encouragement, such as praise, or nonverbal reinforcement, including thumbs-up gestures and smiles, as well as symbolic rewards like small gifts, which help further reinforce students' engagement and motivation in the learning process (Sumiati et al., 2019). CABAMath uses digital stickers with motivational pictures and phrases to reward ASD students after completing each skill. These stickers demonstrated achievement by indicating skill completion and error-free problem solving.

The drill and practice is the third rank sub-element of instructional strategies. Drill and practice involves the acquisition of knowledge or skills through systematic training characterised by repeated rehearsals and practice to enhance learning and mastery (Famildardashti et al., 2024; Laleye & Ogunboyede, 2023). Christensen and Gerber (1990), evaluated the effectiveness of integrating a drill and practice task into an arcade game-like setting for teaching learning disabled students fundamental math concepts. The results showed considerable learning improvements after implementation. Tournaki (2003) conducted a study focusing on teaching addition through drill and practice, which resulted in significant improvement among both students with and without disabilities. CABAMath aims to utilise the drill and practice strategy within a mobile application.

In prioritising the user interface, the first rank was for incorporating readable fonts in standard sizes. Using a suitable font in the user interface helps to gain the attention of ASD students. The guidelines, as outlined in studies such as those by Davis et al. (2010), and the systematic review conducted by Gopalakrishna et al. (2013), were thoroughly used in terms of fonts and images for the user interface design of the CABAMath.

A report on each student's progress and showing a dashboard for that emerged as the first and third priorities among sub-elements of the features and options. To ensure the effectiveness of the chosen approach for an individual child with ASD, systematic monitoring of the child's progress is crucial (Siyam, 2018). Nonetheless, educators can effectively monitor each student's academic development with CABAMath's detailed progress reports.

Based on expert consensus, customizable mathematical subjects by instructors, for each student emerged as the second priority. While utilising CABAMath, teachers must ensure adaptive interaction with users, taking into account their profile, limitations, preferences, requests, and needs (Dattolo & Luccio, 2017). In addition to improving the user experience and efficacy of the setting where students feel supported and encouraged, this customisation guarantees that the programme takes into account individual needs and preferences (Aguiar et al., 2022). Because of the flexibility of the CABAMath's architecture, educators can modify assignments according to the skills and knowledge of each individual student . Moreover, fewer cognitive skills are required for ASDs to engage with the content and solve tasks (Dattolo & Luccio, 2017). By providing a blank canvas for drawing within each mathematics skill, CABAMath allows teachers and instructors to construct and personalize projects, further adapting and customising the learning experience. Students study math subjects by painting, colouring, and drawing throughout the CABAMath, making learning enjoyable. The software is adjustable and simply provides hints and answers for particular tasks to assist students learn.

The next phase involved the development of the CABAMath application based on framework designed from experts' consensus. The CABAMath application are employed instructional strategies such as drill and practice and reinforcement with the flexibility of repeating tasks multiple times and at the students' own pace (Famildardashti et al.,in press). shows selected The user interface for the CABAMath mobile application on the understanding of shapes and learning numbers from 0 to 5 are shown in Figure 2 and Figure 3 respectively.

CONCLUSION

In conclusion, CABAMath is a significant endeavor to improve mathematics skills among ASD students categorised in level one severity based on DSM-IV. The Fuzzy Delphi Method (FDM) was employed to achieve experts' consensus on CABAMath's design. The experts ranked objectives, mathematical content, instructional methodologies and curriculum, user interface, features, and options. The CABAMath app uses creative art including digital drawing and painting on a blank

Figure 2. User interface of understanding of shapes in the CABAMath application
Source: Famildardashti (2025)

Figure 3. User interface of learning numbers 0 to 5 in the CABAMath application
Source: Famildardashti (2025)

canvas and colouring shapes and objects (Figure 2 and 3).

Implications of the Study

The CABAMath was designed to cater to the diverse needs of ASD students, incorporating elements of creative art to engage learners in enjoyable and effective mathematical learning experiences. CABAMath transcends traditional pedagogical approaches, offering a dynamic and interactive learning environment. With customisable features and a range of activities spanning from basic to advanced levels, the application offers flexibility to accommodate the varying abilities of students.

Challenges of using CABAMath Application

There are several challenges in developing the CABAMath application for students with ASD. A major issue is the need to address the different cognitive capacities due to differing level of understanding and the variety of learning styles among students with ASD. In addition, students need to be motivated with an engaging user interface. The interface should be structured, without leading to excessive stimulation which could cause sensory overload, and yet insufficient interaction could fail to sustain the students' motivation. In order to accommodate ASD children's sensory sensitivities, the user interface design to be balanced in considering visual attractiveness and simplicity.

Further, there could be technological challenges such as availability of digital devices and compatibility with assistive technology, which may limit ASD individuals' use of the application. Another crucial concern is the need for training among teachers and parents to ensure the CABAMath application is implemented effectively. Without sufficient training support, the potential benefits of CABAMath could be limited. Finally, teachers need to balance the time spent on the CABAMath application so as not to encourage an addiction to the use of mobile tools, but to optimise digital learning to ensure the effectiveness of the application as an assistive tool for improving mathematical skills among ASD students.

Limitations and Recommendations for Future Research

The study is limited by the experts who participated in the study. Although efforts were made to ensure the experts achieved the criteria of expertise in the areas identified, the experts were influenced by their personal outlook and view of ASD students' condition and needs based on their experience. A panel of different experts could provide different opinions.

Future research endeavors could entail the integration of the CABAMath application in teaching ASD students mathematics in schools and learning centres catering to ASD students to evaluate the effectiveness and usability of CABAMath in different contexts.

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REFERENCES

Abdullah, J. B. B., & Yusof, S. (2018). A fuzzy delphi method-developing high-performance leadership standard for Malaysian school leaders. *Journal of Education and Social Sciences*, *9*(2), 1-10.

Aguiar, Y. P. C., Galy, E., Godde, A., Trémaud, M., & Tardif, C. (2022). AutismGuide: A usability guidelines to design software solutions for users with autism spectrum disorder. *Behaviour & Information Technology*, *41*(6), 1132-1150. https://doi.org/10.1080/0144929X.2020.1856927

Allahverdiyev, M., Yucesoy, Y., & Baglama, B. (2017). An overview of arts education and reflections on special education. *International Journal of Educational Sciences*, *19*(2-3), 127-135. https://doi.org/10.1080/09751122.2017.1393956

Anderson, A., & Valero, L. (2020). Supporting academic vocabulary and social-emotional skills of students with learning disabilities through an arts-integrated social studies approach. *Teaching Exceptional Children*, *53*(2), 150-162. https://doi.org/10.1177/0040059920942266

Asahar, S. F., Malek, K. A., & Isa, M. R. (2021). Quality of life and child's autism-specific difficulties among malaysian main caregivers: a cross-sectional study. *International journal of environmental research and public health*, *18*(18), 9861. https://doi.org/10.3390/ijerph18189861

Aunio, P., Korhonen, J., Ragpot, L., Törmänen, M., & Henning, E. (2021). An early numeracy intervention for first-graders at risk for mathematical learning difficulties. *Early Childhood Research Quarterly*, *55*, 252-262. https://doi.org/10.1016/j.ecresq.2020.12.002

Awang, S., Ahmad, S., Alias, N., & DeWitt, D. (2016). Design of an instructional module on Basic Life Support for homeschooled children. *Cogent Education*, *3*(1), 1188439. https://doi.org/10.1080/2331186X.2016.1188439

Bawazir, R. S., & Jones, P. (2017). A theoretical framework on using social stories with the creative arts for individuals on the autistic spectrum. *World Academy of Science, Engineering and Technology, Open Science Index 129, International Journal of Medical and Health Sciences*, *11*(9), 533-541. https://doi.org/10.1999/1307-6892/10008097

Bin, C. L. X., Ping, A. W. S., Lim Tse Yunn, Xuen, Y. S., & Rasit, H. H. (2023). Visual arts integration on geometry achievement for special education pupils. *Proceedings of International Conference on Special Education*, 5, https://zenodo.org/record/8337105

Butera, G., Horn, E. M., Palmer, S. B., Friesen, A., & Lieber, J. (2016). Understanding science, technology, engineering, arts, and mathematics (STEAM). In B. Reichow, B. A. Boyd, E. E. Barton, & S. L. Odom (Eds.), *Handbook of Early Childhood Special Education* (pp. 143-161). Springer International Publishing. https://doi.org/10.1007/978-3-319-28492-7_9

Che Ku Mohd , C. K. N., Shahbodin, F., Sedek, M., & Samsudin, M. (2020). Game based learning for autism in learning mathematics. *International Journal of Advanced Science and Technology*, *29*(5). http://sersc.org/journals/index.php/IJAST

Christensen, C. A., & Gerber, M. M. (1990). Effectiveness of computerised drill and practice games in teaching basic math facts. *Exceptionality:*

A Special Education Journal, *1*(3), 149-165. https://doi.org/10.1080/0936283900952475l

Dattolo, A., & Luccio, F. (2017). Accessible and usable websites and mobile applications for people with autism spectrum disorders: a comparative study. *ICST Transactions on Ambient Systems*, *17*(13), 1-11. https://doi.org/10.4108/eai.17-5-2017.152549

Davis, M., Dautenhahn, K., Powell, S., & Nehaniv, C. (2010). Guidelines for researchers and practitioners designing software and software trials for children with autism. *Journal of Assistive Technologies*, *4*(1), 38-48. https://doi.org/10.5042/jat.2010.0043

Deno, S. L. (1985). Curriculum-based measurement: The emerging alternative. *Exceptional Children*, *52*(3), 219-232. https://doi.org/10.1177/001440298505200

Famildardashti, A. (2025). *Development of CABAMATH mobile application based on creative arts for enhancing ASD children's mathematical skills* [Unpublished Thesis, University Malaya]. Malaysia.

Famildardashti, A., Ganesan, M., & DeWitt, D. (2024). Difficulties in learning mathematics among ASD students: Perspectives from teachers and parents. *MOJES: Malaysian Online Journal of Educational Sciences*, *12*(4), 35-50. https://mjs.um.edu.my/index.php/MOJES/article/view/57473

Famildardashti, A., Ganesan, M., & DeWitt, D. (in press). Enhancing mathematical skills in students with autism spectrum disorder (ASD): A creative art approach with CABAMATH mobile application. *Jurnal Kurikulum & Pengajaran Asia Pasifik (JuKu)*.

Fernández-Batanero, J. M., Montenegro-Rueda, M., Fernández-Cerero, J., & López-Meneses, E. (2024). Fostering motivation: Exploring the impact of icts on the learning of students with autism. *Children*, *11*(1), Article 119. https://doi.org/10.3390/children11010119

Fortemps, P., & Roubens, M. (1996). Ranking and defuzzification methods based on area compensation. *Fuzzy Sets and Systems*, *82*(3), 319-330. https://doi.org/10.1016/0165-0114(95)00273-1

Glumac, B., Han, Q., Smeets, J., & Schaefer, W. (2011). Brownfield redevelopment features: applying fuzzy delphi. *Journal of European Real Estate Research*, *4*(2), 145-159. https://doi.org/10.1108/17539261111157316

Gopalakrishna, G., Langendam, M. W., Scholten, R. J. P. M., Bossuyt, P. M. M., & Leeflang, M. M. G. (2013). Guidelines for guideline developers: a systematic review of grading systems for medical tests. *Implementation Science*, *8*(1), 1-14. https://doi.org/10.1186/1748-5908-8-78

Hardiman, M. M., JohnBull, R. M., Carran, D. T., & Shelton, A. (2019). The effects of arts-integrated instruction on memory for science content. *Trends in Neuroscience and Education*, *14*, 25-32. https://doi.org/10.1016/j.tine.2019.02.002

Hassan, M. (2020). Designing an interactive mobile learning game for children with autism spectrum disorder (ASD) *FCSIT FYP Symposium 2020.*

Hodges, H., Fealko, C., & Soares, N. (2020). Autism spectrum disorder: Definition, epidemiology, causes, and clinical evaluation. *Translational Pediatrics*, *9*(Suppl 1), Article S55. https://doi.org/10.21037/tp.2019.09.09

Jamil, M. R. M., & Noh, N. M. (2020). Kepelbagaian metodologi dalam penyelidikan reka bentuk dan pembangunan. *Shah Alam: Qaisar Prestige Resources.*

Kahveci, G., Serin, N. B., & Akkuş, O. (2023). Using a tablet application to teach pre-addition skills to children with autism spectrum disorder. *Journal of Education and Learning (EduLearn)*, *17*(1), 35-43. https://doi.org/10.11591/edulearn.v17i1.20509

Karanfiller, T., Yurtkan, K., Ruştioğlu, O., & Göksu, H. (2018). Effect of mobile teaching on students who need special education. *Quality & Quantity*, *52*(Suppl 2), 1353-1363. https://doi.org/10.1007/s11135-018-0715-8

Laleye, A. M., & Ogunboyede, C. O. (2023). Effects of drill-and-practice instructional package on junior secondary school students' performance in mathematics in Ondo state, Nigeria. *European Journal of Education and Pedagogy*, *4*(1), 26-30. https://doi.org/10.24018/ejedu.2023.4.1.547

Lefa, B. (2014). The piaget theory of cognitive development : An educational implications. *Educational psychology*, *1*(1), 1-9. https://www.tandfonline.com

Lim, C. S., Tang, K. N., & Kor, L. K. (2012). Drill and practice in learning (and beyond). In N. M. Seel (Ed.), *Encyclopedia of the Sciences of Learning* (pp. 1040-1042). Springer. https://doi.org/10.1007/978-1-4419-1428-6_706

Lowe, E. (2016). Engaging exceptional students through art activities. *BU Journal of Graduate Studies in Education*, *8*(1), 14-18. https://files.eric.ed.gov/fulltext/EJ1230491.pdf

May, T., Rinehart, N., Wilding, J., & Cornish, K. (2013). The role of attention in the academic attainment of children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *43*, 2147-2158. https://doi.org/10.1007/s10803-013-1766-2

Mayer, R. E. (2005). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (2 ed., pp. 43-71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*(1), 43-52. https://doi.org//10.1207/S15326985EP3801_6

Maykel, C., & Kaufman, J. (2022). The assessment of creativity for people with autism spectrum disorder. *Psychology in the Schools*, *60*(2), 401-407. https://doi.org/10.1002/pits.22729

MOE. (2015). *Matematik. Tahun 1. Dokumen standard kurikulum dan pentaksiran* (M. o. E. Malaysia & C. D. Division, Eds. Tahun 1 ed.). Edisi Bahasa Inggeris.

Munoz, R., Becerra, C., Noël, R., Camblor, M., Barcelos, T. S., Kreisel, S. V., & Villarroel, R. (2018). Design, implementation and evaluation of a learning object that supports the mathematics learning in children with autism spectrum disorders. *Celi Electronic Journal*, *21*(1), 1-13. https://doi.org/10.19153/cleiej.21.1.8

Murray, T. J., Pipino, L., & Gigch, J. P. v. (1985). A pilot study of fuzzy set modification of Delphi. *Human systems management*, *5*(1), 76-80. https://doi.org/10.3233/HSM-1985-5111

Navei, N., Akyem, S. Y., & Diabour, K. K. (2022). Art education for learners with special educational needs: Case study of visual artefacts produced by hearing-impaired pupils of Tetteh Ocloo state school for the deaf. *European Journal of Special Education Research*, *8*(2), 1-24. https://doi.org/10.46827/ejse.v8i2.4210

Ntalindwa, T., Nduwingoma, M., Karangwa, E., Soron, T., Uworwabayeho, A., & Uwineza, A. (2021). Development of a mobile app to improve numeracy skills of children with autism spectrum disorder: Participatory design and usability study. *JMIR Pediatr Parent*, *4*(3). https://doi.org/10.2196/21471

Pakpahan, F., & Saragih, M. (2022). Theory of cognitive development by jean piaget. *Journal of Applied Linguistics*, *2*(1), 55-60. https://doi.org/10.52622/joal.v2i2.79

Papachrysanthaki, A. (2022). *Young Children on the Autism Spectrum: Enhancing Social Interaction and Task Engagements Through Visual Arts*

[Doctoral Thesis, University of Roehampton]. https://pure.roehampton.ac.uk

Park, J., Bouck, E. C., & Josol, C. K. (2020). Maintenance in mathematics for individuals with intellectual disability: A systematic review of literature. *Research in developmental disabilities*, *105*, Article 103751. https://doi.org/10.1016/j.ridd.2020.103751

Peklari, E. (2019). Mathematical skills in autism spectrum disorder. *Asian Journal of Applied Science and Technology*, *3*(1), 111-123. https://www.ajast.net/

Pradiante, V. (2022). The contribution of game-based learning: Children with autism spectrum disorder and dyscalculia. *European Conference on Games Based Learning*, 16(1), 742-749, https://doi.org/10.34190/ecgbl.16.1.620

Rahman, F. B. A., Mustafa, Z., & Kharuddin, A. F. (2021). Employing fuzzy delphi technique to validate multiple intelligence based instructional teaching module for preschool children. *Southeast Asia Early Childhood Journal*, *10*(1), 62-71. https://doi.org/10.37134/saecj.vol10.1.6.2021

Ramli, I. S., Maat, S. M., & Khalid, F. (2023). Learning mathematics in the new norms caused by digital game-based learning and learning analytics. *Pegem Journal of Education and Instruction*, *13*(1), 168-176. https://doi.org/10.47750/pegegog.13.01.19

Rehman, I. U., Sobnath, D., Nasralla, M. M., Winnett, M., Anwar, A., Asif, W., & Sherazi, H. H. R. (2021). Features of mobile apps for people with autism in a post COVID-19 scenario: Current status and recommendations for apps using AI. *Diagnostics*, *11*(10), Article 1923. https://doi.org/10.3390/diagnostics11101923

Ridderinkhof, A., de Bruin, E. I., van den Driesschen, S., & Bögels, S. M. (2020). Attention in children with autism spectrum disorder and the effects of a mindfulness-based programme. *Journal of attention disorders*, *24*(5), 681-692. https://doi.org/10.1177/1087054718797428

Saido, G., Siraj, S., DeWitt, D., & Saadallah, O. (2018). Development of an instructional model for higher order thinking in science among secondary school students: a fuzzy Delphi approach. *International Journal of Science Education*, *40*(4), 1-20. https://doi.org/10.1080/09500693.2018.1452307

Saunders, J. N. (2021). The power of the arts in learning and the curriculum: a review of research literature. *Curriculum Perspectives*, *41*(1), 93-100. https://doi.org/10.1007/s41297-021-00138-4

Scheerer, N. E., Boucher, T. Q., Bahmei, B., Iarocci, G., Arzanpour, S., & Birmingham, E. (2022). Family experiences of decreased sound tolerance in ASD. *Journal of autism and developmental disorders*, *52*(9), 4007-4021. https://doi.org/10.1007/s10803-021-05282-4

Siregar, N. C., Rosli, R., Maat, S. M., Alias, A., Toran, H., Mottan, K., & Nor, S. M. (2020). The impacts of mathematics instructional strategy on students with autism: A systematic literature review. *European Journal of Educational Research*, *9*(2), 729-741. https://doi.org/10.12973/eu-jer.9.2.729

Siyam, N. (2018). Special education teachers' perceptions on using technology for communication practices. *Journal for Researching Education Practice and Theory*, *1*(2), 6-18. https://doi.org/10.5281/zenodo.2537590

Sousa, C., & Costa, C. (2018). Videogames as a learning tool: Is game-based learning more effective? *Revista Lusófona de Educação*, *40*(40), 199-210. https://doi.org/10.24140/issn.1645-7250.rle40.13

Spence, L. K. (2014). *The arts and emergent bilingual youth: building culturally responsive, critical, and creative education in school and community contexts* (1 ed.). Routledge. https://doi.org/10.4324/9780203124680

Sumiati, T., Septiani, N., Widodo, S., & Caturiasari, J. (2019). Building children's learning motivation through positive reinforcement in science and math classroom. *Journal of Physics: Conference Series*, *1318*(1), Article 012023, https://doi.org/10.1088/1742-6596/1318/1/012023

Sweidan, S. Z., Salameh, H., Zakarneh, R., & Darabkh, K. A. (2022). Autistic innovative assistant (AIA): An android application for arabic autism children. *Interactive Learning Environments*, *30*(4), 735-758. https://doi.org/10.1080/10494820.2019.1681468

Talantseva, O. I., Romanova, R. S., Shurdova, E. M., Dolgorukova, T. A., Sologub, P. S., Titova, O. S., Kleeva, D. F., & Grigorenko, E. L. (2023). The global prevalence of autism spectrum disorder: A three-level meta-analysis. *Front Psychiatry*, *14*, Articl;e 1071181. https://doi.org/10.3389/fpsyt.2023.1071181

Tan, P., & Kastberg, S. (2017). Calling for research collaborations and the use of dis/ability studies in mathematics education. *Journal of Urban Mathematics Education*, *10*(2), 25-38. https://doi.org/10.21423/jume-v10i2a321

Tashnim, A., Nowshin, S., Akter, F., & Das, A. (2017). Interactive interface design for learning numeracy and calculation for children with autism. *9th International Conference on Information Technology and Electrical Engineering (ICITEE)*, 1-6, https://doi.org/10.1109/ICITEED.2017.8250507

Tournaki, N. (2003). The differential effects of teaching addition through strategy instruction versus drill and practice to students with and without learning disabilities. *Journal of Learning Disabilities*, *36*(5), 449-458. https://doi.org/10.1177/00222194030360050601

World Health Organisation. (2023). *Autism spectrum disorders* World Health Organisation. https://www.who.int/news-room/fact-sheets/detail/autism-spectrum-disorders:

Winoto, P., Chen, J., Guo, H., Tang, T.Y. (2018). A Mathematical and Cognitive Training Application for Children with Autism: A System Prototype. In: Stephanidis, C. (eds) HCI International 2018 – Posters' Extended Abstracts. HCI 2018. Communications in Computer and Information Science, vol 851. Springer, Cham. https://doi.org/10.1007/978-3-319-92279-9_16

Yusaini, N., Maat, S., & Rosli, R. (2019). Touch-point mathematics instruction for children with autism spectrum disorder: A systematic literature review. *International Journal of Academic Research in Business and Social Sciences*, *9*(3), 609-625. https://doi.org/10.6007/IJARBSS/v9-i3/5730