TANGIBLE INTERACTION LEARNING MODEL TO ENHANCE LEARNING ACTIVITY PROCESSES AMONG CHILDREN WITH DYSLEXIA

By

SITI NURLIANA BINTI JAMALAI@JAMALI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

This thesis is dedicated to
my beloved late father Tn. Hj. Jamali Abd Hamid and
the late Prof Dr. Abdul Azim Ab Ghani
and my loving family.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman : Associate Professor Ts. Novia Indriaty Admodisastro, PhD
Faculty : Computer Science and Information Technology

The Tangible Interaction Learning Model acts as an important supplement to the conventional teaching approach for children with dyslexia, utilizing tools such as alphabets boards, flash cards, blocks, dominoes, and sand study materials. Dyslexic children often struggle with reading, writing, and spelling, as they have difficulty recognizing and manipulating sounds in language and blending letters. A multisensory teaching approach has been shown to help integrate visual, auditory, tactile, and kinaesthetic elements into their learning environment. However, these traditional multisensory teaching materials lack attractiveness, sensory feedback, and fail to address engagement behaviour, requiring constant teacher intervention.

To address these limitations, the Tangible Interaction Dyslexia Learning Model (TIDLM) is proposed for primary school children with dyslexia learning the Malay language. This model is designed to enhance engagement in learning activities. A learning activity refers to a specific task or action that children with

dyslexia perform by using study materials such as flashcards, alphabet boards to facilitate their learning process. The learning process refers to the entire journey of learning which include children with dyslexia to perceive, process and integrate their new knowledge into their existing understanding. The existing learning models are insufficient in supporting the learning process, and none of them focus on designing tangible interaction (TI) learning environments specifically tailored for children with dyslexia. Moreover, there is a limited source of design guidelines to support the development of TI applications for dyslexic children in Malaysia, especially in the learning activity. The TIDLM emphasizes providing a valuable tool for learning by guiding the creation of interfaces and TI applications that are usable, effective, and beneficial for children with dyslexia. A prototype of the TIDLM, named Disleksia Belajar 3Dimensional Tangible (DB3dT) app, was developed based on the proposed learning model. 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. This application 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 kinaesthetic elements, to strengthen literacy skills. The TIDLM was evaluated through expert validation to assess the usability aspects of the prototype and relevancy of the learning activity modules to student engagement. The expert validation results show that 75% agree that the

DB3dT app is usable, and the learning activities received 100% acceptance as appropriate for dyslexic students. Furthermore, a quasi-experiment was conducted on 30 students aged between 7 and 12 years old at Dyslexia Association Malaysia (DAM). The DB3dT app was compared with the DisleksiaBelajar mobile app, a non-tangible approach application for learning the Malay language, to evaluate the effectiveness of the DB3dT app in student engagement for children with dyslexia. The cognitive results of engagement obtained from performance checklist shown that the treatment group had higher engagement with the average total marks of 77.5% compared to 67.5% for the control group. This suggests that children with dyslexia were more engaged in the learning activities facilitated by the DB3dT application. The behavioural results of engagement indicate a significantly longer on-task time, with an average of 33 minutes and 58 seconds when using the DB3dT app compared to 14 minutes and 93 seconds with the DisleksiaBelajar mobile app (p value <0.05) using the Mann-Whitney U test. The results clearly indicate the children with dyslexia using the DB3dT app spend more time engaged compared to children using the DisleksiaBelajar mobile app. Additionally, the emotional engagement results indicate children with dyslexia prefer activities with tangible objects due to these tangible elements greatly influence their interest in learning. The evaluation of usability aspects during the experiment with the children revealed an average score of 79.5% for the DB3dT app compared to an average score of 51% for the DisleksiaBelajar mobile app. Most of the learning activities in the DB3dT app were found to be fun and enjoyable, indicating that the children were willing to replay them and displayed higher engagement while using the DB3dT app. In conclusion, the

TIDLM effectively supports the learning activities of students, and the DB3dT app provides an enjoyable and interactive learning experience for children with dyslexia to learn the Malay Language.

Keywords: Tangible Interaction, Special Education Needs, Children with Dyslexia, Learning Engagement

SDG: GOAL 4: Quality Education, GOAL 10: Reduced Inequalities

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MODEL PEMBELAJARAN INTERAKSI KETARA UNTUK MENINGKATKAN PROSES AKTIVITI PEMBELAJARAN DALAM KALANGAN KANAK-KANAK DISLEKSIA

Oleh

SITI NURLIANA BINTI JAMALAI@JAMALI

Februarl 2024

Pengerusi : Profesor Madya Ts. Novia Indriaty Admodisastro, PhD
Fakulti : Sains Komputer dan Teknologi Maklumat

Model Pembelajaran Interaksi Ketara bertindak sebagai pelengkap penting kepada pendekatan pengajaran konvensional untuk kanak-kanak dengan disleksia, menggunakan alat seperti papan huruf, kad imbas, blok, domino, dan bahan kajian pasir. Kanak-kanak disleksia sering mengalami kesukaran membaca, menulis, dan mengeja, kerana mereka menghadapi kesukaran mengenali dan memanipulasi bunyi dalam bahasa dan mencampurkan huruf. Pendekatan pengajaran multisensori telah terbukti membantu mengintegrasikan elemen visual, auditori, taktil, dan kinestetik ke dalam persekitaran pembelajaran mereka. Walau bagaimanapun, bahan pengajaran multisensori tradisional ini kurang menarik, tidak memberikan maklum balas deria, dan gagal menangani tingkah laku penglibatan, memerlukan campur tangan guru secara berterusan. Untuk mengatasi batasan ini, Model Pembelajaran Disleksia Interaksi Ketara (TIDLM) dicadangkan untuk kanak-kanak sekolah rendah dengan disleksia yang belajar bahasa Melayu. Model

ini direka untuk meningkatkan penglibatan dalam aktiviti pembelajaran. Aktiviti pembelajaran merujuk kepada tugas atau tindakan khusus yang dilakukan oleh kanak-kanak dengan disleksia menggunakan bahan kajian seperti kad imbas, papan huruf untuk memudahkan proses pembelajaran mereka. Proses pembelajaran merujuk kepada keseluruhan perjalanan pembelajaran yang termasuk kanak-kanak dengan disleksia untuk melihat, memproses dan mengintegrasikan pengetahuan baru mereka ke dalam pemahaman sedia ada mereka. Model pembelajaran sedia ada tidak mencukupi dalam menyokong proses pembelajaran, dan tidak ada yang fokus kepada reka bentuk persekitaran pembelajaran interaksi ketara (TI) yang direka khusus untuk kanak-kanak dengan disleksia. Selain itu, terdapat sumber panduan reka bentuk yang terhad untuk menyokong pembangunan aplikasi TI untuk kanak-kanak disleksia di Malaysia, terutamanya dalam aktiviti pembelajaran. TIDLM menekankan penyediaan alat yang bernilai untuk pembelajaran dengan membimbing penciptaan antara muka dan aplikasi TI yang boleh digunakan, berkesan, dan bermanfaat untuk kanak-kanak dengan disleksia. Prototaip TIDLM, yang dinamakan aplikasi Disleksia Belajar 3Dimensional Tangible (DB3dT), dibangunkan berdasarkan model pembelajaran yang dicadangkan. Aplikasi DB3dT membolehkan kanak-kanak berinteraksi dengan maklumat digital menggunakan objek ketara seperti kad huruf ketara, blok huruf, dan mainan dalam persekitaran fizikal. Aplikasi ini memudahkan perkembangan kemahiran fonologi, ejaan, dan membaca yang khusus untuk corak pembelajaran disleksia. Melalui interaksi intuitif dengan objek ketara, kanak-kanak dapat membina perkataan daripada suku kata dan melihat kandungan overlay realiti tambahan 3D pada skrin semasa aktiviti

pembelajaran. Aplikasi ini menggabungkan pelbagai pengalaman deria, termasuk elemen taktil, auditori, visual, dan kinestetik, untuk menguatkan kemahiran literasi. TIDLM dinilai melalui pengesahan pakar untuk menilai aspek kebolehgunaan prototaip dan kesesuaian modul aktiviti pembelajaran terhadap penglibatan pelajar. Hasil pengesahan pakar menunjukkan bahawa 75% bersetuju bahawa aplikasi DB3dT boleh digunakan, dan aktiviti pembelajaran menerima penerimaan 100% sebagai sesuai untuk pelajar disleksia. Selain itu, satu kuasi-eksperimen dijalankan ke atas 30 pelajar berumur antara 7 dan 12 tahun di Persatuan Disleksia Malaysia (DAM). Aplikasi DB3dT dibandingkan dengan aplikasi mudah alih DisleksiaBelajar, sebuah aplikasi pendekatan bukan ketara untuk belajar bahasa Melayu, untuk menilai keberkesanan aplikasi DB3dT dalam penglibatan pelajar bagi kanak-kanak dengan disleksia. Hasil kognitif penglibatan yang diperoleh daripada senarai semak prestasi menunjukkan bahawa kumpulan rawatan mempunyai penglibatan yang lebih tinggi dengan jumlah markah purata 77.5% berbanding 67.5% untuk kumpulan kawalan. Ini menunjukkan bahawa kanak-kanak dengan disleksia lebih terlibat dalam aktiviti pembelajaran yang difasilitasi oleh aplikasi DB3dT. Hasil tingkah laku penglibatan menunjukkan masa on-task yang lebih lama dengan purata 33 minit dan 58 saat apabila menggunakan aplikasi DB3dT berbanding 14 minit dan 93 saat dengan aplikasi mudah alih DisleksiaBelajar (nilai $p < 0.05$) menggunakan ujian Mann-Whitney U. Hasil ini jelas menunjukkan kanak-kanak dengan disleksia menggunakan aplikasi DB3dT menghabiskan lebih banyak masa terlibat berbanding kanak-kanak menggunakan aplikasi mudah alih DisleksiaBelajar. Selain itu, hasil penglibatan emosi menunjukkan kanak-kanak dengan disleksia lebih suka

aktiviti dengan objek ketara kerana elemen ketara ini sangat mempengaruhi minat mereka dalam pembelajaran. Penilaian aspek kebolehgunaan semasa eksperimen dengan kanak-kanak mendedahkan skor purata 79.5% untuk aplikasi DB3dT berbanding skor purata 51% untuk aplikasi mudah alih DisleksiaBelajar. Kebanyakan aktiviti pembelajaran dalam aplikasi DB3dT didapati menyeronokkan dan menghiburkan, menunjukkan bahawa kanak-kanak bersedia untuk mengulanginya dan mempamerkan penglibatan yang lebih tinggi semasa menggunakan aplikasi DB3dT. Kesimpulannya, TIDLM menyokong aktiviti pembelajaran pelajar secara berkesan, dan aplikasi DB3dT menyediakan pengalaman pembelajaran yang menyeronokkan dan interaktif untuk kanak-kanak dengan disleksia belajar Bahasa Melayu.

Keywords: Interaksi Ketara, Keperluan Pendidikan Khas, Kanak-kanak Disleksia, Penglibatan Pembelajaran

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Ts. Novia Indriaty Admodisastro, PhD
Associate Professor, Ts
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Chairman)

Azrina binti Kamaruddin, PhD
Senior Lecturer
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Member)

Sa'adah binti Hassan, PhD
Associate Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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LIST OF ABBREVIATIONS

TI	Tangible Interaction
GUI	Graphical User Interface
MOE	Ministry of Education
ICT	Information and Communication Technology
HCI	Human-Computer Interaction
DB3dT	DisleksiaBelajar 3D Tangible
OG	Orton-Gillingham
TTRS	Touch-Type Read & Spell
AR	Augmented Reality
TUI	Tangible User Interface
DAM	Dyslexia Association Malaysia
SPSS	Statistical Package for the Social Sciences
LINUS	Literacy and Numeracy Screening
UCD	User-Centered Design
TIDLM	Tangible Interaction Dyslexia Learning Model
UPM	Universiti Putra Malaysia
CV	Consonant Vowel
JKEUPM	Ethics Committee Research University
TL	Types of learning
CTI	Characteristics of Tangible Interaction
TLA	Types of Learning Activities
TR	Types of Representations
3D	Three Dimension
SRS	Software Requirements Specifications
SUS	System Usability Scale

MCO	Movement Control Order
SD	Standard Deviations
OS	Operating System

CHAPTER 1

INTRODUCTION

This thesis explores the fields of tangible interaction, dyslexia, and dyslexia learning models. By integrating these domains, it aims to address the learning difficulties faced by children with dyslexia. This chapter introduces the research by discussing its motivation, followed by the problem statements, research questions, and objectives.

1.1 Motivation

Tangible interaction (TI), which facilitates the interaction between physical objects and computer applications, has expanded in recent years to create embedded and cooperative user experiences. Compared to traditional keyboard or mouse interfaces, TI inherently provides a more natural environment and instant haptic feedback that integrates digital and physical responses. Research demonstrates that TI allows students to engage in learning activities cognitively, emotionally, physically, and socially, creating a more immersive experience.

However, challenges exist in engaging students with realistic depictions or physical stimulation when applications offer dynamic content and interactions. Designing TI for dyslexic children has specific requirements, as current models focus on typical learners with limited dyslexic engagement. Researchers (Al-Dokhny et al., 2022; Antle et al., 2015; Lindgren et al., 2016) suggest involving more senses makes learning more meaningful. Visualization is especially

beneficial for children, strengthening their understanding (Galuschka et al., 2020).

Various works discuss the benefits of adopting TI in learning activities for dyslexic children learning Malay. MyBaca, an intervention program, focused on word recognition but required active teacher involvement during instruction, leading to potential dependence challenges (Lee, 2019). To address this, integrating TI in language learning activities was proposed.

Moreover, TI has great potential for dyslexic children's learning by enhancing engagement with tangible items (Price et al., 2003). Researchers recommend visual, auditory, and kinesthetic approaches to make learning more effective for dyslexic children (Falcao & Price, 2010). TI encompasses user interface and interaction approaches, emphasizing four key elements: interface tangibility and materiality, physical data embodiment, whole-body interaction, and embedding the interface and interaction in real spaces (Hornecker & John, 2011).

As noted by Ishii and Ullmer (1997), TI serves as an alternative to graphical displays by reintroducing physical device interaction richness into the digital realm. This approach can enhance learning and create more engaging educational experiences for dyslexic children. As Liang et al. (2021), Fan et al. (2019), Marichal et al. (2017b), and Marshall (2007) highlight, TI critically supports learning activities including exploratory and expressive learning.

Shaer and Hornecker (2009) also agreed that TI can offer rich learning environments, providing opportunities for cognitive, linguistic, and social learning, surpassing the traditional Graphical User Interface (GUI) approach. Furthermore, Shaer and Jacob (2009) mentioned that TI enables learners to interact with digital information intuitively, making the process of using and learning from it more spontaneous. The benefits of using TI extend to various application domains, such as learning, problem-solving, entertainment, programming, music, and social communication. Specifically, TI holds promise for adapting to the learning environments of children with dyslexia by aiding them in developing reading, spelling, and phonological skills.

Dyslexia is a language impairment that impacts reading, writing, speaking, and listening abilities. The conventional approach to dyslexia learning involves a multi-sensory procedure, which has proven effective in supporting individuals with dyslexia. However, this method requires extensive one-on-one teaching, making it highly demanding. It primarily targets students with specific needs in special education, especially those with common learning disabilities. Dyslexia encompasses various learning difficulties, such as reading complications, spelling challenges, writing difficulties, word recognition issues, decoding problems, and phonological deficits.

According to data from the Ministry of Education (MOE) in Malaysia, approximately 50% of the 90,000 children with learning difficulties face dyslexia. These learning difficulties are observed in children as young as 5 years old. Additionally, statistics from the MOE reveal that around 5 out of

every 100 children have the potential to experience learning difficulties. The Malaysia Education Blueprint for 2013-2025 aims to ensure all children with learning difficulties, including dyslexia, receive high-quality education tailored to their individual needs. For children with dyslexia, suitable learning programs that specifically address their difficulties are essential. These populations often benefit from incorporating computer-assisted technologies and multisensory techniques into their learning activities. To achieve this, the MOE blueprint underscores adopting Information and Communication Technology (ICT) for learning and investing in ICT solutions for groups with specific needs.

Based on a field study conducted by the researcher, several issues were identified with the current conventional teaching approach. This approach, which relies on the multisensory technique crucial for engaging children with dyslexia in learning Malay, has significant limitations. In the Malaysian educational context, materials like flashcards, alphabet boards, blocks, dominoes, and sand are typically used to teach single sound values, letter sounds, word identification, and phonological awareness. These methods require instructors to deliver and produce sounds effectively, which is essential for dyslexic children who struggle with phonology and spelling (Pandey, 2011; Pandey & Srivastava, 2011; Hamid et al., 2015).

However, the current tangible tools lack dynamic visual and audio elements necessary to fully optimize multisensory learning. There is a pursuing need to incorporate these multisensory elements through technology to create more adaptive, interactive, and engaging learning experiences for children with

dyslexia. Such integration can offer real-time feedback, automated assessments, and progress tracking features that were previously unattainable.

Integrating technology in education has brought significant benefits to learners by enabling more effective teaching methods and improving their overall learning experiences. Incorporating technology makes learning more enjoyable and exciting for students. Engaging students this way leads to better comprehension, enhanced knowledge retention, and the practical application of learned concepts in real-life situations. Therefore, there is a need for research to propose a TI learning tool for dyslexic children to support learning. Using TI can help children with dyslexia utilize all their senses in learning. The numerous benefits of TI promote dyslexic children's engagement and language learning.

1.2 Problem Statements

Based on conducted studies, a few problems persist due to current limitations in existing work. Current approaches are proposed for common learners and do not specifically address students with special needs like dyslexia. Children with dyslexia have different learning models, user interface design guidelines, subject difficulties, and learning styles. Additionally, children with dyslexia may have low engagement when learning, causing boredom. As a result, TI can improve student engagement by enabling learning through various senses and interacting with digital representations using tangible objects to enhance learning. The following are explanations of the research problem statements:

The first problem pertains to using each TI model's themes to provide design guidelines for HCI designers. Existing guidelines mainly focus on general interaction design aspects including interface design, navigation, sound, and multimedia elements (Admodisastro et al., 2021; Alrowais et al., 2013; Aziz et al., 2013; Daud & Abas, 2013; Gupta et al., 2019; Hamid et al., 2017; Skiada et al., 2014). Consequently, TI applications developed based on these guidelines may not suit or be usable for children with dyslexia, as they do not sufficiently incorporate whole bodily engagement and collaboration.

Most TI applications take a structured approach, dictating task series rather than allowing children to freely engage their minds and bodies (Keay-Bright & Howarth, 2012). However, TI should encourage embodied manipulation and provide sensory modalities like touch, sight, and kinesthetic digital interaction. This approach allows children more flexibility in deciding activity sequences. Current guidelines lack considerations for suitable learning activities and interventions specifically designed for dyslexic children, particularly regarding learning Malay in Malaysia. Thus, there is a need for inclusive design guidelines that not only address interface design but also encompass learning styles, activities, dyslexia methods, student levels, and feedback to ensure effective that are appropriate to be incorporated into TI models for children with dyslexia.

The second problem is the lack of existing TI models that specifically address learning for children with dyslexia. TI models typically offer guidelines and themes to facilitate developing TI applications for intended users (Mazalek &

Hoven, 2009). However, models by Hornecker & Buur (2006), Fishkin (2004), Koleva et al. (2003), and Ullmer & Ishii (2000) are general, focusing on abstract TI aspects, providing thinking tools, and categorizing systems. Meanwhile, works by Zuckerman et al. (2005), Edge & Blackwell (2006), Marshall (2007), Price et al. (2008), Antle & Wise (2013), and Zhou & Wang (2015) developed learning TI models but not tailored to children with dyslexia. Consequently, this may prevent dyslexic children from fully optimizing their learning experience and engagement with the tangible approach.

For instance, children with dyslexia may only recognize defined alphabet shapes illustrated through tangible objects, limiting learning potential. Additionally, other research by Suman Deb (2018) explored how TI could enhance nonverbal communication between students and teachers. TI has also been designed to entertain children in various learning environments. According to Tsong et al. (2017) and Chau et al. (2017), tangible objects can manifest tangibility for preschoolers' multimedia learning. However, there is a need to propose a TI learning model providing concrete learning concepts specifically tailored to children with dyslexia.

The third problem is that while many studies report the positive effects of TI on engagement, excitement, and collaboration (Price et al., 2003; Rante et al., 2018), existing models fail to comprehensively address these aspects for HCI designers. Engagement is crucial for promoting learning (Rante et al., 2018) and can be categorized into behavioral, cognitive, and emotional engagement. For instance, Cho et al. (2017) examined physical block involvement levels by

assessing children's proactive and passive activities during learning sessions in various educational settings.

HCI designers need to consider these aspects when developing tangible interactions. However, current learning models only cover certain engagement categories. Measuring student engagement is particularly crucial for children with dyslexia, as they tend to have higher disengagement tendencies (Tomas et al., 2020). Therefore, comprehensively addressing engagement in TI design becomes essential for supporting effective learning experiences, especially for dyslexic students.

Studies such as Phonoblocks (Antle et al., 2015) and Tactile Letters (Fan & Antle, 2015) demonstrated the effectiveness of tangible learning systems using color-coded tactile letters to provide sound and feedback during dyslexic children's interactions. TI allows embodied manipulation using sensory modalities like touch, sight, and kinesthetics, providing activity sequencing flexibility and promoting more natural human-oriented interactions (Antle & Fraser, 2007; Shaer & Hornecker, 2009).

Collaboration in TI-based learning encourages social interaction, resource-sharing, and communication, enhancing the overall experience (Hornecker & Buur, 2006). TI applications can be designed to encourage self-exploration and minimize the need for constant trainer intervention (Falcão & Price, 2010).

TI presents advantages over other interactions, including simplicity, realism, and potential for extended virtual and augmented reality use (Florian, 2004).

Touchscreen interaction with tangible objects is more straightforward than using a mouse (Shaer & Hornecker, 2009). Besides, students can manipulate objects using various modalities to interact with digital information spatially (Antle & Fraser, 2007). Overall, evidence suggests adopting TI in learning can benefit children with dyslexia by promoting engagement, collaboration, and a more flexible, familiar experience. Ultimately, our work is to establish design guidelines that are compatible for children with dyslexia. Then, we propose a TI learning model in which the design guidelines we established earlier are integrated into the model.

1.3 Research Questions

To address the research objectives, the following questions were investigated:

RQ1 - What design guidelines should be considered when developing a tangible interaction learning model for dyslexic children learning Malay?

RQ2 - What specific components and features should be included in the TI prototype to facilitate effective Malay language learning for dyslexic children?

RQ3 - How usable is the tangible interaction dyslexia learning model and TI application for improving engagement and learning outcomes of dyslexic children in Malay, as perceived by the children and teachers?

1.4 Research Objectives

The research objectives addressed in this thesis are as follows:

1. To determine a set of themes and design guidelines for a tangible interaction learning model for children with dyslexia in learning Malay.

2. To devise the tangible interaction learning model for children with dyslexia in learning Malay.
3. To evaluate engagement of the model and usability of the developed TI prototype using expert validation, quasi-experiment, and usability testing with experts and children with dyslexia.

1.5 Research Scope

This research presents tangible interaction design guidelines for dyslexic primary school children aged 6-12 years old. The focus of this research is on phonology, spelling, and reading skills in the Malay language, specifically targeting primary school children aged 6-12 years old with dyslexia. The Malay language is chosen because of the minimal number of works on the TI application compared to English and Mandarin. In addition, the language instruction used in the school setting in Malaysia is using Malay language and children must learn the Malay language as it is a compulsory subject in the school. Although writing skills pose a learning difficulty, this research specifically focuses on phonology, spelling, and reading. The tangible interaction dyslexia learning model is introduced and mapped with the dyslexic design guidelines. The learning contents are developed and mapped into the TI system, with a main emphasis on phonology, spelling, and reading.

1.6 Thesis Organization

This thesis is organized as follows:

Chapter 2 - Literature Review: This chapter reviews relevant past and current studies on TI approaches in education. Explains general TI understanding,

learning theories, dyslexia TI models, related TI works for children's learning, and gaps in the learning environment.

Chapter 3 - Research Methodology: This chapter provides detailed explanation on the research design, approach, techniques, setting, population, sampling, and data collection instruments and procedures. Uses a mixed methods approach with initial qualitative followed by quantitative methods to evaluate the proposed model.

Chapter 4 – Tangible Interaction Design Exploration Using Secondary Data: This chapter explains initial TI design exploration results from literature review and secondary data analysis using thematic analysis.

Chapter 5 - Tangible Interaction Design Exploration with Experts: This chapter discusses TI design exploration with experts to meet the second research objective. Uses semi-structured interviews and walkthroughs with a TI design guidelines checklist, observation, and font verification. Establishes final TI design guidelines.

Chapter 6 - Tangible Interaction Dyslexia Learning Model: This chapter reviews the model to meet the second objective. Establishes final TI guidelines, determines the model, and implements it by developing a prototype called *DisleksiaBelajar 3D Tangible* (DB3dT). Derives implementation from the guidelines and includes five learning modules.

Chapter 7 – Results and Discussions: This chapter discusses prototype evaluation using expert reviews and quasi-experiments to validate effectiveness and usability.

Chapter 8 - Conclusion and Future Work: This chapter summarizes research conclusions, research contributions, revisits objectives, discusses limitations, and provides recommendations for future work.

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