Learning Engagement of Children with Dyslexia Through Tangible User Interface: An Experiment

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***Abstract*—This paper presents the evaluation of a mobile application employing Tangible User Interface (TUI) technology to enhance the educational involvement of children experiencing dyslexia. The primary objective of this application is to assist these children in overcoming challenges related to reading, spelling, pronunciation, and writing, issues often associated with lower self-esteem and dissatisfaction in an academic setting. The study adopts a User-Centered Design (UCD) approach, focusing on the specific needs and preferences of children with dyslexia during development. The evaluation involved 30 children with dyslexia, divided into two groups: a control group utilizing the non-tangible DisleksiaBelajar mobile app (DB) and a treatment group utilizing the DisleksiaBelajar 3D Tangible (DB3dT) app, which incorporates tangible elements. Results indicated that the DB3dT app achieved significantly higher usability scores (79.5%) compared to the DisleksiaBelajar app (51%). Furthermore, the treatment group utilizing the DB3dT app surpassed the control group in learning performance. In summary, the evaluation demonstrated that integrating tangible elements into the DB3dT app notably enhanced the learning experience for children with dyslexia when compared to the non-tangible DisleksiaBelajar app. The children exhibited increased engagement and a willingness to repeat activities, suggesting potential advancements in learning outcomes and performance.**

***Keywords*—Dyslexia; Tangible User Interface; mobile application; user centered design; engagement**

I. Introduction

Dyslexia is a learning disorder which is commonly found to have difficulty explicitly in language. Children with dyslexia tend to have language difficulty that leads them to be incompetent in reading skills, word recognition, differentiate the sound of letters, recognize mirror letters, and create the syllables in the sentences. Besides, dyslexic students also may face difficulty with spelling, writing, and speaking. In current teaching method, dyslexic students have limitation as the study material unable to offer feedback in learning and multisensory technique is not being embraced appropriately [1].

Multisensory techniques are required to allow dyslexic students to use all senses such as touch, see, hear, and kinesthetic movements in learning to read, make sound of the letters correctly and recognize, and distinguish the mirror letters. Besides, the current teaching module has constraints in terms of delivery to the students while learning. For instance, teachers are required to teach single sound values or letter sounds, word recognition and phonological awareness module such as rhyming and blending the words to the students which relying heavily on the teachers as well as required to teach one- to -one to students which lead to extremely labor intensive, and prolonged in performing the teaching procedure. This teaching module can be a real challenge to deliver and difficult to produce the sound of the letters correctly to students.

An appropriate tangible interaction learning model is developed to promote interactive and engaging learning experiences for dyslexic students to improve the current teaching approach [32]. One technique that has extremely beneficial in learning for dyslexic students is incorporating Tangible User Interface (TUI). TUI provides numerous advantages such as fun learning, collaboration, and support for children with dyslexia in learning mostly in language [2, 3]. TUI allows users to interact with physical objects in the real world, connecting to the digital information in the virtual world and including spatial and embodied facilitation. The advancement of interactive systems has been propelled by the increasing availability of novel devices and methods of interaction. Users now have access to a range of innovative interactive technologies across various application domains, including natural user interfaces, multi-touch displays, cameras, and sensor-based interactions [28].

TUI has been applied with success to children with special education needs. The works in [12, 13, 14, 15, 16, 17, 31] collectively demonstrate the benefits of tangible interaction for children with Dyslexia and Attention Deficit Hyperactivity Disorder (ADHD). TUI provides a suitable method for engaging children in playful learning and has been shown to facilitate improvements in reading, spelling, writing, and letter sound correspondence skills, as well as higher retention abilities in learning environments. The incorporation of tactile and multisensory elements enhances the learning experience, promoting exploratory activities and offering a playful learning environment that supports the unique needs of children with dyslexia. Overall, TUI has proven to be an effective approach in supporting the learning and development of children with dyslexia.

In research [29] discussed systematic mapping of toy user interfaces which focus on physical tangible toys and revealed the opportunities of TUI in education domain. As an example, in [30], the authors furnish a comprehensive examination of the TUI. They delve into its functional characteristics, present various application cases, and explore the design and application considerations related to TUI in the context of education. This paper presents the evaluation of TUI system using experiment for children with dyslexia in improving learning engagement.

The structure of the study is based on the following: Section II will present the literature review, Section III will present the methodology used in the research, Section IV and Section V will present the results and discussion, Section VI will present the conclusion and future work.

II. Literature Review

A. Tangible User Interface (TUI)

Over the years the benefits of TUI have been rapidly expanded to build embedded and cooperating user experiences. TUI allows the interaction of physical items known as tangibles with computer applications. TUI has several inherent benefits compared to traditional user interfaces (e.g., keyboard or mouse interfaces), with a natural environment and rapid haptic feedback when users get both digital and physical feedback. Research demonstrates TUI enables students to participate in learning activities cognitively, emotionally, physically, and socially. TUI is also recognizable to students who have difficulty with learning such as dyslexics. Dyslexia is an impairment in the language that affects reading, writing, speaking, and listening. The conventional dyslexia learning using multi-sensory procedure has proven to be effective in assisting individuals to learn. However, owing to its rigorous, extended, and one-on-one teaching procedure, this method is highly demanding.

For children with dyslexia, who benefit from multisensory learning, TUI offers advantages through tactile and kinesthetic modalities that are absent in GUI. These modalities enhance the learning experience for these children, providing them with a more engaging and effective learning environment. For children with dyslexia, it is crucial to incorporate tactile and kinesthetic senses when designing TUI systems for teaching them to read and write. By considering their specific needs, the design space must include necessary guidelines that highlight not only the interface but also the learning styles, learning activities, dyslexia learning methods, student's level, and feedback.

TUI in children's learning has garnered significant interest due to its benefits. One such benefit is that tangible interaction, which utilizes embodiment and various forms of feedback (e.g., audio, visual, and haptic), supports different learning styles of children [4]. TUI in learning is commonly incorporated into play activities, which have the potential to promote the cognitive, motor, and physical development of children. When children play, they engage their cognition to think, explore, and enjoy the learning process. However, ensuring children's engagement in learning poses significant challenges [5, 6].

B. Engagement

One of the most important aspects in learning performance is student engagement. This is because level of engagement leads to improved retention, which improves learning performance [7]. In the teaching and learning of children with dyslexia, engagement functions as a nonverbal behavior that necessitates attention. In the context of children with dyslexia, learning engagement is often a big struggle due to the difficulties they face such as They may feel frustration and anxiety due to their difficulties in reading and writing, leading to negative attitudes toward learning, emotional outbursts, or withdrawal from academic tasks [8]. These struggles can impact self-esteem, giving rise to feelings of inadequacy and reluctance to participate in school activities [9]. As a coping mechanism, children with dyslexia may exhibit avoidance behaviors, such as avoiding reading or writing tasks, resisting class participation, or hiding their difficulties from others [10]. Consequently, they may struggle to maintain focus during reading or writing tasks, leading to distractibility and difficulty staying on task. This can significantly affect their overall academic performance and hinder their ability to engage in learning activities and follow instructions [11].

C. Related Works

TUI has been utilized as an assistive technology in educational settings for children with learning difficulties. In this context, six TUI learning systems related to language learning for children with special needs are discussed. The first system, Character Alive [12] a TUI system to support children with dyslexia aged between 5-7 years old in reading and writing skill was developed. The system emphasized on the learning Chinese literacy acquisitions for Mandarin language and provides multisensory approach to allow children in reading and writing of the Chinese characters and words. The system incorporates tangible objects which use dynamic color cues, 2D tangible cards and provide intuitive feedback such as audio, tactile and visual using animations representations. The function of using color cues in the system to inform children on the common patterns of similar characters. Besides, children can arrange and organize the 2D tangible cards which allow them on the tactile feedback and kinesthetic learning environment. Moreover, the use of animation in the system can capture children attention and enable them to memorize the Chinese characters effectively. Though, the work is still in progress which the researcher has not conducted any usability testing to evaluate in terms of the effectiveness of the system.

The second system PhonoBlocks [13] a TUI system developed for reading that uses dynamic colour cues embedded in 3D tangible letters to provide additional decoding information and modalities for children aged 5-8 years old, who are having difficulty learning to decode English letter-sound pairs. The work has addressed several TUI design guidelines in assisting dyslexic to read such as spatiality, various types of interaction modalities, and multiple ways of letter representation as well as structured procedures. PhonoBlocks allows simultaneous use of visual, auditory as well as kinesthetic or tactile approach in both physical and digital representations. It also focuses on the 3D design of tangible letters which facilitates dyslexic children to learn letter as a basis rather than words because they often struggle with letter-sound correspondences and mirror-letter such as b and d.

Third, Block Talks [14] is a system that combines TUI and augmented reality (AR) to support children aged 8-10 in learning English sentence construction. The system utilizes tangible blocks that represent different elements of a sentence, such as subjects, verbs, and objects. Children can physically manipulate and arrange these blocks to create meaningful sentences. This hands-on approach provides a structured and scaffolded learning experience that fosters language development and helps children grasp grammar rules and sentence formation. The engagement and fine motor skills involved in the tangible interaction promote a deeper understanding of sentence structure. Additionally, AR technology enhances the learning experience by providing visual and auditory feedback, contextual information, and interactive storytelling elements. For example, through the AR display on the screen, children can better comprehend sentence construction concepts and see their constructed sentences come to life. Evaluation results show that Block Talks effectively engages children and promotes their understanding of sentence structure. The use of TUI with the blocks stimulates hands-on learning and facilitates the development of language skills, including grammar and syntax.

Fourth, Interactive Fruit Panel (IFP) [15] is a TUI serious game developed to support children with special needs in learning an alternative communication system. IFP offers three key advantages in facilitating communication skills for children with special needs. Firstly, it utilizes a tangible interface in the form of a fruit panel, allowing children to physically interact with the panel. This hands-on approach promotes engagement, fine motor skills, and a multisensory learning experience. Secondly, IFP incorporates a serious game element, making the learning process enjoyable and motivating for children. Finally, IFP is specifically designed to address the unique needs of children with special needs in learning alternative communication. It provides a structured and intuitive interface that supports language and communication development, enabling children to express themselves effectively. Evaluation findings indicate that when children played with IFP, they showed increased concentration compared to using traditional games. Moreover, the use of IFP resulted in less distraction for the children.

Fifth, Tactile Letters is a multimodal TUI tabletop system developed to teach English alphabet sounds to children with dyslexia aged five to six years old [16]. The system utilizes texture cues in the form of two sets of tangible letters, each consisting of 24 letter cards. Children can choose to interact with the 3D tangible letters or use the letter cards on the interactive tabletop. When children connect the tangible letters correctly, audio feedback is provided to reinforce their learning. The design guidelines of this work emphasize spatiality, allowing children with dyslexia to decode and arrange the letters in their environment. Additionally, multiple senses, including audio, visual, and tactile, are incorporated into the prototype. By providing a hands-on and multisensory learning experience, Tactile Letters aims to improve letter recognition and enhance visual processing for children with dyslexia. The evaluation results indicate that the incorporation of texture cues successfully captures the participants' attention and increases their engagement with the program. The inclusion of frequent kinesthetic movement promotes brain activity and aids in word retention, surpassing the effectiveness of traditional flashcards. Participants expressed interest in the program and gained knowledge from the phonics-based reading program. Tactile Letters serves as a potential reading tool for children with dyslexia, assisting them in independent reading practice and learning, complementing their regular classroom instruction.

Six, TraceIt is another tool designed to support children with dyslexia in reading through a hands-on and interactive learning activity [17]. TraceIt utilizes air tracing interaction to improve letter formation and enhance visual processing. The program incorporates color-based physical objects and offers a multisensory learning experience. The evaluation results reveal that the air tracing interaction technique successfully captures the participants' attention and increases their engagement with the program. The inclusion of frequent kinesthetic movement promotes brain activity and aids in word retention, surpassing the effectiveness of traditional flashcards. Participants not only expressed interest in the program but also gained knowledge from the phonics-based reading program. TraceIt demonstrates good potential as a reading tool for children with dyslexia, providing a playful and interactive learning environment that complements their regular classroom instruction.

The works by [12, 14, 15, 16, 17] collectively demonstrate the benefits of TUI for children with dyslexia. TUI provides a suitable method for engaging children in playful learning and has been shown to facilitate improvements in reading, spelling, writing, and letter sound correspondence skills, as well as higher retention abilities in learning environments. Overall, TUI has proven to be an effective approach in supporting the learning and development of children with dyslexia.

III. METHODOLOGY

User-Centered Design (UCD) was adopted in this study, which involves understanding the user and their needs and context throughout the entire process from user requirements to evaluation stages. UCD consists of four phases: understanding the context, specifying user requirements, designing solutions, and evaluating against the requirements [18]. In this research, UCD was incorporated to develop a prototype and gain a deep understanding of users by involving them in the design process and product development. The focus was on meeting users' needs and improving their experience with the proposed solutions.

A. The Experiment

A quasi experiment was conducted in DAM centers in Ampang and Bandar Baru Bangi that aimed to evaluate the effectiveness of the DB3dT app in engaging students with dyslexia. Due to the limited number of participants available for randomization, a quasi-experiment was chosen. The participants in this study were children with dyslexia who were already attending predetermined classes in the DAM centers and were assigned to an eight-week intervention conducted within their school setting. These children were classified based on their level of study, which included beginner, intermediate, and advanced levels. The experiment consisted of two groups: the control group and the treatment group. The control group comprised 15 children with dyslexia who did not receive any stimulus. In their case, a non-tangible approach using the DisleksiaBelajar mobile app was provided. On the other hand, the treatment group consisted of 15 children with dyslexia who received stimulus in the form of the DB3dT app. For this group, tangible objects such as tangible cards and toys were prepared to enhance their interaction with the app (see Fig. 1). The children in the treatment group engaged with the DB3dT app through task activities specifically prepared for them.

Fig. 1. The tangible objects- flashcards, 3D alphabet and toy.

B. The Procedure

The experiment was conducted on school property, utilizing a private space provided by the school principal. The location for the evaluation activity was assigned by the teacher and chosen based on its convenience, accessibility, and suitability for video recording purposes [19]. The decision to conduct the experiment in a school setting was aimed at providing the participants with a familiar and comfortable environment throughout the procedure [20]. Creating a comfortable atmosphere was important to promote a sense of ease for the participants [21] and ensure their comfort during the session [22].

Fig. 2. Experiment with children.

The session began with an introduction between the student, facilitator, and observer to help the student become acquainted with the setting and the session. The facilitator then explained the instructions regarding the instruments and the tasks required. In the control group, fifteen children were instructed to use the non-tangible approach using the DisleksiaBelajar mobile app. On the other hand, the treatment group, comprised of another fifteen children, were asked to use the tangible approach with the DB3dT app. Throughout the experiment, a facilitator was present near the students to assist them in using the application. An observer was also seated in front of the students to observe their engagement through facial expressions and behavior. Considering the vulnerability factors associated with the participants, such as their age and disabilities, maintaining a high-quality relationship between the facilitator and students was crucial [23] (see Fig. 2). Additionally, the facilitator communicated instructions in the Malay language to ensure clarity and understanding for the children.

During the session, whenever a student required assistance, such as when they needed help with spelling specific terms or when they were unfamiliar with the vocabulary of an object in Malay, support was provided and recorded. If a student struggled significantly with the exercises and remained inactive for a prolonged period, the question was skipped to save time and minimize demotivation. Two mobile tablets were utilized during the experiment, specifically for the DisleksiaBelajar mobile app and the DB3dT app. The DisleksiaBelajar mobile app was developed specifically for children aged between 6 to 12 years old with dyslexia, aiming to enhance their Malay language skills. Both instruments were introduced in this quasi-experiment as entirely new approaches. This was done to ensure that neither group of dyslexic children had any prior knowledge or bias when using these apps. The DB3dT app employed a tangible approach, while the DisleksiaBelajar mobile app utilized a non-tangible approach. These two apps had similar activity modules focusing on phonology, spelling, and reading skills. Prior to the start of the experiment, the children with dyslexia were introduced to and familiarized with the mobile tablets, including learning how to use the camera, and understanding the functions and settings of the devices. For the experiment setup, materials such as a mobile tablet, a video recorder, and a mobile phone were used. The session lasted for 45 minutes and was recorded using a video camera for further analysis.

C. The Instruments

Several data collection instruments were used in this experiment: Tangible approach using DB3dT application, non-tangible approach using DisleksiaBelajar application, System Usability Scale (SUS), Again-Again Table and Observation Form. The SUS serves the purpose of evaluating the system's usability from the perspective of dyslexic children. In addition, the use of a five-point Smileyometer scale, as shown in Fig. 3, allows students to rate their experience with the SUS ranging from 1 to 5, with a rating of 5 representing the most positive response. Fig. 4 displays the ten items that are evaluated in this scale. To ensure comprehension among children, the items were translated into Malay language without altering their original meaning. This instrument has been validated and previously used in the study conducted by [24]. As some children may not be able to read fluently, facilitators assist in reading the items. The Again-Again table was utilized to evaluate enjoyment, engagement and confirm acceptance of the DB3dT app by children with dyslexia that using 3-point Likert scale of 'Yes, Maybe, No' (*Ya, Mungkin, Tidak*) as shown in Fig. 5. As described by [25], human emotion should be considered when validating user acceptance for assessing user experience. The Again-Again table from the Fun Toolkit [26] was utilized as a self-reporting approach for children. According to [24, 27], the Again-Again table was utilized because students are highly likely to experience enjoyment when an activity is engaging, making them willing to do it again.

D. The Application

The DisleksiaBelajar 3d Tangible (DB3dT) application was developed based on the proposed learning model [32]. The DB3dT app enables children to interact with digital information using tangible objects such as tangible letter cards, alphabet blocks, and toys in the physical environment. In study [12], the author developed a reading augmented reality using 2D and 3D cards to compose a character within a word and sentences in supporting children Chinese reading and writing skills.

This DB3dT facilitates phonology, spelling, and reading skill development specifically tailored to dyslexic learning patterns. Through intuitive interaction with tangible objects, children can construct words from syllables and view augmented reality 3D overlay content on a screen during the learning activity. The application incorporates various sensory experiences, including tactile, auditory, visual, and kinesthetic elements, to strengthen literacy skills. There are five learning activity modules in DB3dT app as depicted in Fig. 6.

Sangat tidak setuju	Tidak setuju	Kurang pasti	Setuju	Sangat setuju

Fig. 3. Smileyometer.

	Soalan	Skala				
1	Saya akan sentiasa menggunakan aplikasi DB3dT ini.					
2	Aplikasi DB3dT ini mudah digunakan.					
3	Saya berjaya menggunakan aplikasi DB3dT ini tanpa bantuan orang lain.					
4	Aplikasi DB3dT ini berfungsi dengan baik.					
5	Saya suka menggunakan aplikasi DB3dT ini.					
6	Saya faham arahan yang digunakan dalam aplikasi DB3dT ini.					
7	Saya seronok apabila menggunakan aplikasi DB3dT ini.					
8	Aplikasi DB3dT ini membantu saya dalam mempelajari Bahasa Melayu dengan baik.					
9	Saya berjaya menggunakan aplikasi DB3dT ini tanpa sebarang masalah.					
10	Saya yakin menggunakan aplikasi DB3dT ini.					

Fig. 4. The 10-items for system usability scale.

Adakah anda mahu bermain modul aktiviti ini lagi?

Aktiviti	Ya	Mungkin	Tidak
1.Belajar Fonologi Huruf 			
2. Belajar Fonologi Suai huruf 			
3. Belajar Fonologi Suku kata  			
4. Belajar Fonologi Suku kata Digraf  			

Fig. 5. Again-Again table.

Fig. 6. Five learning activity modules in DB3dT app.

1) Huruf, Suai Huruf and Suku Kata modules: This module focuses on phonology skills, specifically vowels, consonants, and syllable exercises. The vowel activity evaluates the student's knowledge of vowels, requiring them to differentiate vowel sounds and match the world's first letter in the Huruf module. Pictures are provided alongside the words to assist students in selecting the correct vowel. On the other hand, the consonant practice addresses five common consonant mistakes in the Malay language, as shown in Fig. 7. This task assesses a learner's ability to identify consonant sounds and match them correctly. The syllables exercise consists of two types: Vowel + Consonant Vowel (V+CV) and three-syllable combinations (CV+CV+CV), among others. This activity evaluates the learner's ability to recognize pictures, choose the correct syllable, and drag it into the appropriate word. To provide a challenge, similar syllables are also presented as distractors. In the Suai Huruf module, students match initial letters with corresponding pictures. This module introduces six letters: b, d, c, e, n, and m, which are known to cause confusion among dyslexic children. The objective is to help dyslexic students understand and recognize these letters, as shown in Fig. 8. The Suku Kata module focuses on sorting and recognizing CV and CVCV syllables using picture hints, as depicted in Fig. 9.

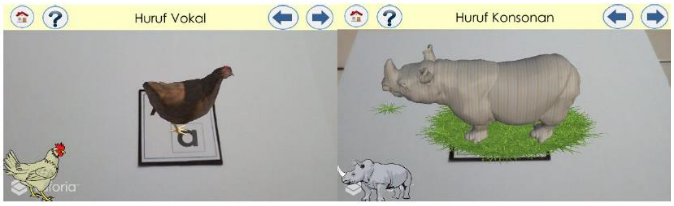

Fig. 7. Vowel and consonant activity in the *Huruf* module.

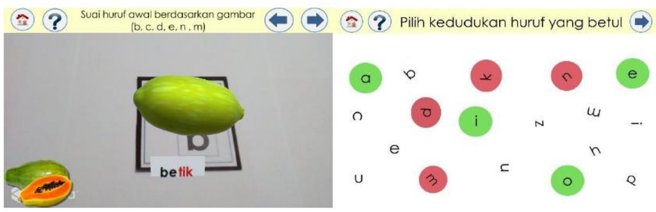

Fig. 8. Matching initial letters with picture and identify correct letter position in the *Suai Huruf* module.

Fig. 9. Sorting syllables using CVC and CVCV in the *Suku Kata* module.

2) Ejaan (Spelling) module: The Ejaan module is designed to assist dyslexic children in identifying spelling based on picture hints provided at the bottom left of the screen. The students are asked to manipulate tangible letters to construct the correct spelling. Each letter is accompanied by its corresponding sound. An example of the activity involves spelling the word "kuda" using CVCV words, as shown in Fig. 10. Additionally, dyslexic students learn to spell digraphs (ny, ng, kh, sy) and diphthongs (ai, au, oi), as depicted in Fig. 11. Finally, the module includes an activity where dyslexic students need to identify the correct spelling of colors, helping them practice spelling words correctly, as depicted in Fig. 12.

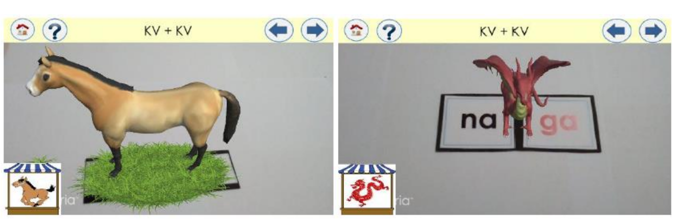

Fig. 10. Spell and divide the CVCV in the *Ejaan* module.

Fig. 11. Spell and divide the CVCV in the *Ejaan* module.

Fig. 12. Choosing correct colors spelling in the *Ejaan* module.

3) Bacaan (Reading) module: This module provides children with short passages themed around animals in the zoo. Students have the option to read the passages on their own or listen to the system narrator by pressing the audio icon. They can then select and interact with tangible animal figurines displayed on the screen. Four animal figurine toys are available for selection: Tiger (Harimau), Rhinoceros (Badak sumbu), Turtle (Penyu), and Orang Utan. Students can scan the tangible animals, triggering an augmented video of the animal along with accompanying sounds and a narration of its story. Following the Bacaan module, dyslexic children can engage in comprehension exercises by clicking on the Latihan icon at the top of the screen. These exercises require them to answer questions based on the animal stories they previously learned, with three exercises provided for each animal, as shown in Fig. 13.

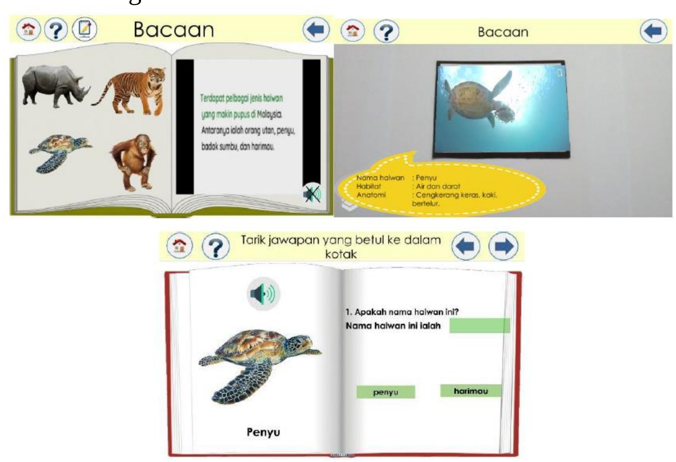

Fig. 13. Reading a short passage and learning comprehension modules.

IV. Results

In this study the primary objective is to examine the effectiveness of the DB3dT app to enhance student engagement in learning for children with dyslexia through a quasi-experiment. We presented descriptive statistics to determine the average on-task behavior of the students as a measure of the effectiveness of the DB3dT app. The experiment results were analyzed for usability testing using the System Usability Scale (SUS), usability observations, user experience using the Again-Again Table, and a checklist of children's performance in learning activities.

A. Descriptive Statistic

According to the results presented in Table I, the average on-task time for beginner students in the control group, who used the non-tangible approach (DisleksiaBelajar mobile app), was recorded as 14 minutes and 93 seconds (SD= 2.72). In comparison, for the treatment group that used the tangible approach (DB3dT app), the average on-task time was recorded as 33 minutes and 58 seconds (SD= 6.18). This indicates that students in the treatment group were more engaged with the activity modules, even at the beginner level. Furthermore, among students at the intermediate level, those in the control group exhibited an average on-task time of 12 minutes and 49 seconds (SD= 1.37), while the treatment group recorded an average of 31 minutes and 30 seconds (SD= 7.74). This translates to a twofold increase in on-task time for the treatment group indicating that students using the DB3dT app retained their engagement for a longer period compared to those using the DisleksiaBelajar mobile app. Some students mentioned that the DisleksiaBelajar mobile app was too easy for them, leading them to complete tasks quickly. Finally, the analysis of average on-task time between the control group and treatment group for advanced students was conducted.

The results showed that students in the control group were engaged with the activity modules for approximately 11 minutes and 39 seconds (SD= 2.72) using the DisleksiaBelajar mobile app, whereas the treatment group recorded an average of 22 minutes and 54 seconds (SD= 3.73) using the DB3dT app. These values indicate that there was a twofold difference in on-task time between the two activity modules due to the higher mastery level of the advanced students. Since advanced students were more proficient in performing the activity modules, their engagement time was shorter compared to beginner and intermediate levels. Nonetheless, the treatment group still retained twice the engagement time compared to the control group. This suggests that using the tangible approach (DB3dT app) in the treatment group resulted in higher engagement levels with the activity modules compared to the non-tangible approach used in the DisleksiaBelajar mobile app. In general, the adoption of a tangible approach in learning activity modules plays a crucial role in measuring student engagement based on on-task time. The results clearly indicate that students using the DB3dT app spend more time engaged compared to students using the DisleksiaBelajar mobile app.

B. System Usability Scale

Based on these scoring rules, the average score for the DB3dT app (tangible approach application) is 79.5%, whereas the average score for the DisleksiaBelajar app (non-tangible application) is 51%. In conclusion, the DB3dT app with its integration of tangible elements like augmented models, animations, videos, and text, was found to be more usable for students with dyslexia compared to the DisleksiaBelajar mobile app. This can be seen in the analysis of each questionnaire item, which showed more positive responses (odd numbered items) for the DB3dT app versus the DisleksiaBelajar app (see Fig. 14). The DB3dT app also had fewer negative responses (even numbered items) than the DisleksiaBelajar app for most items. For item 5, which asked about system function integration, the treatment group scored 4.3 and the control group scored 4.1, a minor 0.2-point difference. This small difference is likely because students felt the functions were good in both apps. Overall, the tangible elements incorporated in the DB3dT app made it more engaging and usable than the non-tangible DisleksiaBelajar mobile app for children with dyslexia.

TABLE I. RESULT FOR ON-TASK TIME FOR BOTH GROUPS

	Control Group					**Treatment Group**				
Beginner	18.00	17.17	15.17	12.24	12.1	37.37	24.83	30.19	40.54	34.99
Average	14.93					33.58				
SD	2.72					6.18				
Intermediate	11.87	14.34	13.51	11.74	11.03	27.31	26.3	43.99	33.4	25.51
Average	12.49					31.30				
SD	1.37					7.74				
Advanced	10.37	14.89	13.52	9.89	8.3	27.74	18.63	21.12	20.21	25.02
Average	11.39					22.54				
SD	2.72					3.73				

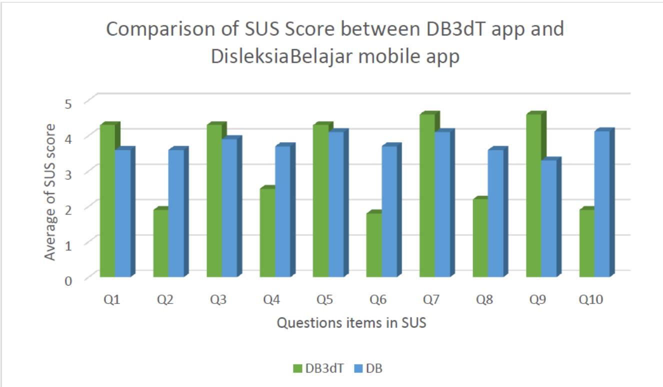

Fig. 14. Comparison of SUS score for DB3dT app and DisleksiaBelajar mobile app.

C. *Usability from the Observation*

In this study, observational notes were utilized to capture the students' signs, expressions, and behavior while interacting with both tangible and non-tangible applications. These notes were used to make a comparison between the DB3dT app as a tangible application and the DisleksiaBelajar mobile app as a non-tangible application as shown in Table II. During the experiment, it was observed that each student had different abilities in responding to the applications. Students at the beginner level encountered challenges in answering comprehension questions and struggled with reading lengthy passages. On the other hand, students at the intermediate and advanced levels demonstrated confidence in engaging with the activities and were able to answer comprehension questions effectively. Based on the observations, two distinct types of students emerged: those who were on-task (engaged) and those who were off-task (disengaged). Engaged students exhibited dynamic concentration and active interaction with the application. They required less supervision and demonstrated independent participation. In contrast, disengaged students displayed various behavioral issues such as excessive talking, difficulty sitting still, hyperactivity, fear of making mistakes, easy distractibility, and a tendency to give up quickly during the activities. The results indicated that the tangible approach offered additional advantages for both engaged and disengaged students. Using the DB3dT app, both types of students remained engaged for longer periods. The DB3dT app's activities allowed students to interact with the learning materials based on their level of engagement, encompassing cognitive, behavioral, and emotional aspects.

D. *User Experience using Again-Again Table*

The Again-Again table was also used to evaluate enjoyment and engagement for children with dyslexia. The children scored each DB3dT app activity interface that they wanted to play again using a 3-point Likert scale of 'Yes, Maybe, No'. Thirty children completed the scoring. Frequencies of the scales were calculated to analyze the activities. This study relates to the work of [27], which used enjoyment as a metric to quantify students' emotions while interacting with a mobile app for those with speech delays. The result in Table III indicates that most children highly enjoyed certain DB3dT activities, such as *Fonologi Suku Kata* and *Ejaan*, with all students willing to play them again. They found these activities easy and engaging, attributing their enjoyment to the fun tangible letter cards they could arrange on the board, interesting 3D visuals on screen, and letter sound feedback. Additionally, the children needed minimal assistance during these tasks, displaying genuine enjoyment and enthusiasm while using the app. In contrast, activities like *Fonologi Huruf, Fonologi Suku Kata Digraf*, and *Latihan Pemahaman* had only 73% agreement among students to play again. Some students found these activities more challenging due to reading difficulties, needing more facilitator support to identify sentences.

TABLE II. COMPARISON OF STUDENT'S RESPONSE FROM OBSERVATIONAL NOTES

Study Level	DisleksiaBelajar mobile app (DB) (non-tangible)	DB3dT app (tangible)
Beginner	• Displayed no reaction when they were asked about the letters. • Kept on trying and making mistakes of each letter.	• Amazed with the tangible objects. • Kept playing with the tangible cards and figurine toys.
	• Unable to sit still and were restless.	• Got distracted with the tangible objects/ cards.
	• Confused by some letters, especially 'b' and 'd', and were unable to read long passages	• Unable to sit still and restless.
	• Asked for help from the facilitator when doing the activity.	• Followed the words and letters when learning letters.
	• Bored and wanted to quit the activity.	• Abled to engage with the learning activity even when facing technical issue.
Intermediate	• Showed excitement when answering the questions.	• Displayed astonishment as soon they saw 3D objects appearing on the screen.
	• Confidently saying 'yes' and finding it easy after completing the activity.	• Clapped their hands when scanning tangible objects.
	• Confused by some letters, especially 'b' and 'd', and were unable to read long passages	• Smiled while doing the activity.
Advanced	• Showed no expression and were bored because the activity was deemed easy.	• Abled to read the passages of the animal story.
	• Felt shy but still wanted to do the activity.	• Excited to use the black board to arrange letters.
	• Displayed no expression when they answered the questions correctly.	• Smiled when they were able to answer the learning comprehension questions.

Additionally, 80% of children agreed to play the *Fonologi Suai Huruf* activity again, while only 53% agreed for the *Bacaan* activity. Feedback showed these activities were more difficult, with some struggling to read fluently, blend syllables, and comprehend long sentences and passages. Overall, the findings indicate children prefer activities with tangible objects like cards and letters, as these elements greatly influence their interest in learning. To enhance the learning experience, incorporating visual, audio, and kinesthetic components is crucial. In conclusion, the Again-Again table demonstrates the DB3dT app is enjoyable to use. This confirms that the children's experiences and feelings while engaging with the DB3dT app, as revealed in Table III, align with the Again-Again table results. The tangibility elements made activities more engaging and fun for children with dyslexia.

E. Performance Checklist

In this experiment, student engagements were evaluated using a performance checklist that consisted of various questions related to their learning activities. The purpose of utilizing this checklist was to assess their progress in the learning tasks and obtain a comprehensive understanding of their learning outcomes. The questions covered different aspects of phonology learning, including identifying vowel and consonant letters, matching letters, learning syllable patterns (CVCV, CVC), spelling, and reading short paragraphs with 4, 5, and 6 sentences. The total possible score for these questions was 40. Both groups were given this performance checklist as an exercise based on the learning modules they had previously completed.

TABLE III. FREQUENCY RESPONSE TO AGAIN-AGAIN TABLE FOR DB3DT APP

Activity	Would you like to play again?	Frequency
Fonologi Huruf (Letter Phonology)	Yes	**11**
	Maybe	**4**
	No	-
Fonologi Suai Huruf (Letters Matching Phonology)	Yes	**11**
	Maybe	**3**
	No	**1**
Fonologi Suku Kata (Syllables Phonology)	Yes	**15**
	Maybe	-
	No	-
Fonologi Suku Kata Digraf (Digraph Syllables Phonology)	Yes	**11**
	Maybe	**4**
	No	-
Fonologi Suku Kata Diftong (Diphthong Syllables Phonology)	Yes	**12**
	Maybe	-
	No	**3**
Ejaan (Spelling)	Yes	**15**
	Maybe	-
	No	-
Bacaan (Reading)	Yes	**8**
	Maybe	**6**
	No	**1**
Latihan Pemahaman (Comprehension Exercise)	Yes	**11**
	Maybe	**2**
	No	**2**

The average total score of all 15 participants was 67.5%. It is worth noting that the control group scored slightly lower, at 60%, while the treatment group achieved a score of 65% at the beginner level, as depicted in Fig. 15. At the intermediate level, the control group attained an average score of 72%, whereas the treatment group scored 77% (see Fig. 16). Lastly, at the advanced level, the control group obtained an average score of 69.5%, whereas the treatment group excelled with an average score of 89.5% (see Fig. 17). These results suggest that the children with dyslexia in the treatment group displayed higher levels of engagement in the learning activities across all three proficiency levels compared to the control group.

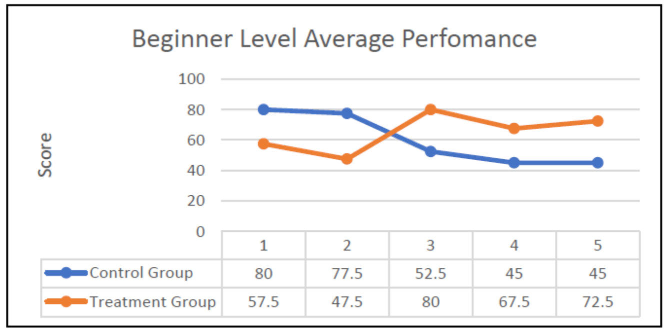

Fig. 15. Beginner level average performance.

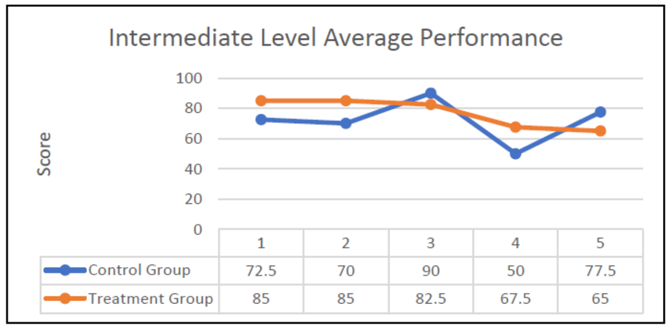

Fig. 16. Intermediate level average performance.

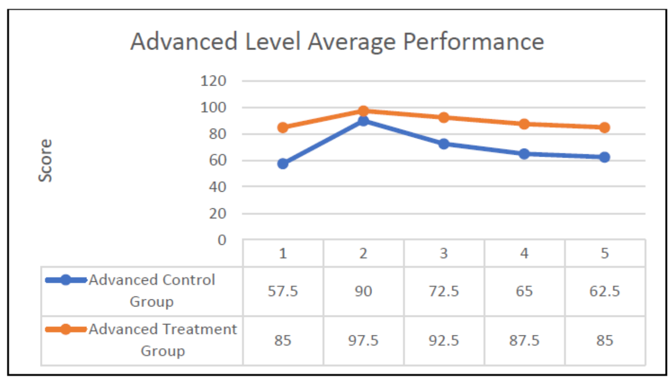

Fig. 17. Advanced level average performance.

V. DISCUSSION

This section discusses on evaluating the usability aspects and engagements of the DB3dT app. The evaluation encompasses the main aspect which is the effectiveness of the DB3dT app in promoting children's engagement. To evaluate the effectiveness of the DB3dT app in promoting student engagement, a quasi-experiment was conducted involving dyslexic students. The students were divided into control and treatment groups to compare the results based on their on-task time when using the non-tangible approach using the

DisleksiaBelajar app (control group) and the tangible approach using the DB3dT app (treatment group). The on-task time was utilized as a measure of student engagement. The results indicated that the treatment group, which used the DB3dT app, exhibited better and longer engagement compared to the control group using the DisleksiaBelajar mobile app, additionally, the hypothesis testing revealed a significant effect, indicating that the DB3dT app had a significant impact on improving engagement for children with dyslexia in the learning process.

Additionally, the SUS and Again-Again table were used to measure DB3dT app usability. Results showed the DB3dT app (tangible approach) had higher average usability at 79.5% versus 51% for the DisleksiaBelajar app (non-tangible). The Again-Again table also measured enjoyment and engagement. Most DB3dT activities were found to be fun and enjoyable, with children willing to play them again, indicating higher engagement. This aligns with research showing increased performance from sustained learning engagement [33].

The learning performance checklist and exercises also showed the treatment group had higher engagement, with average total marks of 77.5% compared to 67.5% for the control group. The higher scores for the DB3dT app group indicate its effectiveness at retaining engagement. In summary, usability and engagement metrics showed tangibility elements in the DB3dT app enhanced the learning experience for children with dyslexia versus the non-tangible DisleksiaBelajar app. The children were more engaged and willing to replay activities, suggesting potential learning and performance improvements.

VI. Conclusion and Future Work

Overall, the effectiveness of the DB3dT app in promoting student engagement was evaluated by conducting a quasi-experiment that involved children with dyslexia. In conclusion, the DB3dT app demonstrated positive outcomes in supporting children with dyslexia learning the Malay language. The tangible elements incorporated in the DB3dT app increased engagement and understanding compared to the non-tangible mobile app. Based on the findings of this research, it is evident that the DB3dT app enhances learning activity and improves engagement among children with dyslexia. It also provides a usable approach for children in the learning process. Considering the constraints of limited time and funds, there are several recommendations for future research that can further enhance the understanding and application of the DB3dT app. For future work, we will replicate this research using students with diverse learning disabilities, such as dysgraphia or dyscalculia, would allow for an examination of how different types of learning disabilities impact the behavioral intention to use the DB3dT app accurately. This broader applicability of the results would provide valuable insights into its effectiveness across various learning disabilities.

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