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Design and Development of an iOS-Based AAC Application to Assist Nonverbal Autistic Children in Communication

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ABSTRACT

The treatment of children with Autism Spectrum Disorder (ASD) in Indonesia is still very concerning. The lack of competent educators and therapists means that ASD children in Indonesia show slow development. Another limitation in Indonesia is the common view that children should be able to speak verbally, so many children with ASD are forced to undergo speech therapy, including tongue massage and other methods. Unfortunately, this approach often hinders their development, especially for children with non-verbal tendencies. This research aims to develop an Augmentative and Alternative Communication (AAC)-based application in Indonesian to help ASD children communicate with their surroundings. The method used is Challenge-Based Learning (CBL), which involves ASD therapists in Indonesia directly in the app development process. With the involvement of experts, the app was designed to fit the needs of ASD children based on practical and clinical considerations. The results showed that ASD children responded well and could use the AAC board effectively, optimizing the communication process in ASD children's learning.

I. INTRODUCTION

Handling children with special conditions such as ASD (Autism Spectrum Disorder) is complex. In Indonesia, inclusive schools tend to be underprepared to handle children with special needs due to a lack of educators and unpreparedness in terms of learning materials or curriculum [1]. The unpreparedness of learners to teach children with ASD can hinder their success in regular education [2].

In addition, the prevalence of ASD in Indonesia is increasing, with an estimated 1.14% of the population possibly affected [3]. This increase underscores the urgent need for a comprehensive strategy to address the educational and social needs of children with ASD. The Indonesian government has recognized the importance of improving health accessibility and disability inclusion, in line with the Sustainable Development Goals (SDGs) [4].

One of the main symptoms experienced by ASD children is difficulty in communicating. More than 25% of children with ASD are unable to speak verbally. This makes ASD children on the non-verbal spectrum even more isolated from the outside world due to their limitations in communication [5]. Another obstacle faced by ASD children on the non-verbal spectrum is decreased phonological working memory which can affect their ability to develop the necessary speaking skills [6].

PECS (Picture Exchange Communication System) is currently one of the most widely used communication systems worldwide for non-verbal autistic individuals. The system consists of pictures or photographs that are selected based on the vocabulary possessed by everyone. PECS not only replaces speech with pictures, but also encourages individuals to express their needs and wants [7].

Making PECS itself requires a variety of complex materials, including picture cards, mini-objects, plastic boxes, picture books, cameras, and various gifts and toys to enhance learning effectiveness [8]. Many parents feel that they do not have enough time to create PECS that is appropriate for the vocabulary they want to teach their child. Along with the development of technology, the concept of PECS was adapted

into a digital system called AAC (Augmentative and Alternative Communication). Based on existing research, AAC has been shown to lead to improvements in a range of communicative functions, including turn-taking, vocabulary acquisition, and message complexity, which are important for effective interaction and social engagement [9], [10].

In addition, the implementation of AAC systems can facilitate better interactions between therapists and ASD children, thus creating effective therapy sessions. Therefore, it is very important to implement the AAC system in Indonesia given the limited number of educators. With the implementation of AAC, the limited number of learners will be greatly helped to communicate effectively with ASD children so that the therapy process and delivery of learning materials will be better.

Furthermore, the selection of iOS as a platform for the development of AAC apps for children with ASD in Indonesia can be explained through some fundamental reasons. Firstly, iOS is known to have a clear and responsive screen that allows children to interact with apps effectively, enhancing their user experience [11], [12]. The results of the drawing performance test show that iOS is faster than Android in rendering views and UI elements without causing user interface fluidity issues [13].

In addition, the AVFoundation technology available on iOS allows the author to integrate voice into the app, which is essential for vocalizing existing vocabulary, AVFoundation supports multiple languages, so the app can not only be used by children in Indonesia but can also be expanded to help children from different countries learn other languages. Furthermore, the latest iOS is also equipped with eye-tracking technology, which allows children with other special needs, such as cerebral palsy, to communicate using the app [14], [15].

In the context of AAC, research shows that the appropriate use of technology can improve the communication abilities of individuals with autism. For example, effective use of AAC systems has been shown to increase the amount of communication and children's desire to interact [16], [17]. By utilizing the iOS platform and existing technology, this app will not only support autistic children in communicating but also provide them with the tools to learn and develop in a supportive environment.

II. METHOD

In this study, the authors used the Challenge-Based Learning (CBL) method. CBL is a method that emphasizes real-world problem solving through collaborative methods. CBL was first proposed by educators at Apple Inc. and is rooted in problem-based learning principles as well as John Dewey's educational philosophy, which supports experiential learning and active engagement in the learning process [18]. CBL itself involves 3 interconnected phases namely Engage, Investigate, and Act. After passing through the 3 phases, a reflection process must be carried out. The results of the reflection process will be processed again in the next 3 phase cycle. The following are the details of the steps taken by the author to create an application by applying the CBL method.

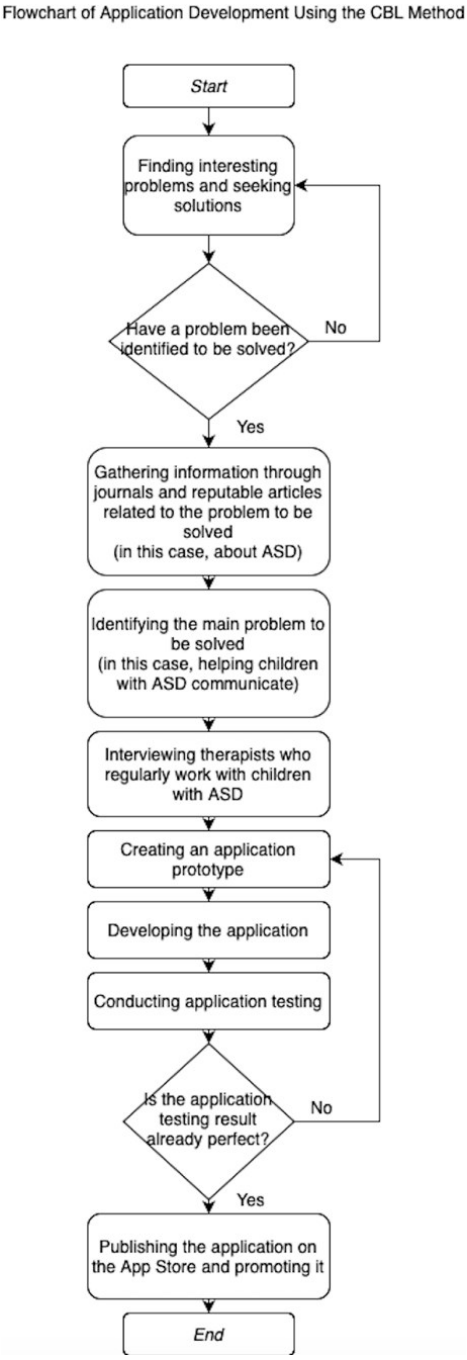

Figure 1. Flowchart of Application Development Using the CBL Method

CBL is a very flexible method that can be adapted to real-world needs. In contrast, Project-Based Learning (PBL) focuses on completing projects by answering complex questions. The focus of PBL is limited to the academic environment, with minimal external involvement. Below is a comparison table of the Challenge-Based Learning (CBL) method with the Project-Based Learning (PBL) method.

TABLE I
COMPARISON OF CBL METHOD AND PBL METHOD

Aspects	Challenge-Based Learning (CBL)	Project- Based Learning (PBL)
Focus	Real-world problem solving with social impact	Projects to answer complex problems or questions
Final Goal	Real solutions and sharing results with the community	Final product or presentation
Stakeholder Engagement	Involving the community, experts, and industry partners as part of the learning process	Usually limited to the academic environment, with more minimal external involvement

By considering all the advantages, the author chose the CBL method to be applied in the research process. Apart from its flexibility, CBL also emphasizes reflection at the end of each cycle so that it is expected that the final cycle is the best version that answers the existing problems.

III. RESULT AND DISCUSSION

In line with the application of the CBL method in this study, the author applies several stages.

1. *Engage*

In the Engage stage, the first thing to do is to determine the Big Idea. The author chose a child with ASD as the Big Idea in this research. After determining the Big Idea, the next thing to do is to create an Essential Question. The Essential Question set by the author is "How to help ASD children on the non-verbal spectrum to communicate with people around them?". To answer this question, a challenge was formulated in the form of developing an application that can help ASD children on the non-verbal spectrum communicate with their surroundings.

2. *Investigate*

Before designing the AAC application, the author created several Guiding Questions which were then answered through reliable information from journals and interviews with ASD therapists.

- What methods can make it easier for ASD children on the non-verbal spectrum to communicate?

The researchers suggest that the highly visual nature of PECS makes it particularly suitable for use by learners with ASD, who tend to be visual learners [19]. In addition, the therapist explained that AAC is an effective and efficient method because some ASD children on the non-verbal spectrum who had therapy using AAC boards became easier to communicate and did not experience tantrums.

- What can support the application of the visual method?

Children using an AAC system with auditory feedback showed improvements in their ability to request items and express needs [20]. The therapist also added that the word buttons on the AAC board should be able to make a sound when pressed to train children with ASD to be able to voice their wishes. The more vocabulary they hear, the more they will understand the meaning of the words.

- Does the selection of pictures and colours in the AAC board make it easier for children with ASD to understand and use the tool?
  - Yes.
- How can the selection of images and colours in AAC make it easier for children with ASD to understand and use the tool?

Structured categorization can facilitate better understanding and retrieval of vocabulary, making it easier for children to express themselves in various contexts [21]. The interview with the therapist stated that the words on the AAC board should be grouped by category. In this case, the use of Fitzgerald Key to determine the colour of each word makes it very easy for children with ASD to express their feelings.

The Guiding Question was then summarized into a synthesis, namely that the design of AAC applications for ASD children on the non-verbal spectrum must be visual based, because they understand information more easily visually. The AAC app needs to have auditory features, such as buttons that make sounds, so that it can improve vocabulary comprehension and help children voice their wishes. In addition, a clear visual structure, including grouping words by category with the Fitzgerald Key, makes it easier for children to express feelings. With this approach, AAC can be a more effective and intuitive communication tool for children with ASD.

3. *Act*

Based on the findings obtained from the Investigate process, the author began to create an AAC application prototype. The author uses Figma as a tool for making AAC application prototypes. Here is the prototype of the AAC application.

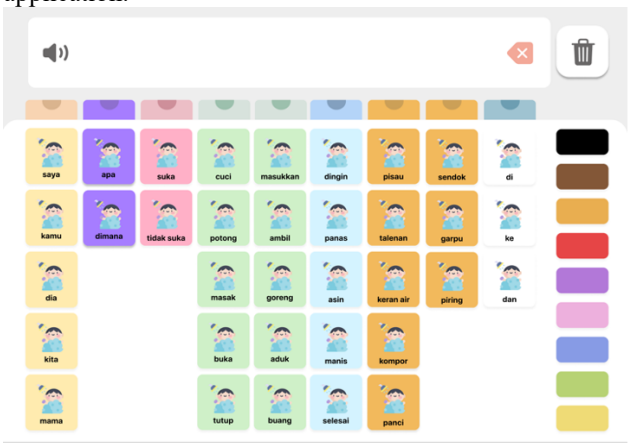

Figure 2. AAC Application Prototype

After creating the prototype, the author started creating the app. The author used XCode to create an application that is compatible with iPad devices. In addition to having a clearer and clearer visual layer, iPad also has AVFoundation technology that can support auditory features to improve vocabulary understanding in ASD children. The application was then put into TestFlight so that it could be tested by users. Here are the applications. Here is the application.

The app was then tested on several ASD children. They were able to press the buttons on the AAC board and voice their simple wishes such as "I want to pee", "I want to drink water", "I want a blue ball". However, there are some considerations given by the therapist which are as follows. The size of the boxes is too small on an 11-inch iPad. This makes the child a bit confused to find the desired word. It is better to focus on the AAC board only, there is no need for a home menu in the lower right corner which disturbs the child's concentration. Also, there are some basic words that are missing so the feature of adding boxes privately needs to be added.

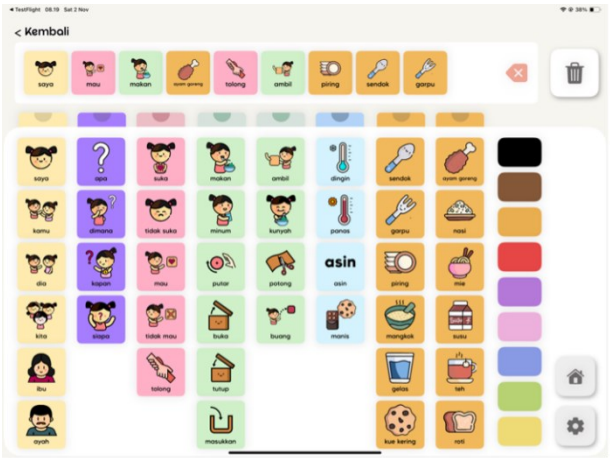

Figure 3. AAC Application

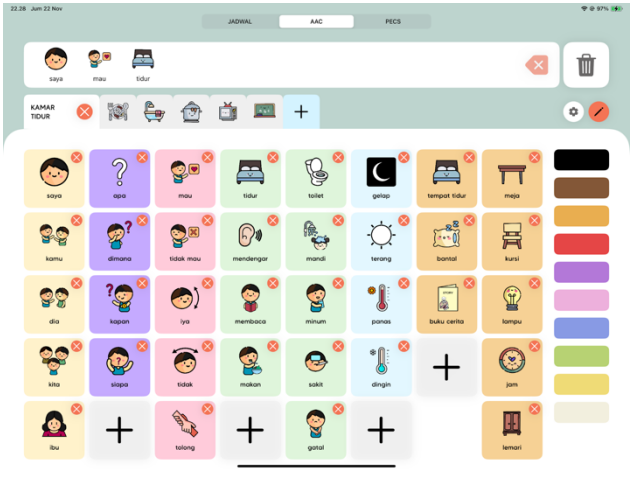

Figure 4. AAC Application After Revision

From the feedback received, the author decided to simplify the appearance of the AAC application to improve ease of use. The first time the app is opened, the user is immediately directed to the AAC board that is ready for use. The AAC board is divided into categories or rooms, which are designed to help children with ASD access vocabulary more easily, avoiding confusion caused by too much vocabulary in one view.

In addition, the author also added a new feature (edit feature) where the therapist or assistant of the ASD child can add new words to increase the vocabulary of the ASD child. The edit feature also includes the ability to add new card objects, either live images or images imported from the device.

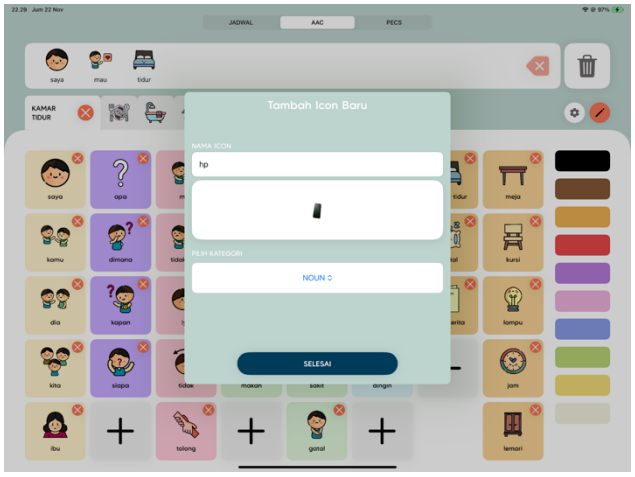

Figure 5. Edit Feature Adding a New Card Object

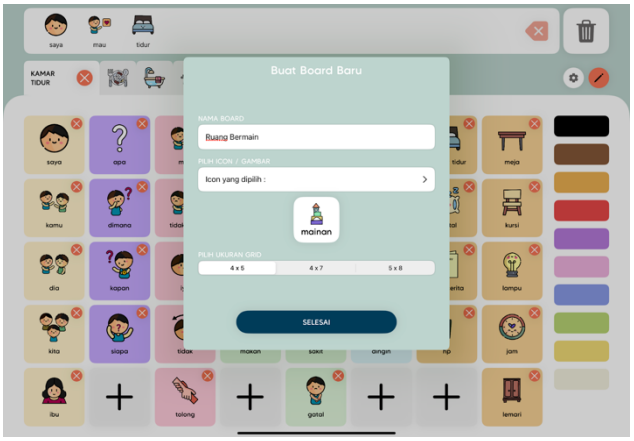

Figure 6. Edit Feature to Add a New Room

Users can also create new room boards to expand their vocabulary options. The app provides AAC board size customization options with various configurations, such as 4x5, 4x7, or 5x8, which can be tailored to the user's needs. This allows the app to provide a more personalized and effective experience in supporting the communication of children with ASD.

After updating the application, the author then conducted User Acceptance Testing (UAT) to evaluate whether the system has met the needs and expectations of users. This testing phase involves real users with the aim of ensuring that

the system meets their needs [22]. In terms of this testing, the author wanted to see if ASD children in Indonesia could understand how to use the AAC application. To support this, the author first tested a therapist (Mrs. Winda Dwi Puteri H.) from Happy Angela Center special school and a parent of an ASD child (Mrs. Dian Sonnerstedt). After that, the therapist and the parent of the ASD child will guide the child to use the AAC application. The following is the user testing scenario created by the author to test the success of the AAC application.

TABLE 2
USER TESTING SCENARIO

User	Goals	Scenario	Expected Output	Success/No
Child with ASD	Testing sentence construction skills using the AAC board	Pressing the word button to construct a sentence (e.g. "I want to eat")	The sentences appear in the sentence box above in the correct order	Successful
		Delete a word or an entire sentence in the sentence box	Words or sentences are removed according to the child's interaction	Successful
		Pressing the sentence box to sound out the composed sentence	Sentences read with clear and appropriate audio	Successful
Therapist Parents	Testing the ability to add new vocabulary to the AAC board	Adding a new word (e.g. "Apple") and selecting an image via *import* from the device gallery	Words and images were successfully added to the AAC board	Successful
		Add new words and select images through live photos using the camera	Words and images were successfully added to the AAC board	Successful
		Add new words and select images via search from the app *library*	Words and images were successfully added to the AAC board	Successful
	Test the ability to add and organize custom rooms	Create a new room (e.g. "Dining Room"), adding vocabulary related to the room	The new room is successfully created, and the vocabulary appears according to the room context	Successful
	Test the ability to save and apply settings	Save all the settings that have been made, ensuring the child can use the customized AAC board right away	All settings are saved and applied correctly without *errors*	Successful

Testing has shown that the use of AAC can help children express their wishes more clearly and effectively. They can express their basic wants and needs such as "want to eat", "want to pee", "want to play" well and can be understood by the people around them including the therapist.

TABLE 3
COMPARISON OF VOCABULARY COUNTS BEFORE AND AFTER USING AAC

Children	Number of Vocabulary Before AAC	Number of Vocabulary After AAC
A	2	8
B	2	5
C	3	5
D	1	3
E	3	7

Because the therapist can understand and fulfill their wishes, ASD children on the non-verbal spectrum no longer experience tantrums. In addition, in just one month the number of vocabulary words they mastered increased significantly compared to before using the AAC board. The data was then tested using a paired t-test with the Statistical Hypothesis as follows. H_0 (Null hypothesis): There is no significant difference before and after the use of AAC. H_1 (Alternative hypothesis): There is a significant difference after the use of AAC. Based on this hypothesis, there will be 2 interpretations of the results, namely:

- If p-value <0.05, H_0 is rejected → meaning there is a significant difference after using AAC.
- If the p-value ≥ 0.05, H_0 fails to be rejected → meaning there is no significant difference.

After calculating using Python with the help of the scipy library, a p-value of 0.010469669289615218 was generated, which means that there is a significant difference after using AAC.

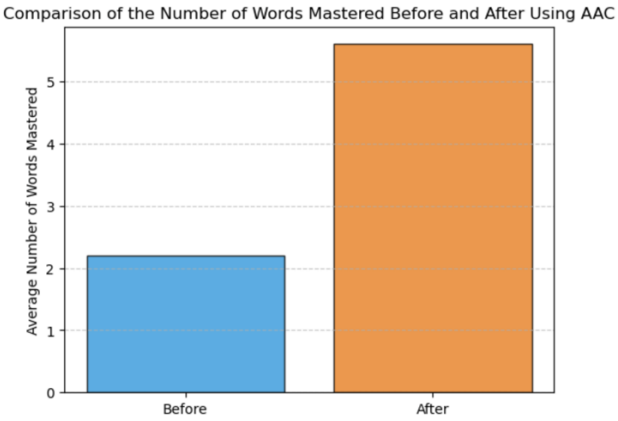

Figure 7. Comparison of the Number of Words Mastered Before and After Using AAC

With this app, ASD children on the non-verbal spectrum can communicate their wants and needs more independently and master more new vocabulary, reducing frustration due to limitations in verbal communication. This has clearly debunked the stigma in Indonesian society that the use of communication aids such as AAC can slow down the speech development process in ASD children due to dependence on the communication aids. The results of this test are also in line with existing research, where 89% of the studies analysed reported an improvement in the speech of individuals using AAC and no participants experienced a decrease in speech due to the use of AAC [21].

IV. CONCLUSION

The testing results showed that some children experienced confusion when using the app, especially in understanding how to navigate and the functionality available. However, after receiving direction and guidance from a trained therapist, they were able to understand and use the app properly. This process demonstrates the importance of adult support in helping children adapt to new technologies [20]. In addition, AAC has been shown to be very helpful for ASD children in conveying their wants and needs, thus reducing frustration due to limitations in verbal communication.

As an improvement, the author added an edit feature for more flexible customization. This came about in response to feedback from one parent who wanted the ability to customize the AAC board according to their child's specific needs. With the addition of this feature, it is hoped that the app will be more personalized and effective, allowing users to make settings that better suit their individual communication context.

A suggestion for future research is to add a voice personalization feature so that the voice of the sentence pronunciation is that of a person close to the ASD child. This is evidenced by a study showing that pronunciation by caregivers, especially mothers, can increase engagement with children with ASD, indicating that these children are more responsive to the voices and interactions of people they know well [23]. In addition, future research can develop Android-based AAC applications so that more users can access them, thus improving the quality of life and independence of ASD children in Indonesia.

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