**International Journal of Evaluation and Research in Education (IJERE)**
Vol. 14, No. 2, April 2025, pp. 1044~1055
ISSN: 2252-8822, DOI: 10.11591/ijere.v14i2.29952 

# Assessing the effectiveness of the adaptation learning model for dyslexic students' engagement: a quasi-experimental study

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**Article Info**

***Article history:***

Received Jan 15, 2024
Revised Sep 24, 2024
Accepted Sep 30, 2024

***Keywords:***

Adaptive learning
Effectiveness
Engagement
Quasi-experiment
Students with dyslexia

**ABSTRACT**

Students with dyslexia require individual learning approaches due to different mastery and engagement levels. The conventional approach could not adjust the learning style automatically and burdened the teacher, especially in bigger class sizes. We proposed an adaptive learning model for students with dyslexia (ALMo-DML) that personalized the learning based on the mastery level and behavior. ALMo-DML can retain the students longer using adaptive elements. This paper examines the effectiveness of the ALMo-DML prototype in increasing student engagement by comparing it with MyLexic, non-adaptive learning using a quasi-experiment. The parameters involve on-task/off-task behavior, time spent, and usability test. Descriptive statistics, hypothesis testing, software usability scale (SUS), and observation forms were used to measure the engagement parameters. The result shows a longer on-task time with an average of 22 minutes when using the ALMo-DML prototype compared to the non-adaptive application with only 12 minutes (p-value<0.05) using the Mann-Whitney U test. Besides, observation data support the finding indicating engagement from gestures, keyboard, and mouse clicks. This study proved that ALMo-DML showed a positive effect on the engagement of students with dyslexia compared with non-adaptive learning. Hence, ALMo-DML is highly recommended as a supporting material in helping students with dyslexia.



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## 1. INTRODUCTION

Language learning is a crucial phase in every child's development. It starts with orthographical recognition, phonic awareness to word articulation [1]. Dyslexia is an example of a learning difficulty that results in difficulties in cognitive learning, such as spelling, reading, and writing [2]. Students who have dyslexia are reported to have difficulties in reading-related activities, which has an impact not only on their academic performance but also on their self-esteem and social-emotional development [3]. Besides having language processing difficulties, students with dyslexia reported comorbid problems in other areas like

attention, emotional, and behavioral problems [4]. Students with dyslexia suffer from attentiveness and concentration issues resulting disengaged towards learning. Such behavior includes task avoidance, running around class, talking out loud, refusing to follow instructions, and talking out of the learning context [5]. Relying heavily on teachers to teach students with dyslexia at different paces and expect progressive results from the students is challenging [6]. Therefore, the use of a technology-based approach has become an alternative for support in the education area, especially for students with learning difficulties [7], [8].

For the Malay language-based learning intervention, MyLexic is a pioneer among researchers who introduced a computer-based application for students with dyslexia [9]. The application provides assistance using audio and visual intervention to help students recognize letters, syllables, and words. Four years later, Dyslexia Baca is introduced to support the required intervention [10]. It is a mobile application with a multisensory approach that focuses only on the confused letters such as 'p', 'q', 'b', 'd', 'w', and 'm'. Based on the literature, the existing non-adaptive learning solutions served the purpose of helping students with dyslexia to reduce their language difficulty. The only limitation of these solutions is lacking personalization that is able to adjust based on a difficulty level and a variety of student preferences. This is where the adaptation is needed to reduce the student's difficulty and gain student engagement [11].

Adaptive learning is the interaction between computer and human response where feedback can be adjusted by tracking the condition of the user. Therefore, an adaptive learning model for students with dyslexia also called ALMo-DML is introduced. The ALMo-DML implements a computer-based intervention with adaptive teaching strategies that is similar to the conventional teacher approach. The approach incorporates students' errors and engagement state in learning the Malay language. This intervention is essential as not many works focus on dyslexia within the Malay language framework [12]. The language has unique characteristics and cultural relevance which requires a tailored intervention and adaptive learning. By exploring the challenges faced by Dyslexic students in their interaction with the Malay language, this study addresses a crucial area of research with potential implications for enhancing learning outcomes and promoting inclusivity.

Engagement in education measures the level of satisfaction and interest experience towards learning [13]. It is important to measure student engagement as it can improve student performance when the satisfaction and motivation to learn are increased. Evidence from the survey discovers that active involvement will eventually affect student's learning performance. The study shows a positive correlation between students' engagement and learning performance [14]. Measuring student engagement is, however, challenging. In a conventional classroom, student engagement is measured face-to-face by the teacher through the students' attitudes, feedback, and academic results [15]. Alternatively, the engagement is assessed through time spent, contribution, on-task activity, and self-reporting [16]. Hence, we proposed ALMo-DML to improve student engagement using on-task and feedback. In this study, we aim to investigate the effectiveness of the adaptive learning model also known as ALMo-DML by comparing it with the non-adaptive learning model, namely MyLexic. To achieve our objective, the following research questions (RQ) were addressed:

i) How effective is adaptive learning towards the engagement of students with dyslexia? (RQ1)
ii) Is there any significant difference between non-adaptive learning and adaptive learning using quasi-experiments? (RQ2)

## 2. METHOD

This section elaborates on the method to evaluate the effectiveness of adaptive learning towards student engagement. The evaluation process aims to prove that adaptive learning can be used to maintain the engagement of students with dyslexia. The evaluation includes a quasi-experiment as shown in Figure 1 to measure the effectiveness of the adaptation by comparing the adaptive learning with non-adaptive learning towards student engagement.

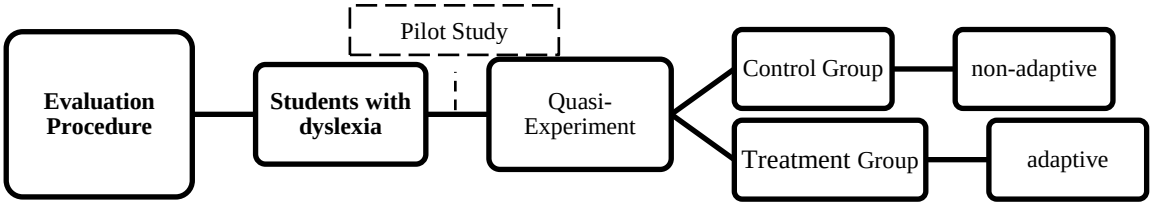


Figure 1. Evaluation procedure

### 2.1. Participants

In this study, 18 students with dyslexia from Dyslexia Association Malaysia (DAM) center were selected as participants based on age, dyslexia level, and language spoken. The students were in the age range of 7 to 12 years old and diagnosed by a medical expert as dyslexia. The selection of participants is based on the voluntary participation and permission from parents. An ethical clearance is acquired from the Ethics Committee Research Involving Human Subject (JKEUPM) before conducting the research. A consent letter from DAM and parents was obtained before the study began.

In addition, the students have to understand the Malay language to reduce bias. The reason for the limited number of participants is due to parents' restrictions on participation and limited school times. The minimum sample size in this work is adequate as agreed by other researchers who work on dyslexia students with small samples, such as four students [17], six students [18], 11 students [19], and 16 students [20].

### 2.2. Applications

The applications used for this experiment comprise non-adaptive and adaptive learning. Both applications are Malay language-based and have similar content knowledge. The syllabus is adopted from the Malay language textbook which covers alphabet recognition, syllables sound, reading words, and sentences.

#### 2.2.1. Non-adaptive learning

MyLexic is chosen as a non-adaptive learning application for this study. MyLexic is assistive courseware used by DAM center to teach students with dyslexia to learn the basic Malay language. MyLexic adopts a multi-sensory approach by applying pictures, feedback sounds, and user interaction using drag-and-drop mouse clicks [9]. MyLexic was developed using the 'dual coding theory' to strengthen alphabet and syllable recognition using visual and verbal forms. In terms of teaching strategy, MyLexic utilizes scaffolding techniques in assisting learning, such as repetition, text representation, and self-assessment activities. MyLexic comprises three sub-modules, which are alphabets, syllables, and words.

Multimedia plays an important role in the MyLexic application. Colorful and musical backgrounds are said able to reduce the amount of memory effort of children with dyslexia. Visual and kinesthetic elements support the reinforcement for optimal learning through the participation of the students. Picture as cue is suggested to be used in helping students with dyslexia to improve poor decoding and alphabet recognition skills. The authors utilize teaching components such as hear, say, see, and write to improve spelling skills. The word module teaches the students to read a simple Malay word. The students are expected already mastered the alphabet recognition and basic syllables. Interestingly, the teaching approach introduced in this module uses a family group of patterns, sounds, and words. Two different colors namely red and blue are used to differentiate the syllables to ease the students read. MyLexic delivers a great teaching approach as a non-adaptive learning for students with dyslexia which is suitable to match our proposed adaptive learning.

#### 2.2.2. Adaptive learning model for students with dyslexia

The ALMo-DML is proposed to help students with dyslexia to learn the Malay language. ALMo-DML has four modules that encompass phonology, spelling, reading, and writing exercises. The adaptation strategies used in ALMo-DML are using a mastery level answering the exercise and the prediction of the behavior of the students [21]. The mastery levels are achieved through a number of errors while the behavior prediction is established from face detection. If the face is detected longer, and more frequently, the behavior is predicted as engaged.

In ALMo-DML, adaptation comprises two stages. The first stage is to adapt the next exercise based on previous mastery-level exercises. Each error is recorded to see the difficulties the students experience when answering the exercise. Mastery level is divided into four, namely beginner, intermediate, advanced, and super advanced. It is assigned to the topic that scored less than two errors. Students who get the mastery level and are engaged with the system will receive a higher level of difficulty. Students who are not at the mastery level but engaged with the system will obtain a similar mastery level in other modules. On the other hand, if the student is not at the mastery level and disengaged with the application, the student will get a lower difficulty level.

On the other hand, adaptation in the second stage is regarding affective intervention. Affective intervention is an element to attract student's attention towards the learning such as hints and feedback. Multimedia elements in the form of images, sound, and text have been used to represent the activity. Colorful images help to attract students, especially primary school students, to the learning content. In addition, a catchy background sound has been chosen to avoid stressful activities.

Feedback is a response given to the students for any activity that the students performed. Positive and negative encouragement through audio-based feedback is given to the students as a response to each answer given. This is because students with dyslexia need encouragement and praise along with intervention

to enable them to deal with the difficulties [22]. There are three types of feedback used for this study, which include positive, negative, and idle feedback. When the students can answer all the questions correctly in each exercise, positive feedback will be broadcast. However, when the students answer any of the questions incorrectly, negative feedback will be perceived. If the students are idle with the system or no mouse as well as keyboard clicks are detected for 2 minutes, the system uses an audio message to ask the students to interact with the system. An energetic child's voice is used to attract the students to the application.

### 2.3. Measures

The measures used in this experiment involve quasi-experiment, usability, and observation. The quasi-experiment was conducted to assess the effect of the adaptation on the student's engagement. Quasi-experiment was chosen due to the lack of randomization when choosing the participants [23]. The participants were selected from a pre-determined class which was already categorized based on the level of difficulty. The categorization during class placement in DAM was purposely to ease the teacher in focusing on suitable teaching interventions.

Measuring the quasi-experiment needs an inferential statistical test to conclude the effects of the adaptive learning model on students with dyslexia. Therefore, hypothesis testing was performed to infer the effect of the adaptive model on student engagement by comparing an observed value of a sample with the control value [24]. On-task time was used to measure the engagement for this study. On-task time is the time spent by the student focusing on a specific task [25], which is similar to engagement [26].

The system usability scale (SUS), conversely, was used to measure usability for this experiment. The SUS is a highly reliable tool for gathering students' feedback and satisfaction [27]. It comprises 10 items related to perceived usefulness and ease of use. The items were translated into Malay language to ease the student's understanding. The facilitator helped to read the items since some of the students were not able to read fluently. In addition, the use of the five rates of Smileyometer helped the students to rate the SUS. This approach has been used widely among human-computer interaction (HCI) researchers to measure the student's opinions [28]. SUS is suitable as a tool to compare usability studies among applications.

The last instrument is the observation form which is used to observe and measure the student's response towards both applications. Observational notes can be supplementary for usability testing [29]. In this study, the observation notes were used to record the signs, expressions, and displayed behavior of the students while interacting with both adaptive and non-adaptive applications. Students with dyslexia are known to have limitations in language processing skills, such as phonology, spelling, reading, and writing. These cognitive states may differ among the students. Therefore, the cognitive states and behavior were observed. Conditions such as fatigue, boredom, and hunger/thirst were taken into consideration to reduce biased factors. Therefore, a five-minute break was given upon completion of the task in each activity.

### 2.4. Experiment design

The quasi-experiment was designed to identify the effectiveness of the ALMo-DML towards student engagement. Therefore, to conduct the study, two types of groups, namely control and treatment groups as shown in Table 1, were used to compare the significant difference between the proposed model and the current model. The treatment group uses the DBCB application that represents the ALMo-DML (adaptive learning) as the proposed model whereas, the control group uses MyLexic as a non-adaptive application. A total of 18 students voluntarily participated in this experiment with eight females and 10 males. These students were divided equally and randomly into treatment and control groups. In each group, nine students were assigned based on the student's level, which comprised beginner, intermediate, and advanced. The students' levels were derived from their classroom.

Table 1. Types of groups

| Group | Student's level based on class | Num. of student |
|---|---|---|
| Treatment (DBCB) | Beginner | 3 |
| | Medium | 3 |
| | Advance | 3 |
| Control (MyLexic) | Beginner | 3 |
| | Medium | 3 |
| | Advance | 3 |

Each student was given a maximum of 30 minutes to interact with the assigned application based on their group. The session was accompanied by one facilitator to help with any arising issues and to observe the session. The students were also informed that they could quit at any time during the session. The treatment and control groups were observed in terms of on-task time to see the adaptation effect on the student's

engagement time [25]. On-task time is the time spent by the student focusing on a specific task, while off-task is the time spent on other activities that are not associated with the learning task. Besides time, activities can also be interpreted as on-task and off-task. The list of on-task and off-task activities are shown in Table 2. On-task activities involve asking for help from the teacher and commenting on their achievement, progress, successes, and failures. The example of off-task is considered to happen at least 20 seconds on activities like talking about a non-related subject, skipping doing a task given, inactive, and taking some rest.

Table 2. On-task and off-task

| On task | Off task (at least 20 seconds) |
|---|---|
| Commenting on the achievement | Talking about anything other than subject materials |
| Commenting if they made progress | Doing things that are not involved in the materials given (tutoring software) |
| Commenting on success/failure | Inactive (staring into space, putting head down to the desk) |
| Asking for help from the teacher | Resting their head on one or both hands and looking away from the screen |

### 2.5. Threat of validity

Validity is concerned with the accuracy and truthfulness of findings. In this research, the validity is concerned when making inferences during observation, especially on the students without clear expressions. Therefore, asking to confirm their feelings and why they behaved is crucial before making any decision on the judgments. Besides, the validity of the student's engagements also becomes a threat. Looking at the screen sometimes does not reflect engagement or attention. Thus, input like mouse clicks and keyboard helps to reduce the threats.

## 3. RESULTS AND DISCUSSION

This study aims to evaluate the effect of adaptation on the engagement of students with dyslexia through a quasi-experiment. The result is discussed based on: i) descriptive statistics; ii) hypothesis testing; iii) usability studies; and iv) observation.

### 3.1. Descriptive statistic

A descriptive statistic was used to describe the central tendency of the student's on-task using average to see the effect of the adaptation. The on-task time was measured because it can reflect the engagement time [25]. On-task time was counted from the beginning of the exercise until the students either exited, surrendered, or finished the exercise. Based on the result shown in Table 3, the average time for the on-task behavior made by the beginner-level students (S1, S2, and S3) from the control group that used MyLexic, was 10 minutes and 96 seconds (SD=1.19). Compared with a similar class from the treatment group students (S4, S5, and S6) that used DBCB, the average of the on-task time recorded was 24 minutes and 29 seconds (SD=4.56). This depicted that students in the treatment group engaged longer with the learning materials given despite still being at the beginner level, which can be seen in Figure 2.

Table 3. Overall result for the on-task time between groups

| Groups | Control group | | | Treatment group | | |
|---|---|---|---|---|---|---|
| Student | S1 | S2 | S3 | S4 | S5 | S6 |
| Beginner (time in minutes) | 12.3 | 10 | 10.6 | 29.3 | 20.3 | 23.2 |
| Average | | 10.96 | | | 24.29 | |
| SD | | 1.19 | | | 4.56 | |
| Intermediate (time in minutes) | 10.7 | 12.7 | 11.6 | 30.4 | 29.2 | 19.8 |
| Average | | 11.71 | | | 26.45 | |
| SD | | 0.99 | | | 5.79 | |
| Advanced (time in minutes) | 11.1 | 18 | 14.1 | 14.45 | 19.5 | 21.2 |
| Average | | 14.39 | | | 18.42 | |
| SD | | 3.46 | | | 3.54 | |

In addition, students in the intermediate level students (S1, S2, and S3) from the control group were on-task for an average of 11 minutes and 71 seconds (SD=0.99) whereas the treatment group students (S4, S5, and S6) recorded an average of 26 minutes and 45 seconds (SD=5.79). This reflects a similar effect on the intermediate students for the adaptation model towards the engagement of students with dyslexia. The students' on-task time was twice as long for the treatment group compared with the control group, as presented in Figure 3.

Finally, the analysis for average time between the control and treatment groups for the six advanced students (S1, S2, S3, S4, S5, and S6) was performed. The result shows that the students were engaged with the learning materials for about 14 minutes and 39 seconds (SD=3.46) using MyLexic, and 18 minutes and 42 seconds (SD=3.54) using DBCB. The numbers show that both materials portrayed a slight difference as in Figure 4, due to the mastery level of the students. Advanced students can answer the questions in both learning materials; thus, the engagement time is shorter compared to the beginner and intermediate levels. Nevertheless, the students in the treatment group retained four minutes longer compared to the control group.

In response to RQ1, we found that adaptive learning has a positive effect on the student's engagement. This can be seen from the on-task time which recorded a longer engagement for all students who used the adaptive learning application. Students at a beginner level require intervention in alphabet recognition and phonology knowledge. Thus, the students spend more time (the majority spend more than 20 minutes) performing drag-and-drop activities where they need to match the sounds, images, and text in the adaptive learning application. Hints and feedback using students' voice encouragement helps to attach them longer. Students from a beginner level in a control group, on the other hand, spend 10 minutes to 12 minutes interacting with MyLexic. Activity and the content are almost the same but missing adaptation on difficulty level justifies the time difference.

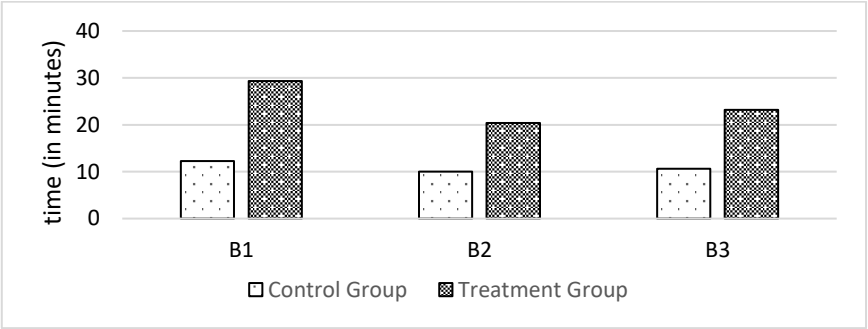


Figure 2. Comparison between groups for beginner students' on-task time

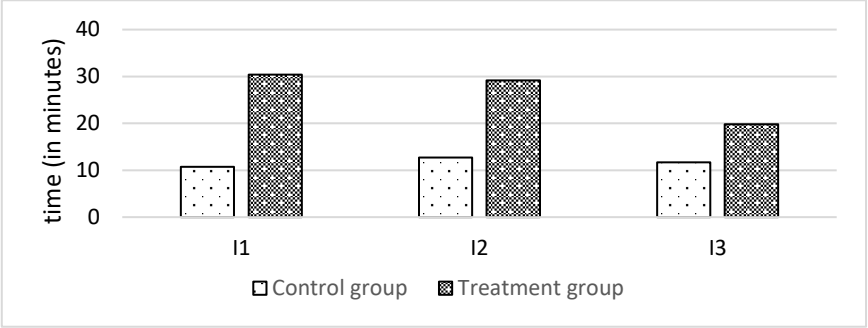


Figure 3. Comparison between groups for intermediate students' on-task time

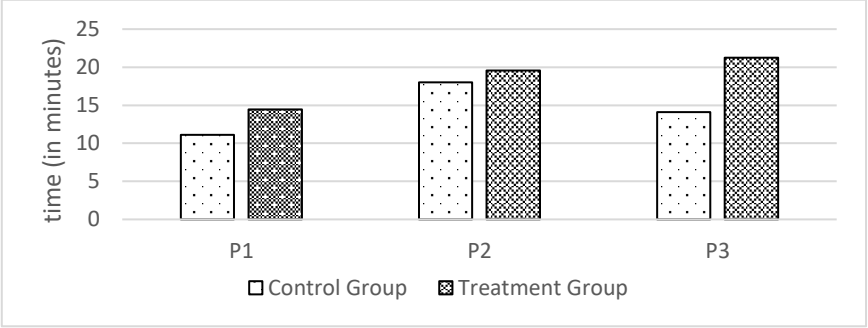


Figure 4. Comparison between groups for advanced students' on-task time

Intermediate students who already have a basic recognition of the alphabet and were able to identify the phonology knowledge similarly produce a positive result on adaptive learning application. Assessment for this group focuses on spelling skills. The activities involve choosing, matching, and sorting the correct spelling. Similar syllables are used between both applications which is a common vocabulary in the Malay language. Despite that, the result showed a longer on-task time when interacting with adaptive learning applications. Likewise, a longer on-task time for advanced students when interacting with adaptive learning. The difference in on-task time between both applications, however, is smaller with only 4 minutes. This is because the students already have a strong fundamental in language skill and the only shortage is the writing skill. Hence, on average, the majority of the students took 14 minutes to finish the activity in MyLexic and 18 minutes for DBCB. The initial outcome concludes that adaptive learning has a positive effect on students with dyslexia despite having different difficulty levels. Therefore, to confirm the substance, we perform hypothesis testing to get a strong result.

### 3.2. Hypothesis testing

The second evaluation is to answer RQ2 on seeking any significant difference between non-adaptive learning and adaptive learning towards students' engagement. The hypothesis is motivated by the previous research [30], [31]. The engagement will be increased using multimedia elements as used in MyLexic. On the contrary, personalization from the adaptation is also important to be considered to derive student engagement. Therefore, hypothesis testing is conducted to identify the effect of the adaptation towards students with dyslexia. Commonly, hypothesis testing is performed to infer the result by comparing an observed value of a sample with the population value [24]. A statistical analysis software, statistical package for the social sciences (SPSS) is used to calculate the hypothesis testing. In this study, the null hypothesis and alternative hypothesis are stated:

- Null hypothesis (H0): the proposed adaptive learning model has no significant effect on the engagement of students with dyslexia.
- Alternative hypothesis (HA): the proposed adaptive learning model has a significant effect on the engagement of students with dyslexia.

The level of significance (alpha level) for rejecting the null hypothesis in this study is decided at 0.05. In addition, in deciding the types of statistics that are suitable to be used, the data are tested on the normality with respect towards the samples. Hence, the normality test found in Table 4 shows that the Sig. value is less than the alpha level with Sig.=0.031. Thus, it represents data that is not normally distributed using Shapiro-Wilk [32]. Shapiro-Wilk is used for the normality test because it is suitable for data less than 50 [33]. Since the data is not normally distributed, it is decided to use a non-parametric test for the hypothesis testing [34].

A non-parametric test, the Mann-Whitney U test was conducted to examine the effect of the adaptation on student engagement between two groups. The level of significance value (p-value) to accept or reject the null hypothesis is 0.05. Since the result of the Mann-Whitney U test shows less than 0.05 (Exact Sig=0.000[a]), the null hypothesis can be rejected. It concludes that there is a significant difference in DBCB towards the MyLexic application that supports the alternative hypothesis as depicted in Table 5. Results from hypothesis testing also support findings from the descriptive statistics. Adaptive learning shows a positive effect on students' engagement through on-task time measurement. The proposed adaptive learning model was engaged longer than the non-adaptive learning model.

Table 4. Normality test using Shapiro-wilk

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| On task time (in sec) | 0.182 | 18 | 0.116 | 0.885 | 18 | 0.31 |

Table 5. Man-Whitney U-test significant result

| Group type | | N | Mean rank | Sum of ranks | Test statistics | On task time (in sec) |
|---|---|---|---|---|---|---|
| On task time (in sec) | Control | 9 | 5.11 | 46 | Mann-Whitney U | 1.00 |
| | Treatment | 9 | 13.89 | 125 | Wilcoxon W | 46.000 |
| | Total | 18 | | | Z | -3.488 |
| | | | | | Asymp. Sig (2-tailed) | .000 |
| | | | | | Exact Sig. [2*(1-tailed Sig.)] | .000 |

### 3.3. Usability

This test aims to identify the system's usability from the point of view of students with dyslexia. The SUS is a highly reliable tool for gathering students' feedback and satisfaction [27], [35]. The SUS measures

using 10 items with scales ranging from 0 to 4 (with 4 being the most positive response). The scoring rule for odd items in SUS is subtracted by one from the user's response, and for even items, five is subtracted from the user's response. After that, the sum of both scores is multiplied by 2.5 to obtain the overall value of the SUS score [36]. Based on the scoring rules mentioned earlier, the average score of DBCB (adaptive application) is 82.5 compared to the average score for MyLexic (non-adaptive application) which is 69.4.

The analysis of each item shows that positive responses (odd items) scored more in DBCB compared to MyLexic, as shown in Figure 5. The majority agree that DBCB meets the usability aspect. The result for negative responses (even item) in DBCB also scored less in most of the items compared to MyLexic, except for Item 8. However, the difference is very small (0.2). The reason is that they prefer to interface with different animal themes instead of bee themes used in DBCB. Another added point to indicate the importance of customization based on student's preferences. As a conclusion, adaptive learning is more usable for students with dyslexia with the adaptation and multimedia elements compared to non-adaptive learning.

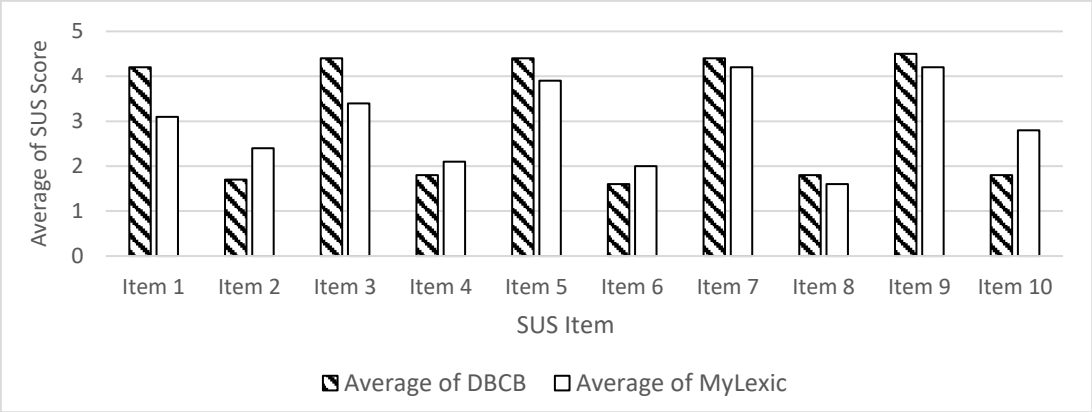


Figure 5. Comparison of SUS score for DBCB and MyLexic

### 3.4. Observation

In this study, the observation notes were used to record the signs, expressions, and displayed behavior of the students while interacting with both adaptive and non-adaptive applications. The comparison between DBCB as adaptive and MyLexic as a non-adaptive application was recorded through observational notes. The observation showed that the student's response depends on their ability to master the skills. This can be seen from the student's level which portrays a different response when dealing with different exercise levels.

The beginner level, for example, shows two prominent aspects when using a non-adaptive application which are cognitive engagement and behavior engagement. The students were interested in answering the exercise and interacting with the activity. Display a fun attitude by clapping hands and being happy when progressing to another module. However, when the level became more challenging, a few students started to feel bored and randomly clicked buttons to try and error. One student clicks the 'Exit' button to indicate he wants to stop. Another student scratches his head when unable to answer the exercise. He also requests to quit playing with the application.

In comparison with adaptive learning applications, the students are more energetic. They move their body while listening to the background sound. They smile when the application is praised for the correct answer. Some of the students gave high-fives and clapped hands when got the correct answer. However, when the answer is incorrect, some students ask for help from the observer and some get distracted by any object in front of them. This is where the adaptation takes the role of giving the hints and feedback. When the student idled for a few minutes, the application voiced out asking 'where are you'. This makes the student come back again and engage. Hints also help the student to engage longer when she imitates the audio hint after making several errors. She also keeps playing even when constantly making a mistake.

Intermediate level on the other hand shows some confidence for both applications. Behavior such as shaking legs, smiling, and clapping hands indicate they are confident and engaged with the learning. Students at this level already mastered alphabets recognition and phonology knowledge, hence, the majority of them express what they already know and easy. However, when moved to spelling exercises, students who used non-adaptive application started to display a disgusted facial expression especially when got incorrect answers [37]. One of the students clearly states he is bored a bit in learning the language. On the contrary,

students who interacted with the adaptive learning application still engaged with the application even got incorrect answers. The student remained smiling even needed to start all over again due to technical issues. Some of the students independently play around with the application by trying a higher level. The consequence of getting too attached to the application causes the student to refuse to go back to his class. He prefers to play with the application again.

Students in advanced level already have a strong fundamental in alphabet, phonology, and spelling. The only challenge the student faces is writing or sentence constructions. Therefore, when using MyLexic application, majority of the students commented it is an easy exercise. The students keep on changing activity when already bored with the application. One of the students chose to stop the activity as he said the application is too easy for him. Despite of having similar challenge when using the adaptive learning application, the students continue to interact such as enjoying the music background, say out loud the answer and smile when received compliment from the application. All of the behaviors observed proof that adaptive learning application able to engaged the students with dyslexia longer compared with non-adaptive learning.

### 3.5. Implications of the ALMo-DML in the learning of students with dyslexia

The implication of the effectiveness of the ALMo-DML is discussed based on the research questions. The result of this study provided evidence to support that the ALMo-DML effectively improves the engagement of students with dyslexia. The ALMo-DML personalized the learning intervention based on mastery levels and affective behavior such as the face, hints, and feedback. A quasi-experiment between the treatment and control group showed that on-task times using an adaptive learning model were recorded longer than the non-adaptive learning model.

Based on the finding, the implication of the ALMo-DML on the learning of the students impacted four perspectives namely behavioral engagement, affective engagement, social engagement, and cognitive engagement [16]. Behavior engagement is defined as the observable behavior of participatory actions. Students who interact with the adaptive learning model show positive behavior such as the effort to stay on-task and longer time spent on work.

The affective engagement relates to an enduring level of emotions toward learning. When using the ALMo-DML, students manifest positive emotions such as smiles, curiosity, happiness, and enthusiasm. Despite the difference in the dyslexia severity (beginner/intermediate/advanced), students using an adaptive learning model show a longer engagement and portray positive feedback from the observation. Examples of positive feedback include clapping hands, shaking heads imitating the background music, and smiling. This possibly relates to choices of background music, colors, and images that suit students with dyslexia preferences.

Next, social engagement considers bonds between students and their peers, teachers, and facilitators. Students show some cooperation to finish the exercises and interact with the teacher/facilitator such as asking and commenting. Finally, cognitive engagement shows higher-order thinking to endure the difficulty in the given tasks. The finding aligned with Chen *et al*. [38] which proved that adaptive learning increases students' engagement and learning performance. Hence, the outcomes of an effective learning model on student engagement enhanced students' well-being, students' performance, self-motivation, and self-esteem [16].

This study's findings provide evidence of the importance of an adaptive learning model which personalized intervention for students with dyslexia. The higher the engagement, the better the student's performance [39]. ALMo-DML fills the gap in personalized education plans to improve students' engagement and eventually improve the students' learning. Hence, the ALMo-DML is also suitable to be extended to kindergarten students and other learning difficulties such as slow learners.

### 3.6. Limitations and future research

In identifying the effectiveness of the ALMo-DML, we face a few limitations. First, we conduct a quasi-experiment using two different groups with different students. In each group, the students interact with a given application (adaptive or non-adaptive) only once. Therefore, they were unable to compare the applications individually. Some of the students who used the non-adaptive application in the experiment requested to use the adaptive application after that. Due to time constraints, we had to reject the request. For future work, it is best to compare the applications with similar persons to see the improvement in the student's performance. Furthermore, our study involves a limited number of students due to limited parents' consent and time. Involving a larger number (sample size) will give a better result, especially in the observation data. Our findings should be replicated with other learning difficulties such as slow learners and students without learning difficulties.

Finally, this study sought to investigate the effectiveness of the ALMo-DML on the students' engagement. The intervention was only conducted for two weeks due to limited time given by the teacher. For future work, the experiment can be extended to track the student's improvement when the intervention is a longitudinal study with repeated interventions and observation.

## 4. CONCLUSION

The conventional learning approach such as paper-based and object-based relies heavily on the teacher's effort to establish students' engagement. In addition, personalizing the learning to adapt to a different mastery level and behavior is a challenging task, especially in bigger class sizes. Therefore, we introduced ALMo-DML as an adaptive learning model for students with dyslexia that can adjust the learning based on students' mastery level and behavior. This paper explores the effectiveness of the adaptive learning approach towards students' engagement. A quasi-experiment was conducted by comparing non-adaptive learning (MyLexic) and adaptive learning applications (ALMo-DML). The experiments wanted to see the effect of the adaptive model on the engagement of students with dyslexia using the on-task time. Two research questions were constructed to achieve the objective, namely: i) how effective adaptive learning is towards students with dyslexia; and ii) whether is there any significant difference between non-adaptive learning and adaptive learning.

Results in descriptive statistics and hypothesis testing concluded that the ALMo-DML shows a significant effect on the engagement of students with dyslexia. This can be seen from the longer engagement with the adaptive model compared to the non-adaptive model. In addition, we triangulate the experiment data with observation and SUS survey. All of the results support the experiment findings. Students with dyslexia who intervened using the adaptive learning model show positive engagement feedback in their behavior, social, cognitive, and affective elements. Therefore, it is concluded that the adaptive learning model can support students with dyslexia in learning the Malay language. The adaptive learning model has a high potential to support inclusive and equity education for students with disabilities. Hence, it is recommended to be used in a wider range of educational settings such as for students with other learning disabilities and students who are early readers.

## ACKNOWLEDGEMENTS

Special thanks to the president of DAM, dyslexia expert panel, coordinator, teachers, parents, and students for great assistance in this research. We would also like to thank the university's ethics committee which approved our application to conduct this study and IIUM-UMP Grant (RDU223210) for the financial support.

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