

MY CRYSTAL MATH: ENHANCING NUMERACY AND BASIC OPERATIONS SKILLS IN AUTISTIC CHILDREN THROUGH MOBILE APPLICATIONS IN MATHEMATICS EDUCATION

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Abstract: *Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by deficits in social interaction, communication challenges, and repetitive behaviors. These factors create significant challenges for individuals with autism, their families, and society at large. Particularly in the realm of social communication, autistic children struggle to form and maintain connections, relying on nonverbal cues such as facial expressions, gestures, and eye contact. Consequently, teaching mathematics to autistic children requires an innovative and tailored approach. The objective of this research is to develop a mobile application specifically designed to help autistic children learn numeracy and basic mathematical operations. The project follows the waterfall methodology, encompassing requirements gathering, analysis, design, and implementation phases to achieve its specific goals. The resulting mobile app provides a comprehensive learning experience, encompassing numeracy, addition, subtraction, and a final quiz to assess the understanding of autistic children as they engage with the interactive games. The developed mobile application serves as a valuable tool for teachers in effectively instructing and guiding autistic children in mathematics. Its tailored approach caters to the unique learning styles of autistic individuals, enhancing their interaction and overall educational experience. This application has the potential to become an invaluable resource, enabling autistic children to acquire foundational mathematical skills with greater ease and effectiveness.*

Keywords: *Mobile Application, Autistic Children, Mathematics, Numeracy, Fun Learning*

Introduction

All parents desire children, not to mention that children are Allah's most precious gifts and priceless trust. However, not every marriage is fortunate enough to have children who are physically and psychologically normal. Imperfections and impairments should not be excuses to create a barrier between children with disabilities and others because children with disabilities also have a role in fulfilling their obligations (Mohd et al., 2020).

Therefore, vision impairment, mental impairment, bodily impairment, hearing impairment, speech impairment, learning impairments, and other disabilities fall under the category of children with disabilities (OKU). Children with impairments such as Down syndrome, autism, deafness, dyslexia, and others are members of society who cannot be ignored (García-redondo et al., 2019). They are also a target group that should not be dismissed or ignored.

On the other hand, many people today are unaware of autistic disability (Troisi et al., 2020). Autism spectrum disorder (ASD) is a brain-based neurodevelopmental disorder characterised by significant deficits in social interaction, limited, repetitive social communication, and repetitive behaviours or interests, posing a significant burden on people, families, and society (Yousif, 2021). Figure 1 shows the symptoms of autism spectrum disorder in children. Asperger's syndrome and pervasive developmental disorders are the three kinds of autistic.

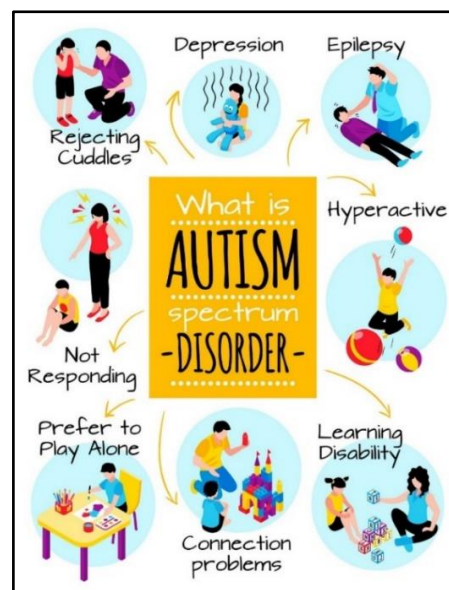


Figure 1: Symptoms of Autism Spectrum Disorder Children. (Johnson, 2021)

Autistic children have heightened sensitivity to sounds or things they have seen or felt that might cause behaviour difficulties (Christensen et al., 2019). Autistic children have a hard time forming and sustaining connections when it comes to social communication. Autistic children also have nonverbal means of communication, such as facial expressions, bodily gestures, and eye contact (Papoutsis et al., 2018). Autistic children are frequently unable to comprehend and articulate their requirements, as well as to interpret and comprehend the needs of others.

According to (Bi et al., 2018), visuals make math problems easier for autistic children. When the problem and solution are accompanied by physical visuals, the arithmetic being done with more graphics becomes substantially clearer. Every question should be reinforced with a visual

reference to make it more tangible and approachable. To begin with, autistic children tend to be better visual learners than aural learners.

The objective of this research is to develop a mobile application specifically designed to help autistic children learn numeracy and basic mathematical operations. Mobile applications can effectively aid impaired children in learning and communication, as autistic children are often drawn to technology. However, it is crucial to develop additional applications that cater to the unique needs of autistic children, considering interface design and a wide range of categories will be pivotal for their success (Howell et al., 2021). This demonstrates the potential of mobile applications in enhancing mathematical learning for autistic children.

Literature review

"Classic" autism refers to autistic disorder. When most people hear "autism," they immediately think of autistic disorder. (Bandovas et al., 2022). Autistic disorders are characterized by language delays, social and communication difficulties, and unique behaviours and interests. Many persons who have autistic spectrum conditions also have learning problems.

Symptoms of autistic are often milder in individuals with Asperger's syndrome compared to those without the condition (Troisi et al., 2020). They may exhibit odd behaviours and interests, as well as social issues. However, However, they typically do not have language or intellectual problems.

Pervasive Developmental Disorder is another term for atypical autistic (Bandovas et al., 2022). Atypical autistic is used to describe people who satisfy some, but not all the criteria for autistic disorder or Asperger syndrome. These individuals typically have fewer and milder symptoms compared to others with autistic spectrum disorders. Only social and communication issues may be caused by the symptoms (El-shoubashy et al., 2020).

Characteristics of Autistic Children

Autism spectrum disorder (ASD) is characterised by difficulties in social communication and interaction, as well as restricted or repetitive behaviours or interests. Individuals with autism spectrum disorder (ASD) may experience differences in learning, movement, and attention (Ur Rehman et al., 2021).

Children with autistic show substantial impairment in utilizing nonverbal behaviours for social interaction, such as eye contact, facial expressions, body postures, and gestures (Masi et al., 2020). They may struggle to establish age-appropriate peer interactions and lack spontaneity in sharing interests or accomplishments with others (Christensen et al., 2019).

Autism spectrum disorder (ASD) involves challenges in social communication and interaction, as well as restricted or repetitive behaviours or interests. Individuals with autistic spectrum disorder (ASD) may also have differences in learning, movement, and attention (Guo & Abel, 2020). Communication symptoms of autistic include delayed or absent spoken language development, as well as difficulties in initiating or maintaining conversations (Christensen et al., 2019). They may exhibit idiosyncratic language or engage in repetitive and stereotyped language usage (Christensen et al., 2019).

Autistic children often display restricted behaviours, such as becoming intensely engaged in one interest and being less focused on other things (Christensen et al., 2019). They may engage

in behaviours like hand-flapping, twisting, or complex whole-body movements (Christensen et al., 2019).

Learning Style for Autistic Children

The VAK (Visual, Audio, kinesthetics) model was introduced by Neil D. Fleming (Agkanak et al., 2020). It is a teaching approach that utilizes multisensory methods to enhance memory and learning processes. This approach benefits from various inputs, including auditory (listening), visual (vision), and kinesthetics (movement). Figure 2 shows the learning style that includes visual, auditory and kinesthetics.

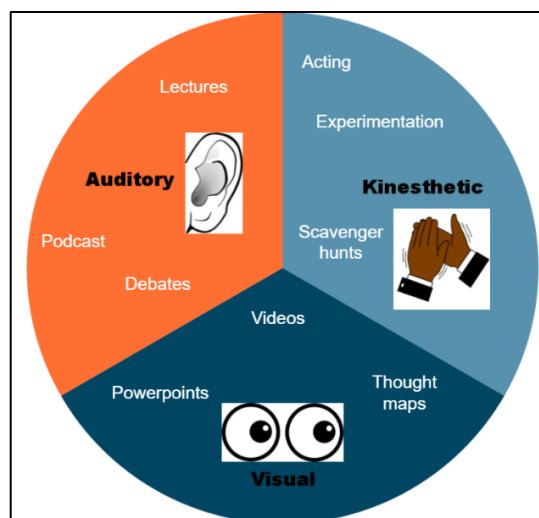


Figure 2: The Visual, Auditory and Kinesthetics. (Agkanak et al., 2020)

This is a list of different learning styles and some examples of activities that can cater to each style. The auditory learning style involves learning through lectures, podcasts, and debates. The kinaesthetic learning style involves learning through acting, experimentation, and scavenger hunts. The visual learning style involves learning through PowerPoints, videos and thought maps. By incorporating activities that cater to different learning styles, educators can engage and support a wider range of students in their learning.

Visual teaching and learning are a process that attracts student interest with the colours present in the visual material (Rohadi, 2021). Additionally, visual teaching and learning are successful in helping convey the content of the lesson and making it easier and faster for students to remember. The use of visual materials in teaching and learning makes the lessons more appealing, effective, and efficient for students. This is because visual teaching and learning are specifically designed for students who are still concrete thinkers, who need each teaching and learning to be proven with their own eyes.

The use of auditory in teaching and learning involves utilizing technology materials, such as recorded sounds, to support the learning process and capture students' attention to sound. The integration of audio and visual images in teaching and learning can also improve students' reading levels, as the combination of text and images aids in their memory retention.

Kinesthetic teaching and learning involve students learning through hands-on experiences, such as engaging in activities or movements that involve other parts of the body. This approach to

education is commonly used to aid in information retention by incorporating physical movement. This method is suitable for students who have difficulty learning through traditional, passive methods and is especially beneficial for autistic students with attention issues, as it provides a more active learning experience to help them focus.

Techniques for Autistic Children Use in Performing the Basic Operations

Educational treatments for autism are given in a classroom setting, and one such approach is the Treatment and Education of Autistic and Related Communication-Handicapped Children (TEACCH) approach. This approach is based on the idea that people with autism benefit from consistency and visual learning. It provides teachers with methods for adjusting the classroom structure to enhance academic and other outcomes, such as using daily routines written or drawn in plain view, setting boundaries around learning stations, and complementing verbal instructions with visual instructions or physical demonstrations (Yusaini et al., 2019).

Special interests can both be a blessing and a curse. If a child's interests consume their mind, they may face difficulties in focusing on their school work.

As technology advances, more studies are being conducted on new and innovative interventions such as the Touch Math program, also known as Touchpoint. Touchpoint is a multisensory method that combines visual, auditory, and tactile learning, especially for children with disabilities or autism. This method uses dot notation to teach math skills where children mark points on numbers while looking at the number visually, counting the points auditorily, and marking the points tactilely with a pencil. Figure 3 shows the points on the numbers that represent the actual quantity of the number.

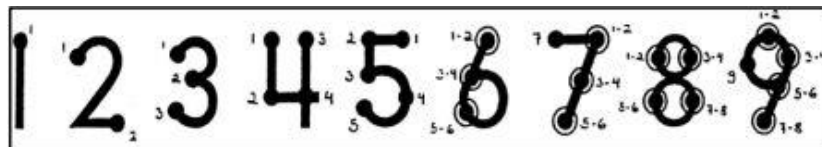


Figure 3: The Dot Notation to Teach Autistic Children in Mathematics (Yusaini et al., 2019).

This method has shown positive results in improving students' performance, both with and without difficulties in understanding basic mathematical concepts. It has been proven successful in solving addition and subtraction problems with single and double digits, specifically for children with autism spectrum disorder who face challenges in learning basic numeracy skills.

Features of Mobile Application for Autism Spectrum Disorder (ASD)

Mobile apps for children with autism spectrum disorder (ASD) often utilize haptic feedback to make the device vibrate in specific scenarios. Design components relevant to communication that are commonly found in most of the analyzed apps for autistic children are (Ur Rehman et al., 2021):

- a) Simple colours instead of bright colours on the main navigation pages.
- b) The simple language throughout the apps, such as simple bullet points and short sentences instead of figures or idioms.
- c) Descriptive and carefully selected buttons.
- d) Consistent screen layouts, cater to the need of autistic individuals for consistency of routine and their difficulties with adapting to change.

Many of the analyzed games also had repetitive levels since autistic children tend to do well in a routine environment with predefined roles. Games can involve repetitive behavior while simultaneously promoting imagination and creativity in problem-solving. The utilization of games, whether for entertainment or educational purposes, aims to help autistic children achieve balance, attention, and gaze control. Figure 4 shows an example of feature games in mobile applications.



Figure 4: The feature games in the mobile application (Ur Rehman et al., 2021)

Methods

The waterfall model has its uses. The waterfall model is used when the criteria are well-defined and understood. It is also used when the product description is the same, technology is comprehended, and there are not any ambiguous requirements (Kumar, 2018). Uses of the waterfall are adequate resources, talent accessible without restriction, and when the project's duration is limited (Gallardo-Montes et al., 2021)

The methodology of a research project refers to its plan and reasoning. It involves studying the methods and underlying concepts used in the field to create a strategy that aligns with the project's objectives. The waterfall model, a widely used traditional method, is being employed in this project with three phases: requirements gathering and analysis, design, and implementation.

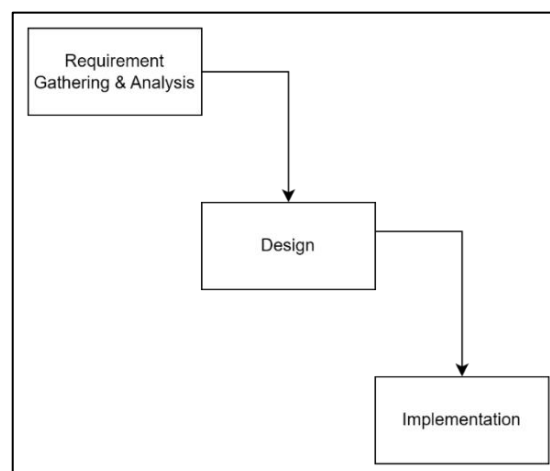


Figure 5: Waterfall Model

As shown in Figure 5, the waterfall method, consisting of only three phases, was selected for this project. The three phases of the project are requirements gathering & analysis, design, and implementation. To develop software that addresses the issue faced by teachers and parents, all phases must be completed sequentially. The main goal of each phase is to achieve specific objectives, which will enable progress to the next phase.

Phase 1: Requirement Gathering and Analysis

The first phase of the project is requirements gathering for learning mathematics in numeracy and basic operations for autistic children using mobile applications. During this phase, one set of questions has been completed to collect the necessary data. To begin, the questions had to be prepared and then sent to the teachers and parents using a Google form concerning teaching fundamental mathematics to autistic children for the teachers and parents to be able to respond to all the questionnaires:

1. *What type of language is used for autistic children throughout the mobile application?*
2. *What type of button is used for autistic children throughout the mobile application?*
3. *What type of colour is used for autistic children throughout the mobile application?*
4. *What type of background is used for autistic children throughout the mobile application?*
5. *What type of picture is used for autistic children throughout the mobile application?*
6. *Do you think autistic children can do simple exercises in Learning Numeracy and Basic Mathematics through the mobile application?*
7. *Do you think autistic children can do simple tests in Learning Numeracy and Basic Mathematics through the mobile application?*

Phase 2: Design

The two-phase is the Design phase, where the focus is on designing the mobile application. The design process starts with creating a storyboard for the mobile application's user interface.

According to Figure 6, there are three user groups in the storyboard for the mobile application: autistic children, parents, and teachers. The storyboard indicates that teachers and parents can register, log in, view the home page, view mathematical numeracy, participate in quiz-based addition and subtraction, view their high scores, and log out. Autistic children can only access the home page after teachers and parents log in to the application. Once they log in, they can view mathematical numeracy, participate in quiz-based addition and subtraction, view their high scores, and log out.



Figure 6: The storyboard for the mobile application in numeracy and basic mathematics.

Phase 3: Implementation

The implementation phase is the final step in the software development process, following the requirement gathering & analysis and design phases. The implementation of the Learning Mathematics in Numeracy and Basic Operations for Autistic Children through Mobile

Application utilizes various tools to ensure smooth operation. The project utilizes Android Studio for the development of the mobile application in numeracy and basic mathematics, and the data is stored in Firebase. The features and animations in the project are produced using the Canva platform, and videos are sourced from YouTube.

Results and Findings

The mobile application for numeracy and basic mathematics has various interface features such as learning mathematics, exercises, tests, and videos. Each of these features has multiple pages.

Choose Menu, Choose Learning Math, and View Learning Math

The menu page is the primary page of the mobile application. It features four buttons: "Learning Mathematics," "Exercise," "Test," and "Video." If an autistic child clicks the "Learning Mathematics" button, the learning mathematics page will be displayed. This page has four buttons of its own: "Learning Numbers," "Writing Numbers," "Learning Addition," and "Learning Subtraction."

If the autistic children click the "Learning Numbers" button, the counting numbers page will be displayed. This page displays numbers from zero to ten and has a sound button for each number. The numbers are accompanied by pictures of balls that are animated to match the number. For example, the picture for the number "two" shows two balls. The "next" button allows the child to move on to the next number. Figure 7 shows the menu page, learning mathematics page, and counting numbers page.



Figure 7: The menu page, learning mathematics page and count number page.

The "Learning Mathematics" page also features a "Learning Addition" button. When an autistic child clicks this button, the main page for learning addition will be displayed. They can then click the "enter" button to start the learning process. This page has audio and animations. The rabbits are used as animations and the sound button counts the total number of rabbits. The "next" button leads to the next page, and there are a total of six pages in the learning addition section.

Similarly, the "Learning Subtraction" button has the same setup as the "Learning Addition" button. The "Learning Subtraction" page also has six pages. Figure 8 shows the "Learning Mathematics" page, the main "Learning Addition" page, and a "Learning Addition" page.



Figure 8: The "Learning Mathematics" page, the main "Learning Addition" page, and a "Learning Addition" page.

View Exercise and View Exercise Score

When an autistic child clicks the "Enter" button on the main exercise page, a multiple-choice exercise will be displayed. This exercise page has a timer for autistic children to answer all questions. There are a total of 6 questions in this exercise. The bag picture serves as an animation on the exercise page. Once the autistic children have answered all questions and clicked the "Next" button until reaching the last question, the score page will be displayed. This page shows the total number of questions and the total number of correct answers.

The "Exercise Subtraction" process is similar to the "Exercise Addition" process. Figure 9 shows the main exercise page, the exercise page, and the score page.



Figure 9: The main exercise page, the exercise page, and the score page.

View Test

To complete the test, both the teacher and parent need to navigate to the menu page, click the "test" button, and fill out the name and age of the autistic children on the displayed page. The "save" button should be used to save the name and age information in the firebase. To begin the test, click the "open" button. Figure 10 shows the test page and the information page for autistic children.



Figure 10: The test page and the information page for autistic children.

View Test Score

The test page contains six questions, a combination of addition and subtraction. There are three additional questions and three subtraction questions. An animation of an aeroplane is present on the test page. The score displays the total number of questions and the total number of correct answers. Figure 11 shows the test page and the score page.

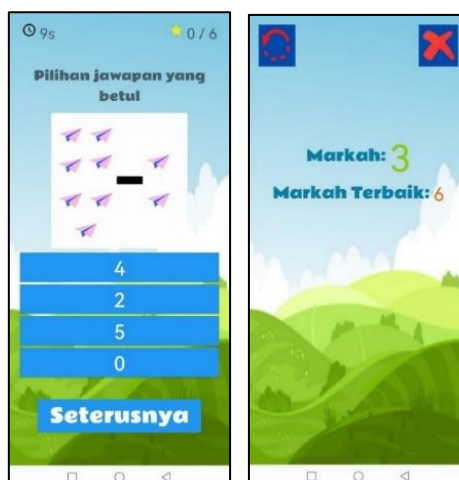


Figure 11: The test page and the score page.

View Video

Lastly, if an autistic child wants to watch a video, they can navigate back to the menu page and click the "video" button. The video page displays three buttons: "video one," "video two," and "video three." Each video has its unique sequence and elements. Video one is for sequence numbers, video two is for counting numbers, and video three is a song about subtraction. Figure 12 shows the menu page, the variation video page, and the video page.



Figure 12: The menu page, the variation video page, and the video page

Conclusions

"My Crystal Math" is a mobile application designed to teach mathematics to autistic children, with a specific focus on numeracy and basic arithmetic operations like addition and subtraction. While the application has several strengths, there are areas for improvement in future updates. Firstly, an important addition would be the inclusion of multiplication and division operations, thus covering all fundamental mathematical operations within the mobile application. This expansion would enable autistic children to learn and practice these operations using three different learning styles: visual, audio, and kinesthetic. Secondly, the incorporation of a kinesthetic feature would further enhance the learning experience. The inclusion of a kinesthetic learning style would allow autistic children to follow step-by-step instructions presented as animated arrows, aiding them in drawing numbers accurately and confidently. In conclusion, the availability of this mobile application will provide valuable support to teachers and parents in teaching mathematics to autistic children. By creating an engaging and enjoyable learning environment, the application helps autistic children develop a solid understanding of mathematical operations. Ultimately, this application has the potential to become an invaluable resource, facilitating the acquisition of essential mathematical skills for autistic children in a more accessible and effective manner.

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