ADAPTIVE LEARNING MODEL IN SUPPORT OF LEARNING THE MALAY LANGUAGE AMONGST PRIMARY SCHOOL STUDENTS WITH DYSLEXIA

SITI SUHAILA BINTI ABDUL HAMID

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By

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

January 2020

DEDICATION

Dedicated to the memory of my mother,
Suhaini Abdul Aziz, who always believed in my ability to be successful in the academic arena. Even she was no longer here but her belief, her support and her prayer has made this journey possible.

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

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

Adaptive learning model acts as an important supplement to the traditional teaching method that commonly uses pen, paper, card or any materials for students with dyslexia. Students with dyslexia have poor fluency in reading, writing and spelling. Additionally, the students also faced difficulties related to engagement behaviour such as giving attention and engaged to the learning materials which constantly need teacher's intervention. The adaptive learning model or ALMo-DML is intended for students with dyslexia in primary school to learn the Malay language. The model is aimed to address dyslexia cognitive difficulties and engagement behaviour pertaining active participation. Existing learning model covers a limited cognitive difficulty such as confusion, spelling or reading and failed to incorporate adaptation with engagement behaviour. ALMo-DML however, focus on a wider aspect of cognitive difficulties that include phonology, spelling, reading and writing. Cognitive difficulties are identified from the number of errors made in the phonology, spelling, reading and writing exercise given. Additionally, the ALMo-DML incorporate the engagement behaviour through engagement prediction from image classification using machine learning approach particularly Support Vector Machine (SVM). A prototype of the ALMo-DML named as *Disleksia Belajar Cerdas Belajar* (DBCB) is developed based on the proposed learning model. The work includes (i) cognitive identification using number of errors, (ii) the engagement behaviour prediction developed using frontal face image classification and (iii) the adaptation intervention established using mastery level adjustment, hints and feedbacks. Lastly, the ALMo-DML is evaluated using expert validation for the correctness of the adaptation and experiment for the effect of the adaptation. The expert validation result shows 89% agree that the ALMo-DML was correct in term of the suitability of the adaptation towards the students with dyslexia. Meanwhile, a quasi-experiment is conducted to the 18 students age 7 to 12 years old in Dyslexia Association Malaysia (DAM). The DBCB is compared with *MyLexic*, a computer-based application to learn the Malay language used in DAM, to see the

significant effect on the engagement to the students with dyslexia. The result shows a longer on-task time with an average of 22 minutes when using the DBCB as compared to the *MyLexic* with only 12 minutes (p value <0.05) using Mann-Whitney U test. As a conclusion, the ALMo-DML able to support the learning of the students through adaptation of cognitive and engagement behaviour with minimal teacher intervention. Despite of that, a few limitations occurred in this research that includes inability to acquire more participants during preliminary study as well as during evaluation. This resulted inadequacy of data relates with student's image for machine learning prediction. Finally, limitation in scope of DBCB application that only cover basic syllabus of Malay language. Therefore, for further work, the participants can be acquired not only from DAM but also public school. In addition, it also suggested for future work to cover a wider area of syllabus in Malay language especially writing skill that currently still lack in research.

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

MODEL PEMBELAJARAN ADAPTIF DALAM MENYOKONG PEMBELAJARAN BAHASA MALAYSIA BAGI PELAJAR DISLEKSIA DI PERINGKAT SEKOLAH RENDAH

Oleh

SITI SUHAILA BINTI ABDUL HAMID

Januari 2020

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Model pembelajaran adaptif bertindak sebagai kaedah sokongan kepada kaedah pengajaran tradisional yang biasanya menggunakan pen, kertas dan sebagainya untuk pelajar disleksia. Pelajar disleksia mempunyai kelemahan dalam membaca, menulis dan mengeja. Di samping itu, pelajar juga menghadapi kesukaran untuk memberi perhatian dan terlibat dengan bahan pembelajaran yang sentiasa memerlukan intervensi guru. Model pembelajaran adaptif atau ALMo-DML khusus untuk pelajar disleksia di sekolah rendah untuk mempelajari bahasa Melayu dari aspek fonologi, ejaan, bacaan dan tulisan. Model ini bertujuan untuk menangani masalah kognitif disleksia dan tumpuan pelajar. Masalah kognitif dikenalpasti dari jumlah kesilapan yang dibuat dalam latihan fonologi, ejaan, bacaan dan tulisan yang diberikan. Tambahan pula, model pembelajaran yang sedia ada tidak menekankan aspek adaptasi tumpuan pelajar sebagaimana aspek kognitif yang telah banyak ditekankan. Manakala, masalah tumpuan diramal dari klasifikasi imej menggunakan pendekatan pembelajaran mesin seperti *Support Vector Machine* (SVM). Prototaip ALMo-DML yang dinamakan sebagai *Disleksia Belajar Cerdas Belajar* (DBCB) dibangunkan berdasarkan model pembelajaran yang dicadangkan. Pembangunan prototaip ini mengandungi (i) pengecaman kognitif menggunakan bilangan salah, (ii) meramal tingkah laku keterlibatan dibangunkan menggunakan klasifikasi imej muka hadapan dan (iii) intervensi adaptasi menggunakan pelarasan tahap penguasaan, maklumbalas dan petunjuk. Akhirnya, ALMo-DML dinilai menggunakan pengesahan pakar untuk ketepatan pengadaptasian dan eksperimen untuk kesan terhadap penyesuaian dari aspek kandungan, intervensi dan peraturan. Keputusan pengesahan pakar menunjukkan 89% bersetuju bahawa ALMo-DML adalah tepat dari segi kesesuaian adaptasi terhadap pelajar disleksia. Sementara itu, satu eksperimen kuasi telah dijalankan kepada 18 pelajar berusia 7 hingga 12 tahun di Pusat Disleksia Malaysia (DAM). DBCB dibandingkan dengan *MyLexic*, satu aplikasi berasaskan komputer untuk belajar Bahasa Melayu yang digunakan di DAM, untuk melihat kesan yang signifikan terhadap

keterlibatan pelajar disleksia. Hasil kajian menunjukkan masa tumpuan tugas yang lebih lama apabila menggunakan DBCB berbanding dengan *MyLexic* (nilai $p < 0.05$) menggunakan ujian Mann-Whitney U. Kesimpulanya, ALMo-DML dapat menyokong pembelajaran pelajar melalui pengadaptasian tingkah laku kognitif dan tumpuan dengan campur tangan guru yang minima. Namun begitu, beberapa kelemahan dikenalpasti sepanjang kajian ini dijalankan iaitu, dari aspek bilangan peserta yang terdiri daripada pelajar disleksia semasa kajian awal dan semasa penilaian. Ini mengakibatkan bilangan data yang terhad bagi meramal imej dengan menggunakan pembelajaran mesin Akhir sekali, skop bagi aplikasi DBCB yang terhad yang hanya mencakupi silibus asas bagi Bahasa Melayu. Justeru itu, bagi kajian untuk masa hadapan, bilangan pelajar dapat diperoleh tidak sekadar melalui DAM malah menerusi kerjasama dengan sekolah awam. Selain itu, dicadangkan juga sillibus Bahasa Melayu dikembangkan dari aspek kemahiran menulis memandangkan kajian dari aspek ini masih kurang ditekankan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ADD	Attention Deficit Disorder
ADHD	Attention Deficit Hyperactivity Disorder
ALMO-DML	Adaptive Learning Model for Dyslexia using Machine Learning
ANFIS	Adaptive Neuro Fuzzy Inference System
BOF	Bag of Features
DAM	Dyslexia Association Malaysia
DBCB	Disleksia Belajar Cerdas Belajar
HMM	Hidden Markov Model
I-CVI	Item - Content Validation Index
ITS	Intelligent Tutoring System
JKEUPM	Ethics Committee Research Involving Human Subjects
kNN	k Nearest Neighbour
LIBSVM	Library Support Vector Machine
LMS	Learning Management System
MoE	Ministry of Education
NLP	Natural Language Processing
SLR	Systematic Literature Review
SpLD	Specific Learning Disability
SVM	Support Vector Machine
UPM	Universiti Putra Malaysia

CHAPTER 1

INTRODUCTION

This thesis presents a research about three disciplinary domains namely dyslexia, Malay language learning model and computer approach. These disciplinary domains are combined with the aim to solve issues related with learning difficulties experienced by students with dyslexia. As an introduction, this chapter discuss the motivation for this research followed by problem statements and its objectives.

1.1 Motivation

Education is changing in line with the changes of the industry as well as technology. In this new world of fast technology and vast amount of information, students are expected to be trained rather than spoon-feed. Information are made accessible so that the students can learn by themselves rather than being taught with a rigid structure. This is because all students are treated as individuals with different background, preferences and ability. This is where Education 4.0 takes place, and it is more flexible with tailor-made curriculum and active class.

Aiming towards Education 4.0, Ministry of Education (MoE) of Malaysia has launched a comprehensive education blue print for 2013 – 2025 (Ministry of Education, 2013). One of the objectives of this blueprint is to understand the current performance and challenges to improve access of education as well as to improve quality and reduce achievement gaps amongst students. Therefore, the Literacy and Numeracy Screening (LINUS) programme has been developed with aims to ensure that all primary school students acquire basic literacy and numeracy by the end of Standard 3 for Malay language, English language and Mathematics subject (Bahagian Pembangunan Kurikulum, 2015). The students are expected to be able to read, write, and understand words as well as constructing sentences for literacy skill. These skills are important for knowledge learning and communication.

LINUS programme has shown a promising success for Malay language literacy with an improvement from 87% literacy to 98% in its first cohort (Ministry of Education, 2013). The remaining percentage will be grouped together during the relevant class and taught based on the students' level and needs. Students who have learning problems such as developmental problem, poor cognitive and lack of motivation are the primary factors of failure in mastering the literacy skills (Sani & Idris, 2012). Thus, it is vital to identify the students' learning problems to minimise the achievement gaps.

Dyslexia is an example of learning difficulties which result in difficulties in the cognitive learning such as spelling, reading, and writing (Shaywitz, 1996). Besides having language processing difficulties, people with dyslexia reported comorbid problems with other cognitive areas like attention, emotional and behavioural problem

(Lyon et al., 2003). Every student with dyslexia is unique because the students differ in terms of difficulties they experience, support needed, comorbid problems and preferences. Relying on the teacher heavily to teach different pace of students with dyslexia and expecting progressive results of the students are challenging (Hoien & Lundberg, 2000). Therefore, the use of technology-based approach becomes an alternative for support in the education area especially for students with learning difficulties (Khakhar & Madhvanath, 2010).

The proposed approach in this study is a technology-based approach that aims to assist students with dyslexia by adapting current student's preferences therefore taking into consideration the human factors (Oxman & Wong, 2014), academic pace (Kast et al., 2011), and the engagement behaviour (Vasalou et al., 2017) towards learning in Malay language. Thus, it is important to understand the students' personas to create personalisation and adaptation to cater for the students' different needs in Human-Computer Interaction (HCI) principle (Haag & Marsden, 2019). These elements are believed to reflect individual needs in learning.

1.2 Problem Statements

The first problem found in the literature review is existing learning models cover a limited dyslexia cognitive difficulty. Subramaniam (2008) identified dyslexia cognitive difficulties as visual dyslexia and auditory dyslexia. Visual dyslexia feature difficulty in spelling, and auditory dyslexia is presented as impairment in distinguishing a phoneme of syllable resulting in misspelling a word. Other researchers addressed the dyslexia's difficulties from the symptoms that related with reading and spelling (Jorge et al., 2020; Tijms et al., 2020). Ndombo (2013) on the other hand, addressed three difficulties in dyslexia that include phonological awareness, reading and writing.

Besides spelling, reading and writing, some work concentrated in addressing the difficulties in phonic, reading and short-term memory (Ouherrou et al., 2019). Majority of the researcher however, chose to focus on the specific difficulties separately like spelling (Alamri & Teahan, 2019; Rello, Ballesteros, & Bigham, 2015), reading (Asvestopoulou et al., 2019; T. Gupta et al., 2019; Sajan et al., 2019) or writing (Isa et al., 2019; Mahmoodin et al., 2019) .

However, in this research, the focus is to tackle the difficulties in the phonology, spelling, reading, and writing. This is because, these four difficulties are the most frequent occurrences detected in children with dyslexia in Malaysia (Subramaniam & Che Mat, 2013). Currently, there is no learning model that covers a wider dyslexia difficulty especially in Malay language. The need to cover the difficulties as much as possible has resulted from the comorbidity issues. Comorbidity is a situation where people with dyslexia might be suffering from more than one difficulty (Lyon et al., 2003).

The second problem, on the other hand, is the lack of adaptation on the cognitive and behaviour aspect. Existing learning models, do not emphasize on students' engagement behaviour as much as the cognitive skill aspect (L. W. Lee, 2019). A typical student's behaviour may include refusal to learn, lack of motivation and disliking schools (Sahari & Johari, 2012). As a result, the students were perceived as lazy, retarded, and were judged as having attitude problems that affect their academic achievement (Oga & Haron, 2012). In conventional teaching approach, teachers manage the student's behaviour by observing his or her engagement or attention when learning (R. A. Sottilare & Schwarz, 2019). However, this requires patience, emotional intelligence and experience to manage both cognitive and engagement behaviour aspect for every student.

It is also essential to monitor the students' behaviour because the longer the students are engaged to the learning, the more they will learn and the better they will perform (Tomás et al., 2019). Higher engagement established robust correlations between student involvement in purposive activities, and positive outcomes of student success that includes satisfaction and persistent (Tomás et al., 2019). Consequently, it is important to measure the students' engagement especially students with dyslexia due to higher tendency in having low engagement.

Current researchers, improve the students' engagement using interaction design (Aziz et al., 2013), text presentation (Ismail & Jaafar, 2014) and multimedia elements (Daud & Abas, 2013). These interventions help the students by facilitating the learning and to retain their attention towards the learning materials. However, the techniques used are not sufficiently adaptive to respond to students with dyslexia's behaviour. This is because, the behaviour can change over a short period of time. It is worse when the students have different types of behaviours and need to be handled by limited number of teachers. Therefore, a computer-based learning model that can adapt to the changes of language learning skill and behaviour for each of the student is needed.

The third problem is associated with high dependency on the teacher. Current conventional method depends heavily on the teacher in delivering the pedagogy (L. W. Lee, 2019). Thus, it is difficult to provide a diverse learning environment for different dyslexia students across different needs and difficulties. Based on MoE statistics in 2018, the number of primary school teachers specialised in special education was only 8,193 teachers as compared to the enrolment of 33,174 special needs students (Ministry of Education, 2018). It is a very demanding occupation as the number of students keep on increasing and majority rely heavily on the teachers' support.

Conventional teaching approach as suggested by Subramaniam et al., (2013) uses a multi-senses explication activity such as block, flash card, sand and etc. This approach is able to attract the students' attention but requires a higher commitment and cost for the implementation. In addition, the students also need different types of learning content based on the different difficulties. Therefore, it is necessary to propose a new

learning model that can help to minimise the dependency towards the teachers by applying an adaptive learning environment to the students with dyslexia.

Machine learning is one of the solutions for an automated teaching approach. Machine learning is used to provide a learning environment for cognitive aspect (D. M. Ndombo, 2013) and engagement behaviour aspect (Cetintas et al., 2010). Learning through machine learning-based application has proved to increase the performance by more than 61% in phonology awareness, reading and writing (D. M. Ndombo et al., 2013).

Pertaining to the cognitive aspect, machine learning has been used in handwriting recognition in learning English (Isa et al., 2019), speech recognition for Indonesian language (Siregar et al., 2019), and dyslexia screening using eye tracking for Spanish language (Rello et al., 2018). There are only two Malay language learning models that apply machine learning in their work that includes dyslexia diagnoses (Ullah Khan, Lee, Cheng, & Bee, 2018) and dyslexia intervention (Husni & Jamaludin, 2010). Ullah et al. (2018) use k Nearest Neighbors (kNN) classifier to classify children who at risk of dyslexia while Husni & Jamaludin (2010) assist students with dyslexia difficulties in learning by teaching pronunciation using Hidden Markov Model (HMM). The use of HMM in speech recognition assist the students in recognizing the numbers, alphabets and simple words.

On engagement behaviour aspect, Cetintas et al. (2010), have used machine learning to automatically detect students' off-task behaviour using log files data while solving math exercise and suggest an intervention using feedback message. Similar approach used by Hussain et al. (2018) that analyse log files data such as demographic, performance and number of click activity in predicting the engagement behaviour in e-learning application. However, majority of the works has focused on sensor-based engagement measurement such as motion sensor (Zaletelj & Košir, 2017), eye tracker (Yue et al., 2019) and camera (Alyuz et al., 2017; Nezami et al., 2018). This is because the application of machine learning in this area is less intrusive and effective. However, none of this work specifically focus for the engagement of the students with dyslexia.

1.3 Research Objectives

The research objectives that are addressed in this thesis are as follows:

1. To propose a set of main components for the adaptive learning model that addresses cognitive and engagement behaviour difficulties of students with dyslexia to learn the Malay language in primary school. The cognitive difficulties include phonology, spelling, reading and writing are addressed using rule-based approach. Whereas the engagement behaviour difficulties are addressed using face of image prediction with machine learning approach.

2. To eliminate mistakes in cognitive and behaviour adaptation by using an adaptive learning model that comprises of the proposed components.
3. To meet the effectiveness and the correctness of the adaptive learning model using expert validation, quasi-experiment and usability studies.

1.4 Research Scope

This research introduces an adaptive learning model for students with dyslexia in primary school. The age of the students ranges between 7 and 12 years old. The adaptation of the learning on the other hand is based on the students' difficulties in cognitive such as phonology, spelling, reading and writing and engagement behaviour using face detection. The cognitive is acquired from the students' difficulty in the Malay language processing skill. An assessment in a form of exercise instrument is used to assess the students' cognitive difficulties based on the syllabus from MoE.

Besides that, the engagement behaviour is acquired from a prediction using machine learning approach. Image classification that utilise machine learning is used to predict the students' engagement behaviour. There are two features used to predict the engagement using face which are looking towards screen for engaged feature and looking away from the screen for disengage feature (Alyuz et al., 2017; Hernandez et al., 2013; Nezami et al., 2018; Whitehill et al., 2014). Despite having a variety of techniques for the purpose of engagement prediction such as pressure sensor, heart rate, and skin monitor (Hernandez et al., 2013), this research however, focuses on the student's face. This is because, camera is one of the most affordable sensors that are readily available in education centres without any extra equipment. In addition, the student's face can also be easily retrieved from the front camera in mobile phone as well through laptops.

1.5 Research Contribution

This thesis has made following contributions:

The first contribution is an adaptive learning model for students with dyslexia. It is a computer-based learning model that can adapt to the cognitive difficulties and engagement behaviour of the students in learning the Malay language. Machine learning approach is used to make the prediction on the engagement behaviour from the student's face using face detection by Viola-Jones, image classification using bag of features model and SVM. Engaged face determined from the detected frontal face (looking at the screen) whereas disengaged face when the frontal face is missing (looking away from screen). While the cognitive difficulties are identified from number of errors in the exercise given. The intervention is given by adapting to the cognitive and the engagement behaviour results. This means, that each student will have a different learning syllabus based on their difficulties and their engagement state. The students may experience a new approach of learning method that uses

computer as a learning model that will adapt to the changes of difficulties and behaviour while learning (more in Chapter 5).

The second contribution is an instrument exercise in Malay language for primary school students with dyslexia. The instrument exercise has been developed from the preliminary study. The limitation of the design guidelines for students with dyslexia has prompted the creation of the instrument. The example of design guidelines includes element of colour, font type, font size, spacing, and image. The instruments are comprised of four types specifically phonology, spelling, reading and writing instruments. The level of difficulty in each instrument are varied from easy to difficult to identify the student's difficulties. This instrument, called the Exercise Model, is later used as one of the components in the adaptive learning model (more in section 5.3 in Chapter 5).

The third contribution is a prototype of the proposed adaptive learning model. The prototype is called *Disleksia Belajar Cerdas Belajar* (DBCB) that aims to support the learning of the students with dyslexia in Malay language. The adaptation approach in the DBCB intervention is intended to minimise teachers' intervention. The exercise for spelling, reading, and writing in the learning model is automatically determined based on the number of error and engagement state from the phonology exercise. DBCB also incorporates multimedia element such as audio, images and text to grab the students' attention when interacting with the system (more in Chapter 6).

The final contribution is an empirical evaluation as well as the results of the expert validation and experiment. This study contributes to the evaluation process and the results based on the perspective of the dyslexia research. Through empirical evaluation processes such as observation and experimentation, the results of the effect and the correctness of the adaptive learning model are measured and evaluated (more in Chapter 7).

1.6 Thesis Organization

The thesis has been structured in eight chapters as follows:

Chapter 2 Literature Review. This chapter provides an analysis of the literature work found that are related to dyslexia and technology. Specifically, this chapter discusses the current approach of adaptive learning and intelligent tutoring system for people with dyslexia. Systematic Literature Review (SLR) that uses systematic methods was applied to find the literature. Therefore, this chapter explains the literature review based on the SLR process.

Chapter 3 Research Methodology. This chapter outlines the research methodology employed in this study. In specific, the research was conducted using both qualitative and quantitative methods. The qualitative methods employed in the beginning of the

research stage involved the gathering of the requirement for students with dyslexia from academic and engagement behaviour perspectives while quantitative methods were used during the last stage of the research to evaluate the proposed model through experimentation. As a conclusion, this chapter provides the details on how the research has been conducted.

Chapter 4 Analysis and Results of Dyslexia Learning Context and Instrument. This chapter discusses the analysis and result of preliminary studies. Preliminary studies were conducted with two aims. The first aim is to understand the learning context and real setting for students with dyslexia in Malaysia. As a result, a design guideline for students with dyslexia was produced. The design guidelines were applied in the instruments for the adaptive learning model. The second aim was to test the instruments with expert's validation and instrument assessment by the students. Thus, this chapter explains the purpose, the procedure, and the result of each study in detail.

Chapter 5 Adaptive Learning Model for Students with Dyslexia (ALMo-DML). This chapter introduces the proposed learning model as the main contribution of this study. The ALMo-DML comprises five components namely Exercise Model, Behaviour Processing Model, Student Model, Expert Model and Teaching Model. Each component is explained in detail in this chapter.

Chapter 6 ALMo-DML Implementation. This chapter explains the implementation of the ALMo-DML by developing the prototype called *Disleksia Belajar Cerdas Belajar* (DBCB). The implementation is derived from the developed learning model in Chapter 5. Generally, the implementation process is divided into four processes namely cognitive identification, engagement behaviour prediction, adaption rules, and adaptation intervention. Each process in the DBCB represents the components of the ALMo-DML.

Chapter 7 Results and Discussions. This chapter discusses the evaluation of the DBCB prototype. There are two types of evaluation conducted namely expert validation and the quasi-experiment. The aims of the evaluation are to establish the validation on the correctness of adaptation, the effect of the adaptation and finally the usability of the system.

Chapter 8 Conclusion and Future Works. This chapter provides the conclusion of this research studies. The conclusion includes revisit of research objectives, research limitation and recommendation for the future works based on the findings from this study.

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