DEVELOPMENT OF A MOBILE APPLICATION FOR DYSLEXIC-FRIENDLY LEARNING MATERIALS

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ABSTRACT: Dyslexia, a prevalent learning disorder affecting approximately 10% to 15% of primary school children in Malaysia, presents a significant educational hurdle. Traditional interventions often rely on in-person sessions, imposing additional demands on parents. Existing technology-based platforms are partially dyslexic-friendly with limitations such as poor user interfaces, limited content, lack of progression to advanced learning, and attempts to address multiple skills simultaneously. This paper proposes an enhanced dyslexic-friendly mobile application (app) to address these issues. The app employs the Orton-Gillingham approach to ensure a continuous and progressive learning environment. Moreover, it also uses the Structured Literacy approach by dividing learning into three modules that reinforce basic phonology, syllable knowledge, and meaning association. This app is developed using several software components: Visual Studio Code, Android Studio, Flutter, and Adobe XD. Besides, the app includes games that serve as diagnostic tools to monitor improvement, identify weaknesses, and measure progress. By catering to diverse learning styles and needs, this app offers a more accessible and supportive learning experience through an innovative mobile tool that promotes inclusivity, independence, and continuous skill development.

ABSTRAK: Disleksia, gangguan pembelajaran lazim yang menjejaskan kira-kira 10% hingga 15% kanak-kanak sekolah rendah di Malaysia, memberikan cabaran pendidikan yang ketara. Intervensi tradisional sering bergantung pada sesi bersemuka, menyebabkan tuntutan tambahan kepada ibu bapa. Platform berasaskan teknologi sedia ada sebahagiannya mesra disleksia dengan batasan seperti antara muka pengguna yang lemah, kandungan terhad, kekurangan kemajuan kepada pembelajaran lanjutan dan percubaan untuk menangani pelbagai kemahiran secara serentak. Untuk menangani isu ini, aplikasi mudah alih mesra disleksia yang dipertingkatkan dicadangkan dalam kertas kerja ini. Aplikasi ini menggunakan pendekatan Orton-Gillingham untuk memastikan persekitaran pembelajaran yang berterusan dan progresif. Selain itu, ia juga menggunakan pendekatan Literasi Berstruktur dengan membahagikan pembelajaran kepada tiga modul yang mengukuhkan fonologi asas, pengetahuan suku kata, dan perkaitan makna. Aplikasi ini dibangunkan menggunakan beberapa komponen perisian yang merangkumi Kod Visual Studio, Android Studio, Flutter dan Adobe XD. Selain itu, aplikasi tersebut menggunakan permainan yang berfungsi sebagai alat diagnostik untuk memantau peningkatan, mengenal pasti kelemahan dan mengukur kemajuan. Dengan memenuhi gaya dan keperluan pembelajaran yang pelbagai, aplikasi ini menawarkan pengalaman pembelajaran yang lebih mudah diakses dan menyokong melalui alat mudah alih yang inovatif yang menggalakkan keterangkuman, kebebasan dan pembangunan kemahiran berterusan.

1. INTRODUCTION

Learning disabilities have become a significant educational and developmental challenge, affecting a substantial portion of the population. A comprehensive report by the Department of Social Welfare revealed an astonishing 236,972 registered cases of individuals grappling with these disabilities [1]. Additionally, a 2023 report from the Ministry of Education discloses that there are up to 97,494 cases of learning disorders in Malaysian schools, with 17,271 (18%) identified as dyslexic [2]. Dyslexia, classified as a neurodevelopmental disorder, affects an individual's ability to grasp basic literacy-related skills, such as spelling and reading [3]. This distinctive impact makes dyslexia easily identifiable, especially in children as they begin their formal education. Individuals displaying symptoms of dyslexia frequently exhibit significant delays compared to their peers, particularly in reading. Regrettably, if left untreated, this can result in diminished self-esteem and reduced confidence [4].

Table 1. Summary of Existing Mobile Applications

Mobile application	Features	Limitations
Dyslexia Baca [5]	• A Malay-language app for early dyslexic readers. • Introduces confusing letters, supports alphabet recognition with multisensory methods, and features rewards for achievements.	Needs better interfaces, offers overly simple levels, focuses narrowly, and lacks continuous learning progression.
Easylexia [6]	A level-based number quiz game with a user-friendly interface and structured learning.	Overemphasis on multiple skills may confuse.
Alexza [7]	A user-friendly app helping dyslexic users overcome reading difficulties in real-life situations.	• Not focused on learning. • Ideal for those with basic reading skills.
Funologo [8]	An Android-based virtual reality app that enhances phonological awareness in dyslexic children using the Orton-Gillingham approach.	Unspecified information on how the learning modules work.
Dys-I-Can [9]	• An app with modules for dyslexic children aged 3 to 12. • Offers a relaxing environment and rewards throughout their learning journey.	Can confuse module transitions
The Hope [10]	• A stage-by-stage app that monitors dyslexic individuals' progress. • Uses the Orton-Gillingham approach to enhance learning benefits.	Requires extra equipment for handwriting recognition assessment and parental guidance.
The Cure [11]	An alternative for individuals with dyslexia and dysgraphia is to practice reading and writing independently with a user-friendly app and diverse practice words.	• No variation in level progression. • Not very engaging for children.
Arunalu [12]	A multisensory mobile app in Sinhala with interactive interfaces and a reward system.	• Only in Sinhala. • No clear distinction between screening and intervention stages.

Given the significant number of dyslexic individuals and the challenges they face, specific educational and support interventions such as treatment sessions and special classes within schools are essential. While these intervention strategies have been employed for a more effective learning environment for dyslexic individuals, these mainly rely on in-person sessions, imposing additional strain on parents already managing demanding schedules. Consequently, there is an urgent need for more accessible and dyslexia-friendly educational

interventions. Though numerous technology-based learning platforms, such as mobile applications (apps) for dyslexia, have emerged, many of these apps struggle with issues like poor user interfaces and content limitations. Response often features distracting colors and unclear designs. Likewise, many apps focus solely on early learning phases, such as alphabet recognition, without a smooth transition to more advanced learning. Moreover, attempts to address multiple skills simultaneously may lead to confusion and burnout, not fulfilling the need for balanced content complexity and user engagement. These limitations are summarized in Table 1.

Considering these limitations, this paper presents the development of a mobile application tailored to the specific needs of dyslexic individuals. Designed for smartphones and tablets, the app offers support anytime, anywhere to promote continuous learning. It features a user-friendly interface to enhance clarity, a structured progression from foundational to more advanced and complex materials, and targeted learning modules to prevent cognitive overload. The app aims to provide accessible, personalized tools for effective education, incorporating interactive features and feedback to boost engagement, support self-directed learning, and foster the development of essential educational skills.

The structure of the following sections is as follows: Section 2 offers an overview of dyslexia, Section 3 outlines the methodology of this study, Section 4 presents and analyzes the results, and Section 5 summarizes the paper.

2. OVERVIEW OF DYSLEXIA

The Special Education Division within the Ministry of Education Malaysia characterizes dyslexic individuals as those with intellectual abilities equal to or surpassing those of their peers of the same age, but who confront substantial challenges in spelling, reading, and writing [3]. Therefore, dyslexia is generally associated with a reading disorder or reading disability. Common characteristics presented by dyslexic individuals include deficits in phonological processing and letter reversal. Phonological processing, essential for understanding written and spoken language, includes phonological awareness [13], memory, and access to lexical storage components. Dyslexic individuals repeatedly struggle with these components, impacting their reading fluency and comprehension and making it harder for them to decode and understand text. Letter reversal is another common deficit in dyslexic children. They have difficulty recognizing between similarly shaped letters [14]. For example, they may write /b/ as /d/, /p/ as /q/, or /m/ as /w/. Furthermore, they might reverse the sequence of syllables in words, such as writing "load" as "laod". Considering the challenges dyslexic individuals face, it is necessary to adopt specific teaching approaches instead of traditional classroom settings. These approaches should be tailored to target specific areas of difficulty to enhance learning outcomes.

This paper studies two well-known teaching approaches, namely Structured Literacy and Orton-Gillingham. These approaches are detailed in the following sub-sections.

2.1. Structured Literacy

Structured Literacy is a teaching approach developed by the International Dyslexia Association (IDA). It offers a comprehensive approach to literacy education by focusing on six key pillars: phonology, phonics, syllable knowledge, morphology, syntax, and semantics. Phonology refers to the rules governing how sounds are pronounced in a specific language. Knowledge of phonology enables individuals to recognize and manipulate letter sounds, identify rhyming words, and segment sounds within words. The sound-symbol correspondence

(or phonics), involves the skill of associating phonemes (sounds) with graphemes (letters). For example, associating the sound /ch/ with the letter "ch."

Syllable knowledge enhances the ability of dyslexic individuals to analyze the comprehension and pronunciation of words, while morphology focuses on the structure of words, including prefixes, suffixes, and roots. Syntax, conversely, concerns how sentences are structured and how words are arranged to convey meaning. Finally, semantics is the study of the meanings of words, symbols, and word units, intending to help individuals understand written and oral texts. In conclusion, this approach introduces reading in small, sequential steps, beginning with sound recognition and progressing to meaning and word association. This method effectively strengthens the foundations of reading and writing, particularly for individuals with dyslexia, by providing them with essential literacy skills.

2.2. Orton-Gillingham

The Orton-Gillingham is an approach designed for one-on-one instruction [15]. Developed in the early 1930s by Anna Gillingham and Dr. Samuel Torrey Orton, it provides a systematic, sequential, and cumulative learning process, with lessons reviewed repeatedly to reinforce understanding and focus. Instruction begins with simple concepts and progressively advances to more complex material. The approach also incorporates multisensory structured language (MSL), which engages visual, auditory, tactile, and motor skills across listening, speaking, reading, and writing activities. This multisensory technique allows students to associate sounds with what they see, hear, and feel, using their eyes, ears, mouths, and hands. Lessons are tailored based on continuous assessments to meet each student's specific needs. In conclusion, the Orton-Gillingham method offers a comprehensive and individualized approach to support individuals with learning disabilities, helping them better understand and retain educational material. Table 2 presents a comparison of the two teaching approaches.

Table 2. Comparison of Structured Literacy and Orton-Gillingham Approaches

	Structured Literacy	Orton-Gilligham
Aim	This approach introduces the fundamentals of Literacy to strengthen students' foundational reading and writing skills.	This approach promotes a systematic, sequential, and cumulative learning environment to help students maintain focus and better understand the learning content.
Characteristics	• Consists of six pillars, namely phonology, sound-symbol correspondence (phonics), syllable knowledge, morphology, syntax, and semantics. • Breaks reading into smaller, sequential steps.	• Applies prerequisite concepts to ensure progressive improvement. • Encourages engagement through MSL. • Tailors teaching plans according to individuals' strengths and weaknesses.

3. METHODOLOGY

This section describes the methodology used in developing the mobile app, encompassing the flowchart, the software components utilized, and the user interface design. The details of each are described next.

3.1. Flowchart

The proposed mobile app incorporates Structured Literacy and Orton-Gillingham approaches to create a dyslexic-friendly learning environment. The flowchart of the proposed

mobile app is illustrated in Fig. 1. It can be observed in the figure that the app encompasses three learning modules aligned with the Orton-Gillingham approach in ensuring progressive and cumulative learning processes. Each module is based on the pillars of Structured Literacy, where Module 1 teaches basic phonology, Module 2 teaches syllable knowledge, and Module 3 teaches meaning association. The app will be available in Malay to boost Literacy for dyslexic individuals in Malaysia. Primarily targeted at users aged 7 to 9 years, the app helps address early signs of dyslexia, such as difficulty learning. It is also suitable for kindergarten-aged children who can use it to begin their learning journey. Designed to improve literacy skills, the app helps dyslexic users spell and read simple sentences.

The app begins each session by randomly selecting a word when users click "Start." This word will be used across Module 1, Module 2, and Module 3, ensuring a consistent and progressive learning experience. Module 1 introduces users to sounds associated with each letter, such as teaching the sound /ch/ for the letter "k." In Module 2, users progress to combining the letters learned in Module 1 into syllables, understanding their corresponding sounds. For instance, if Module 1 teaches the sounds for "a" and "k," Module 2 combines these to introduce the syllable "ka." Module 3 applies learned syllables to construct complete words. This structured progression ensures a systematic approach to phonological learning, supporting gradual and continuous improvement in users' abilities to understand and use sounds and syllables to form words.

After completing each learning module, users take an evaluation test presented as an interactive game. This game incorporates Rapid Automatized Naming (RAN) to assess the speed of verbal material retrieval by measuring how quickly users identify letters, syllables, and words on screen [16]. While the game does not use speech input, it simulates RAN through visual recognition tasks. Dyslexic individuals often score lower on RAN tasks, affecting their reading fluency and comprehension, which can hinder academic progress. Integrating RAN into the monitoring process helps educators and parents identify areas where users may need additional support, promoting continuous growth and academic achievement. Test scores decide whether users can progress to the next module.

The accuracy of answers and response times are recorded to calculate the overall score. A congratulatory page appears if a user's score is above the required minimum. Thereafter, the user can proceed to the next module. Otherwise, the user will be redirected back to the current module. This evaluation continues throughout the modules, generating a cumulative progress report that allows parents to monitor their children's progress over time.

3.2. Software Components

The development process of the proposed app utilizes several software components involving Visual Studio Code, Android Studio, Flutter, and Adobe XD. Visual Studio Code is a widely used code editor that supports multiple programming languages. Additionally, it includes essential tools like debugging and Git integration. Android Studio is a powerful platform for coding, debugging, and testing. Besides, it offers an emulator that allows testing of applications on various Android devices. Flutter empowers the development of local applications for mobile, web, and desktop platforms from a single codebase using Dart. Finally, Adobe XD is a component used to create interactive and visually appealing designs for mobile applications. Its design process seamlessly adapts to diverse mobile sizes, perfecting the user experience. These software components are summarized in Table 2.
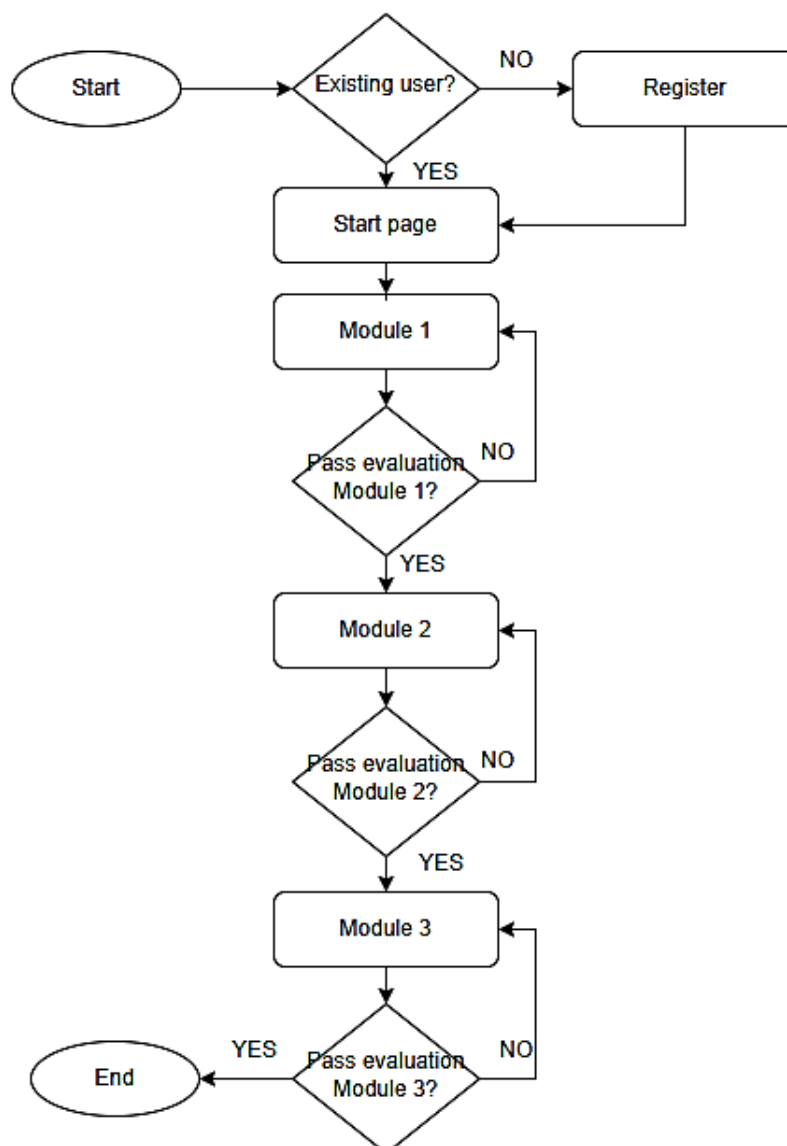
Figure 1. Flowchart of the proposed mobile app

3.3. User Interface Design

The user interface design carefully considers font and color choices to support individuals with dyslexia. Dyslexic readers often struggle when letters are closely spaced or when colors are distracting [17]. As greater spacing has been shown to improve reading speed by reducing visual crowding, the app increases letter spacing (2.0 spacing) and widens the space between words. Helvetica font was chosen because it reduces fixation durations, which are a key measure of reading fluency, and has been associated with faster reading speeds and high user preference among individuals with dyslexia [18]. Furthermore, the app incorporates colored overlays and adjusts text presentation to favor lower brightness and contrast, following recommendations from the British Dyslexia Association. Studies show that highly contrasted colors are less effective for individuals with dyslexia, while cream-black combinations and pastel colors improve readability [19]. Personalized color adjustments are important, as color preferences can vary among dyslexic users.

In addition to the font and color considerations, other factors listed in Table 3 were integrated into the user interface design to accommodate individuals with dyslexia. These user interface designs are grounded in established guidelines and recommendations reported in prior research, ensuring that the developed app follows validated practices rather than independently developed criteria.

Table 3. User Interface Guideline Summary [17]

Components	Descriptions
Fonts	Use large font size: 18 to 26 points.
	Use consistent large spacing within words and larger on between words.
	Suggested font: Courier, Helvetica, Verdana and San Serif font type.
	Use lowercase for ease of reading.
Color	Use dark color text on a light background.
	The background should not be too bright.
Navigation	Easy navigation.
Consistency	The same theme/design will be used throughout the entire application design.
Interaction	Simple instruction in text and voiceover.
	Avoid using too much flashing and moving text.
	Tapping of buttons for selection to avoid many steps and fine motor movement for fingers.
	Simple Click.
Game Type	Drag and drop.

4. RESULTS AND DISCUSSIONS

As previously discussed in Section 3, the proposed mobile app encompasses three progressive learning modules, aligning with the Orton-Gillingham approach. A user must register to use the app for the first time, which must only be done once. This registration ensures that user activity is recorded, allowing for the monitoring of progress and improvements. After registration, the user will be directed to Module 1, Module 2, or Module 3, depending on their achievements. Each module is described next.

4.1. Module 1

After logging in, users can click the Start button, prompting the app to select a word from a predefined list, identify its characters, and begin the learning module. For instance, if the chosen word is "Kucing," users will be prompted to learn each character in "Kucing," including "K," "U," "C," "I," "N," and "G." Each character is displayed in both uppercase and lowercase formats. This module integrates key components of the Structured Literacy approach, such as phonology and phonics. As the user clicks the forward arrow icon, the application audibly pronounces each letter, enhancing the learning experience. Fig. 2 shows the user interface and the flow of Module 1.

Figure 2. Module 1 (Learning Module)

Upon completing Module 1, users move on to a Drag-and-Drop game (Fig. 3) to test their comprehension. In this figure, each box contains a character. The upper boxes contain the characters 'K', 'U', 'C', 'I', 'N', and 'G', respectively, while the lower boxes contain the characters 'I', 'G', and 'N'. The user must drag each lower box and drop it onto its correct matching box above. For example, the lower box labeled 'I' must be dropped onto the upper box labeled 'I'. Incorrect placements/drops trigger sound effects to signal errors, and each drag action plays the corresponding character's sound. Performance is scored based on accuracy. If users achieve 75% accuracy or higher, a congratulatory message as shown in Fig. 4 appears, and they can move on to the next module. Otherwise, they can either retry the game or revisit the learning session. This game uses the Orton-Gillingham method, with repeated lessons to reinforce understanding and gradual progression to more complex content. The time taken to complete the game is also recorded.
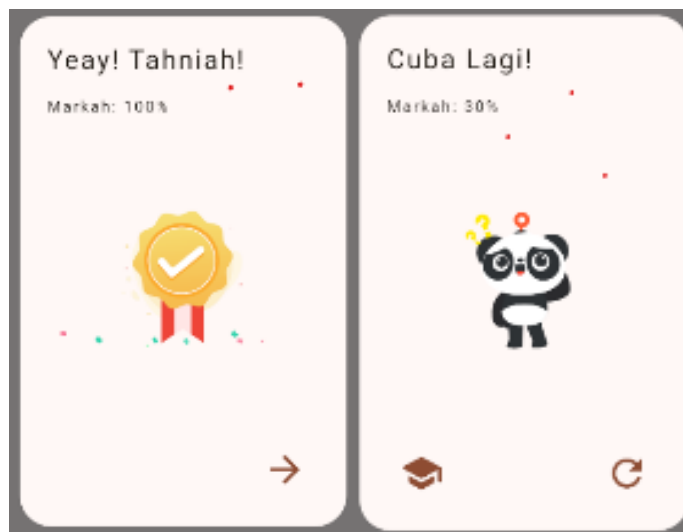

Figure 3. Module 1 (Drag & Drop Game)

Figure 4. Congratulatory and Retry Message

4.2. Module 2

In Module 2, users progress to the next foundational pillar of Literacy as outlined by the Structured Literacy approach, syllable knowledge. Users are now introduced to syllables based on the knowledge gained in Module 1, where words were studied and learned as individual characters. For instance, a word previously introduced, such as "Kereta," is segmented into its constituent syllables: "Ke," "re," and "ta." Like Module 1, Module 2 includes an audio feature that reads each syllable aloud, enhancing phonological awareness and supporting a more comprehensive approach to literacy development. The user interface and the flow of Module 2 are illustrated in Fig. 5.
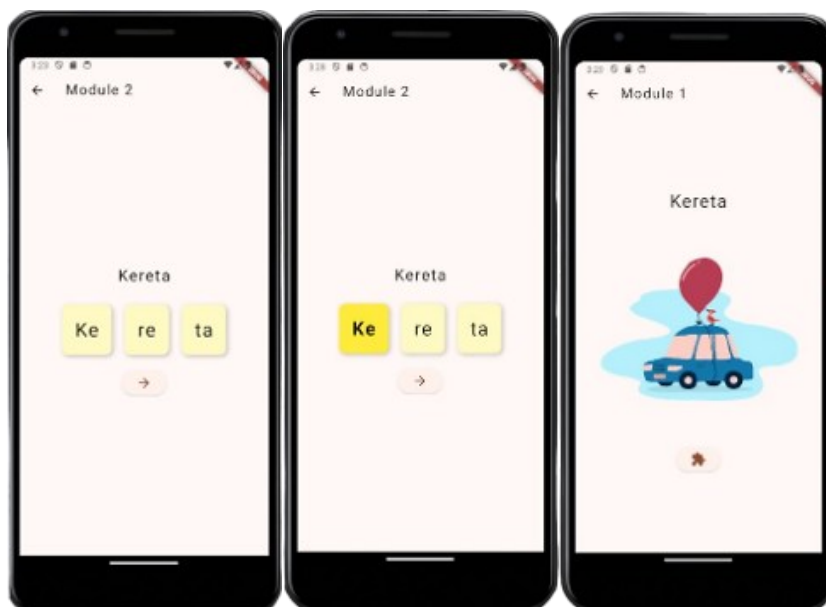
Figure 5. Module 2 (Learning Module)

After successfully completing Module 2, users engage in a puzzle game where they arrange syllables to form complete words, as shown in Fig. 6. This game format enhances syllable recognition and word formation skills. A blue box placed incorrectly in a grey box counts as an incorrect attempt, while a correctly placed blue box that turns the grey box yellow

is considered correct. Accuracy is calculated similarly to Module 1, with a congratulatory message displayed for successful performance.
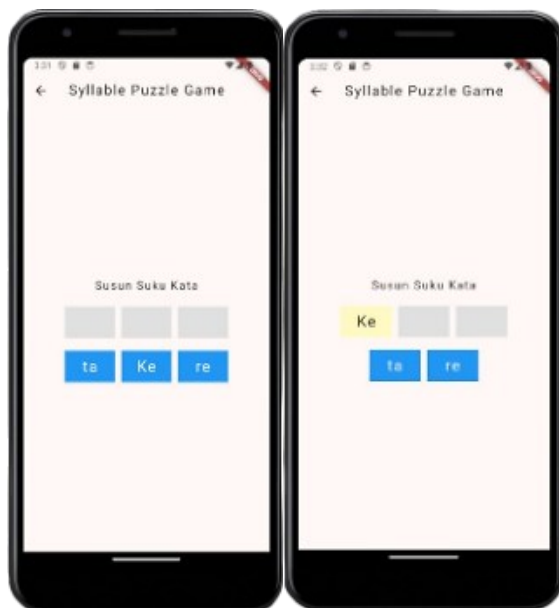

Figure 6. Module 2 (Syllable Puzzle Game)

4.3. Module 3

Following mastering syllables, users progress to Module 3, which focuses on meaning association. To activate this module, users must interact with the app at least twice to familiarize themselves with two different words. This module features two interactive games designed to reinforce meaning association and assess understanding. The first game is a matching game where users pair images with corresponding words. A selected box highlights, and if the correct image is chosen, the box turns yellow to indicate a correct match, as shown in Fig. 7.
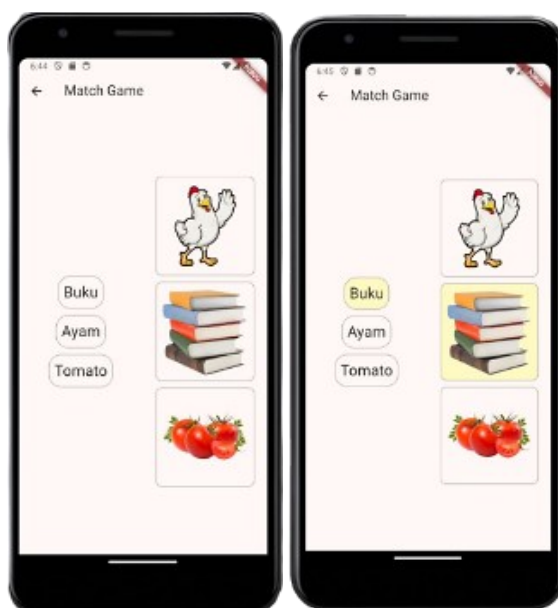

Figure 7. Module 3 (Match Game)

The second game in this module is a classic card memory game where players match pairs of cards with words and images. This game is crucial for enhancing phonological memory, which involves coding information in a sound-based system for temporary storage. Since limitations in phonological memory can impact reading comprehension, engaging in this game helps users practice and strengthen their phonological memory, improving their ability to store and recall sound information effectively.

Each game serves as a diagnostic tool to monitor improvement and identify weaknesses, with accuracy and completion time carefully recorded as critical measures of progress in phonological memory and comprehension skills. To avoid distractions, accuracy results are not displayed on the user interface. Still, they are accessible within the app, as shown in Fig. 9 and Fig. 10. A study comparing word reading accuracy found significant differences between typically developing children and those with dyslexia, with typically developing children achieving a mean accuracy of 91.43%, while dyslexic children averaged 72.47%. These findings underscore the challenges dyslexic children face in decoding and recognizing words. Given these results, the app's 75% accuracy requirement is well justified. This standard applies to all students, including those with dyslexia, who must achieve or exceed this accuracy level to advance to the next module. Setting the threshold slightly above the average accuracy observed among dyslexic students (72%) implies a significant improvement in their reading abilities. It indicates meaningful progress in overcoming the specific challenges associated with dyslexia, potentially facilitated by effective interventions or strategies aimed at enhancing word recognition and overall reading fluency [20].
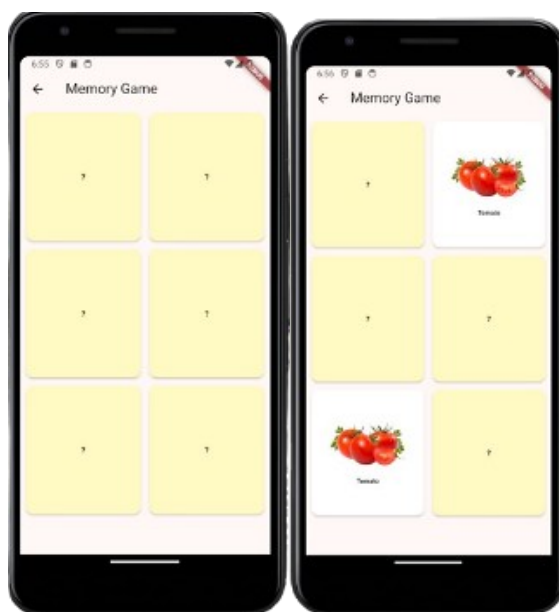

Figure 8. Module 3 (Memory Game)

Figure 9. Accuracy above 75%

Figure 10. Accuracy below 75%

5. CONCLUSIONS

This paper proposes a dyslexic-friendly mobile learning application designed to address the educational challenges of dyslexic children. It integrates the Orton-Gillingham and Structured Literacy approaches to provide progressive and cumulative learning through modules focused on phonology, syllable knowledge, and meaning association. The app was developed in Malay to improve literacy outcomes for dyslexic students in Malaysia and contribute to a more inclusive educational landscape. The app features an enhanced dyslexic-friendly interface with accessible fonts, color configurations, and interactive games that monitor user progress by identifying weaknesses and improvements.

Despite its promising features, the app has several limitations, particularly related to the learning materials and its effectiveness in delivering a dyslexic-friendly user experience. Although the materials were based on a syllabus for dyslexic individuals, further clarification and validation from teaching professionals are needed to ensure the content is appropriately tailored. Additionally, the app's usability, including average completion time, scores across modules, and clarity of instructions and content, has not yet been fully evaluated with both dyslexic and non-dyslexic users. Future work should involve thorough usability and acceptance testing with both dyslexic and non-dyslexic learners to gather feedback and subsequently refine the app's effectiveness. A thorough review of the learning content should also be conducted with input from teaching professionals to strengthen its educational foundation. Planned enhancements will also include improving the text-to-speech functionality, refining syllable segmentation algorithms for Malay, and creating a more interactive score reporting interface for parents. Eventually, the app's performance should be compared with other available tools to assess its capability and effectiveness in supporting dyslexic-friendly learning.

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