Development of the Game-Based Pre-Screening Test for Students with Dyslexia

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Abstract: The conventional approach to screening dyslexia occurrence in Malaysia includes identifying issues by parents or teachers on their childrens performance in spelling, reading, writing, and mathematical understanding. One of the mediums is using the checklist instrument for dyslexia (ISD) developed by the Ministry of Education (MoE) Malaysia under the Special Education Department. It is the first step in identifying children who may have dyslexia. However, the screening needs to be conducted through a written test using paper and pencil. It requires the children to sit and answer the test in an exam setting. This makes the children feel stressed, being judged and monitored for the whole session. The operation of ISD also requires experienced teachers and it becomes difficult if he/she is a new teacher and has not been exposed to identifying dyslexia. Therefore, this project suggesting to overcome the problems through a "Game-Based Dyslexia Pre-Screening Test" which screened the children with or without dyslexia by answering a few questions derived from the ISD and Malay language textbooks standards 1 to 3 while the children played a game. This application allows children to play while going through the test with more fun and enjoyment, and increases their interest to play without knowing they are being assessed. In this project, interviews and surveys were conducted with teachers and parents at the beginning of the project. Design and development of the game include Unity, Visual Studio, and several other applications that were used to produce this project. Finally, evaluation using the Software Usability Scale (SUS) and observation of 30 students showed positive feedback. All of them liked playing the games, and they were engaged in playing the game which was assessed using times taken. This game can be a pre-screening approach to evaluate the students without making the students depressed or feeling different from their peers.

Keywords: Pre-screening, dyslexia, game, Malay language, children.

sectionIntroduction The pandemic made it harder to spot students that have learning disabilities. One of the learning disabilities is Dyslexia. Dyslexia is a learning disability characterized by difficulties recognizing spoken sounds and learning how they relate to letters and words (decoding) [1]. Difficulties in reading, however, cannot be defined by low intelligence quotient (IQ), lack of educational opportunities or obvious sensory or neurological damage [2]. The conventional approach identifies children with dyslexia using a paper-based test and medical expert diagnoses. Children who are at risk need to answer a few questions in an exam setting based on their performance during class. The screening process requires a lot of time for children to answer and the teacher to evaluate it. Moreover, screening dyslexia publicly will demotivate the children as well as their parents. Pre-screening for dyslexia needs to conduct carefully to avoid affecting academic performance as well as impacting the childrens self-confidence and social emotions [3]. If the children are left out and not intervened accordingly, the children can seriously impact their communication, education, career, as well as mental health [4].

Pre-screening is an important step in identifying dyslexia among children before a suitable intervention programme can be conducted as early as possible. In Malaysia, the screening is conducted on a primary student using ISD introduced by the MoE [5]. The ISD is a manual checklist-based assessment to identify the probabilities that a standard 1 student has Dyslexia or not. However, the children need to be in the education system for at least 6 months and are still left behind from their peers in spelling, reading and/or writing as well as poor in academic performance.

The evaluation of ISD is basically based on teacher observation and students comprehension. However, using this approach took a longer time to obtain result and can caused delay in confirmation of dyslexia risk. It is because the students need to go through a few steps such as the nomination process, the score process, the report process and only then they can go through last process which is the medical practitioner confirmation, this can cause a delay in confirmation of dyslexia risk. Besides, screening using conventional approach only involved an identified children by the teacher. Children who "missed out" in the nomination process might left out and risking to have a severe dyslexia condition due to late intervention.

In this project, a game-based Dyslexia pre-screening test is introduced to help the children and teachers. This approach is not only focused on the cognitive but also engagement behaviour aspects. The aim of this study is to develop a game-based approach to pre-screen the children with dyslexia with less teacher intervention and encourage motivation among children. This could be an alternative for early detections intended for parents as well as teachers to seek a medical expert and get a proper intervention. This paper, therefore, discusses the related work which includes current approach of traditional dyslexia screening and computer-based screening.

Section 3 introduces the methodology. Section 4 highlights the development while Section 5 discusses the results of the evaluation. Finally, Section 6 concludes the study.

1. Related Work

In this section, the work discusses the two categories of screening approach namely the manual paper-based screening and computer-based dyslexia screening approach:

1.1 Dyslexia Manual Screening

Dyslexia Screening Instrument (ISD) is a manual checklist-based assessment effort done by the MoE to help schools and teachers in Malaysia identify and recognize dyslexia criteria on primary school children. The ISD aims to make sure that no children will be left out in screening the literacy competency. The children however, need to be identified by the teacher who already teaches him/her for more than 6 months. The identified student can then proceed to get diagnosed by hospital specialist so that the student will get the proper treatment at the early stage. Nevertheless, current approach of ISD as shown in Table 1 is a manual identification based on pen paper exam orientation. There are five phases of operations which start with nominating students, answering phase, scoring, reporting and confirming. All of these processes conducted manually and requires a manual analysis which resulting a longer time to screen the students. In general, the ISD covers (i) measuring perceptions of reading, spelling and proficiency in writing, (ii) measuring perceptions of cognitive abilities or intelligence (existing strengths) and (iii) identify the specific characteristics of dyslexia.

Table 1. ISD operation

Phase	Operation	Description
1	nominating	• It is a process to identify students that need to undergo the ISD. • It is either nomination from the class teacher, subject teacher or from the parents itself. • After the Malay language teacher identifies the children, they have to undergo the ISD.
2	children answer the test	• A paper-based exam-oriented questions will be given to the students
3	scoring	• The Malay language teacher will evaluate based on the childrens response. • The score obtained from the Malay language teacher will be submitted to the coordinator or dyslexia teacher • The coordinator or the dyslexia teacher need to conclude the submitted score. • The result obtained by the coordinator will identify whether the children has the probability of dyslexia or not.
4	reporting	• The coordinator will report the result to the principal or the school administrator. • The principal or the school administrator will immediately hand over the ISD result with the medical practitioner confirmation form to the parents. • Then, the parents or guardians will be recommended to bring the children to see a medical practitioner to get confirmation.
5	confirming	• The hospital specialist will give confirmation based on the ISD result. • The result stating that a student has a possibility of experiencing the dyslexia problem is necessary to get confirmation from a hospital specialist so that the student will get the proper treatment in the early stage.

1.2 Computer-Based Dyslexia Screening Approach

Computer-based screening approach comprises of survey-based, eye-tracking, reading application, game-based, and many more. All of the approaches fit the same purpose with manual screening which distinguishing dyslexia and non-dyslexia. The outcomes of computer-based screening approach demonstrate a promising tool for early detection of dyslexia condition.

Research conducted by Banumathi et al. (2023) uses data from survey to screen dyslexia condition age 5 to 8 years old. The survey includes general behaviour, personality, unique talents, speech and hearing skills, visual acuity and reading skills, writing and motor skills, mathematical ability and memory skills [6]. A mobile application is developed to screened the students with dyslexia in Tamil language using questionnaire. Respondent who is a child at risk is given with three choices namely always, sometimes and never using Likert scale. Results denoted severity using red, orange and green colour. Machine learning specifically decision trees successfully categorised the learner types based on the survey data with 93% accuracy. However, the screening requires the children to self-report themselves with a number of questions.

Eye movement is another feature to detect dyslexia tendency based on eye tracking measures. Group of 30 Serbian children age 7 to 13 years old are asked to read 13 different texts on 13 different colours. Students were placed in a quiet room with monitor and keyboard. A portable eye-tracker is used to capture the eye movement of the student while reading elementary school story "Saint Sava and villager without happiness" [7]. Several colour backgrounds changed to see the effect on the reading performance. Fixation, saccade and blink are the elements recorded by the eye tracker. A Fixation is a condition where children maintaining gaze at single location whereas saccade is changes of an eye movement from the fixation point [8]. Blink also used to predict the engagement of the dyslexia students through blinking time [9]. Logistic regression (LR) algorithm gives the best accuracy with 94% in distinguishing children with dyslexia and children without dyslexia. However, it needs a precision on tracking the eyes movement such as maintaining a suitable distance and surrounding.

Reading fluency through reading application is a measurement tools to identify students with dyslexia. Ability to read with acceptable speed, accuracy and expression can be used to determine students at risk. Researchers from Slovakian utilised machine learning in identifying 27 students age 8 and 9 using audio recording of oral reading [10]. Six test involves comprises reading comprehension, phonological awareness, memory, reading aloud, silent reading and sequencing. The reading application with good colour contrast, left-aligned text and comfortable spacing based on visual processing characteristic for students with dyslexia is followed. Four attributes extracted from audio recorder includes start time, number of words, ending time and type errors. Random forest and Naïve Bayes algorithm show that non dyslexia have shorter reading time and less error whereas students at risk with dyslexia took a longer reading time and higher number of errors. The drawback of this approach is a small sample data used in the machine learning algorithm to make a generalisation on bigger population.

Game-based screening is proposed by analysing the error made by 109 students with dyslexia age 7 to 12 years old while answering Thai language-related questions [11]. Two elements involve such as audio and visual to determine the error. The measurement parameter includes time to click, total click, duration, average clicked time, number of hits and misses. These data are computed and analysed by the machine learning. The result managed to distinguish students with and without dyslexia through number of mistakes and longer reading time. Students with dyslexia needs more time to read and makes more mistakes while doing a writing exercise. Thus, game can be an effective tool to screen students with dyslexia.

Not only effective in determining students with dyslexia, game also proven in increasing students motivation. A visual perceptions games through a picture rotation game is developed to identify students with dyslexia [12]. Problems in identifying shapes, directions and symmetrical figures are the issues faces by students with dyslexia. 18 children age 9 to 10 years old were asked to play with the game. The longer the students interact with this Thai language-based game signify the longer engagement and motivation the student feels. Other parameters include number of missed, time, number of click, accuracy, fixation and number of trials. All of the data were collected from mouse tracking. As a result, most of students loved the games and managed to finish the games. However, some of them (without dyslexia) commented that the game was too easy as it only requires the student to rotate the game character similar to the provided picture in the game.

As a summary, screening students with dyslexia can be establish with a variety of approaches. Games is one of the approaches that not only managed to distinguish students with and without dyslexia but also able to increase students motivation and attention. In addition, limited research in the Malay language based especially on the game-based screening motivates the author to work on this area. Therefore, this paper discusses the development of the game-based pre-screening students with dyslexia.

2. Methodology

In developing the pre-screening game, we adopt the ADDIE model: Analysis, Design, Development, Implementation and Evaluation. The ADDIE model as shown in Figure 1 is suitable to be used in developing the education-based application because it can ensure the task follows a logical process. Besides, the structures of this model are flexible to be applied to all learning environment especially for students with dyslexia and game development [13].

2.1 Analysis Phase

In the analysis phase, the main objective is identifying the dyslexia screening test issue in Malaysia and finding the im-
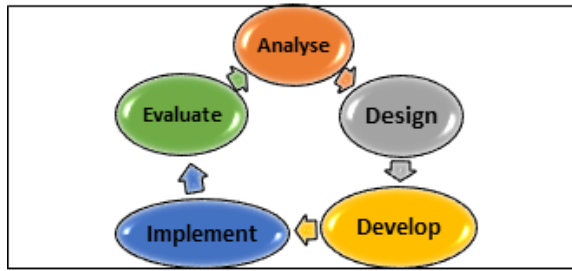
Figure 1. ADDIE Model

portant element for screening dyslexia. Therefore, besides conducting literature review and referring to the ISD manual, we also gather the information from online interview. A semi-structured interview was conducted with Mrs. Rosniza binti Sulieman, a special education teacher from SK Laksamana Kota Tinggi, Johor with more than 10 years of experience since 2003. Some of the questions includes background of the teacher, experiences in teaching students with dyslexia, characteristic of the students, screening students at risk, issues arise when handling the students, and materials used in accessing the students. The interview was conducted using Google Meet based on the teachers suggestion. The interview was transcribed and sorted according to the theme using a quantitative software, Atlas.ti. Analysing the result of the interview involves cleaning a raw data and sorted in table form [14]. The data is coded according to a similar pattern based on scenario. Finally, the codes were groups into themes based on the relations. In addition, a survey is also given to the teachers and parents using Google form and distributed using social media platform. There were 20 peoples participated in the survey. Table 1 shows the questions in the survey.

Table 2. Survey question for user requirement collection

No	Question
1.	Have you ever heard about Dyslexia Screening Test Apps?
2.	Did you know how Dyslexia is screened?
3.	Traditional test on dyslexia screening is through pen and paper-based. What is your comment on this method?
4.	If student with dyslexia is screened while playing a game, would you reject or agree this approach?
5.	Do you think, a game-based pre-screening test can helps identifying students at risk?
6.	What would be their respond towards the game-based pre-screening test?
7.	What would be your expectation towards the game-based pre-screening test?

2.2 Design Phase

Based on the information in the analysis phase, the next step in ADDIE model is a design phase. In this phase, a context diagram and flow chart are developed to helps in visualising the application. Figure 2 shows a context diagram for this

application. Context diagram is a high-level view of a system. In this application, only user determine as external entities that interact with the application.
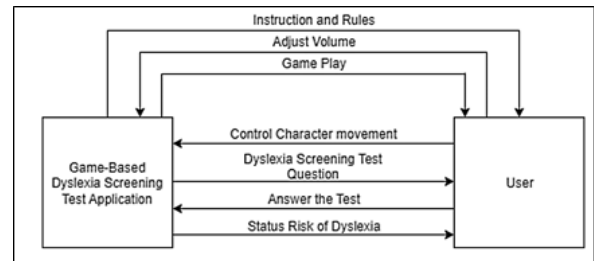

Figure 2. Context Diagram

A flowchart as shown in Figure 3 is used to display the workflow of the game application and how the system works. When user click the "Start" button, it will navigate to an interface of the modules which consist of "Level 1", "Level 2" and "Level 3" user can choose based on their preferences. In each module there will be a game instruction explaining the objective to be completed. There are two task involves namely collecting banana and finding a flag as finishing line. Upon completion the user will be given with 10 questions of screening test. The questions mostly testing a reading skill in Malay language. The score of each test is calculated and the result displaying potential percentage of dyslexia occurrence. There is also a hint to guide the student on how to play by clicking "How to Play" button. If the user wanted to close the game application, the user can click on "Quit" button.
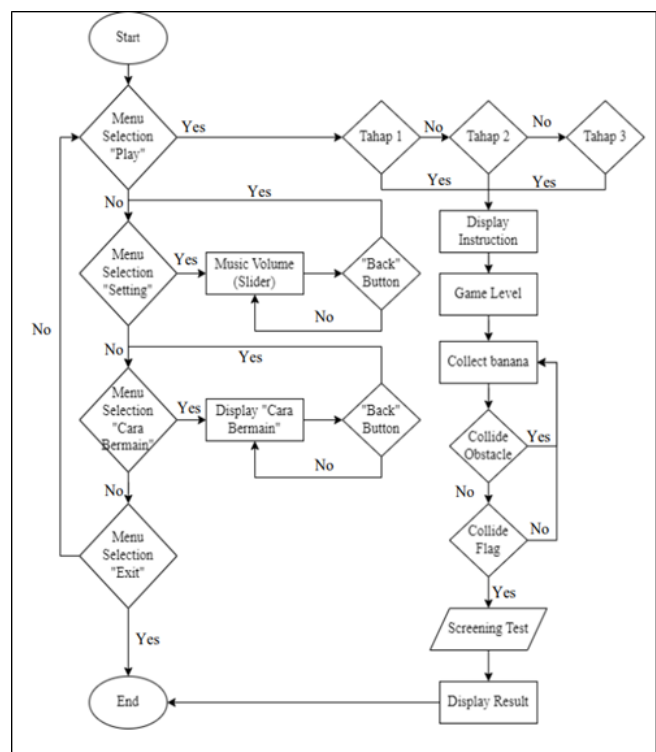

Figure 3. Flowchart Diagram

2.3 Development Phase

In the development phase, a proof of initial concept is created using a prototype development. As a start, a storyboard is developed to visualize the prototypes. Table 2 depicted a layout of prototype for the game-based dyslexia screening application.

2.4 Implementation Phase

In the implementation phase, the prototype is uploaded online in unity collaborate website. The purpose is to make the prototype ready for evaluation purposes.

2.5 Evaluation Phase

Evaluation phase is the last phase for this model. After the Game-based Dyslexia Screening Test is designed, developed and implemented, we need to evaluate the application on the effectiveness. Besides, the evaluation is required to gather all the important information for the prototype improvement. In this phase, the process involves survey and observation.

Interview with teacher is performed to get the feedback from expert. The experts responsible to determine the correctness of the evaluation and the example of questions for screening is suitable and meet the objective. A survey is used to measure whether the application is able to perform in the based on the requirement or not. The form will be given to the user who tested the application to get their feedback and comments. Any improvement that are need for this application will be based on the feedback/comments obtained from the users. In addition, the targeted students were observed while playing the application to see their responds. The observation form is used to observe the students using on-task activity.

3. Development of the Game-Based Pre-Screening Test for Dyslexia

This section elaborates the development process of the Game-based Pre-screening Test for Dyslexia. The development involves several processes such as:

3.1 Designing Graphic and Multimedia Contents

All multimedia element in this project were designed using Canva such as background, draggable item and many more. Figure 4 show a few backgrounds and item that been design using Canva.
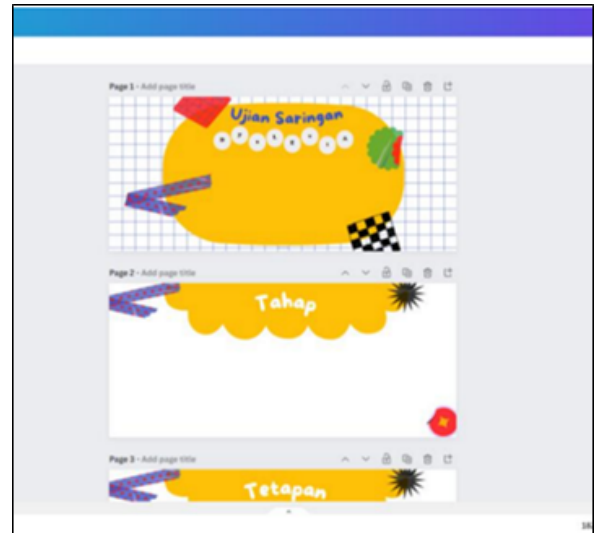

Figure 4. Designing the interfaces

3.2 Development of the Game Application

After designing some of multimedia and graphics content such as button and many more, the game application development is created using Unity (2021.3.10f1). Before start developing the application in unity, all the asset that will be used to develop this game must be gathered first. After searching all relevant resources, a free unity assets store is used. A Unity assets store can be open directly from the Unity application. This game is developed using 2D images. After reviewing asset store, the most suitable asset for this game is Pixel Adventure 1 by Pixel Frog as shown in Figure 5 as it is free, meet a platform game and most of the assets are suitable for the application.
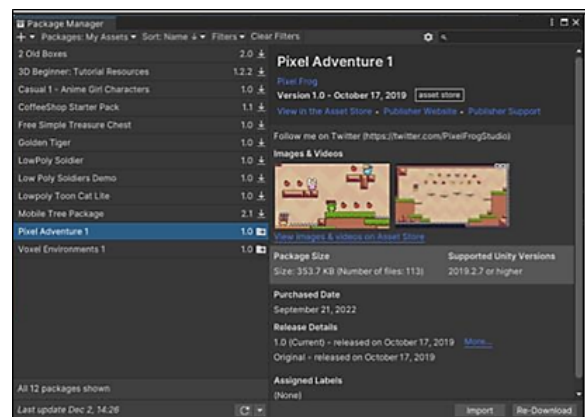

Figure 5. Pixel Adventure 1

3.3 Environment of the Game Application

To build the environment the asset provided in Pixel Adventure 1 is used. Specifically, the assets can be achieved in Assets > Pixel Adventure 1> Assets > Terrain. To create the environment, in the inspector tab the size of the asset is set to "16" for the pixels per unit. Each of the pixels per unit is designed to create a terrain using tile map by selecting right click> 2D object > Tilemap > Rectangular (Name as Terrain).
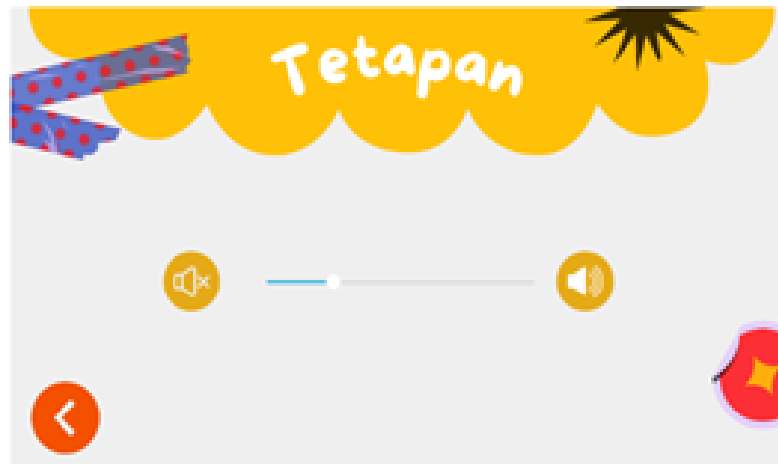
Table 3. Layout of the prototype
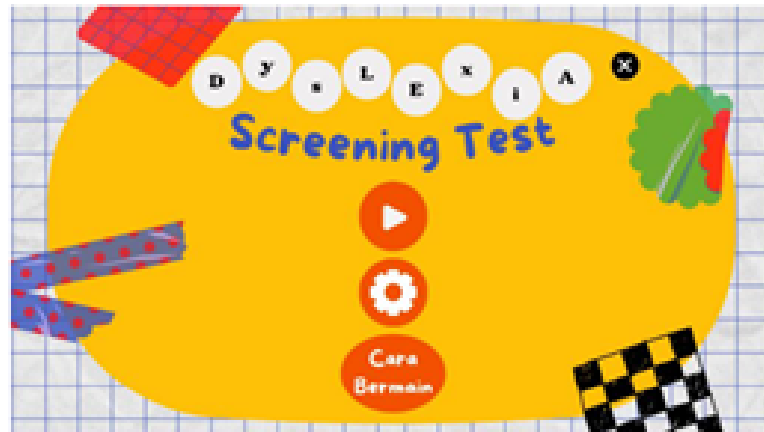
Scene	Layout
Main menu	In main menu page there will be four buttons; "START", "SETTING", "CARA BERMAIN" and "X" (quit). The function of each button is as follow: • START- Navigate to Tahap Page • SETTING- Open Settings Menu • CARA BERMAIN- Open How to play Page • X (quit)- Confirmation Quit Page In setting page, the slider is used to ease the user to control the volume of the background music in the application. There is also "BACK" button. If the user clicks the "<" button user will go to the main page
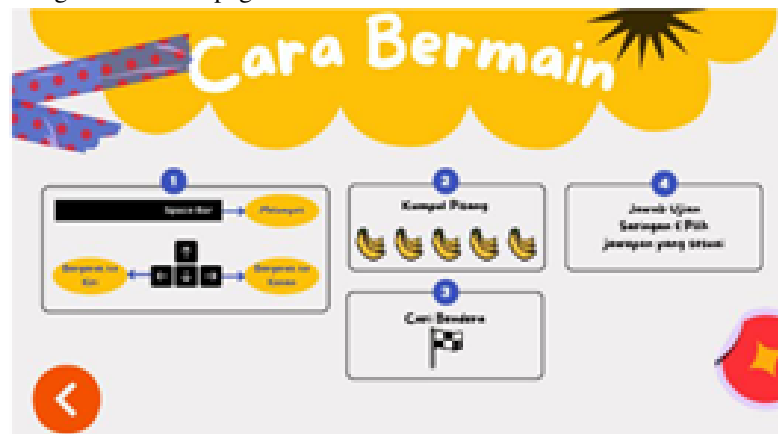
In how to play page, the application will show how to play the game. There are four instructions on how to play the game. There is also "BACK" button which displayed using "<" icon to go back to the main page

Confirmation to quit is option to allows user to select if they want to exit from the game. Some multimedia elements are included in this scene such as, text, image, background music.

Game Module

In this scene there will be three level that can be choosen; "TAHAP 1", "TAHAP 2" and "TAHAP 3".
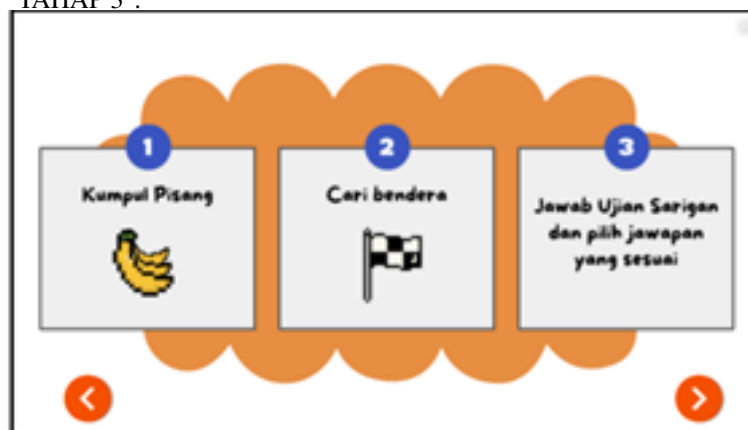
The application guides to accomplish the game mission with 3 objectives:

1. Collect banana

2. Find flag to end the game

3. Answer screening questions

Player needs to collect banana and player can move using keyboards key:

- Spacebar- To jump

- Left Arrow- To move to the Left

- Right Arrow- To move to the Right
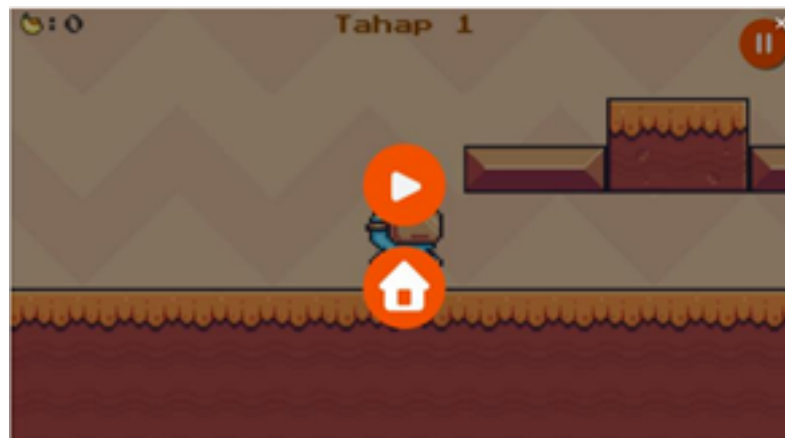
In pause page user can choose "HOME" button and "RESUME" button.

- RESUME- To continue play

- HOME- Go home page

After player collect banana, player need to find flag and collied the flag.

Game Achievement	

Victory page will be displayed after player collied with the flag.

Screening	

Victory page will be displayed after player collied with the flag.

Result	
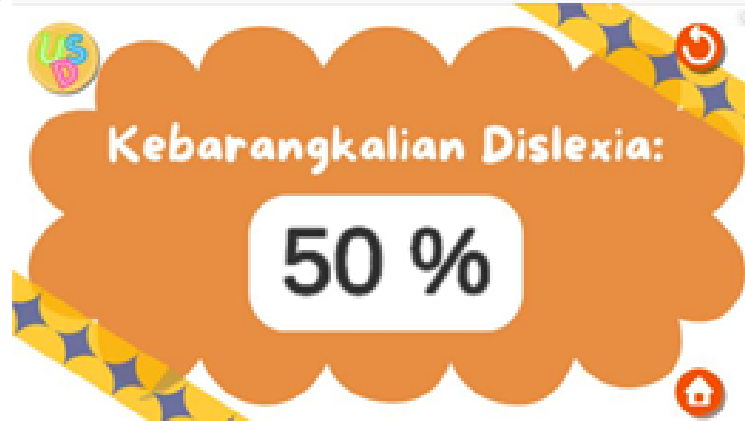
Display the risk of dyslexia, via percentage of the occurence and there will be "HOME" button and "REPLAY" button.

Then go to window> 2D> Tile palette. The tile palette is sorted like a puzzle to build the environment. Table 3 (a) – (c) shows a process of creating the environment using several snapshots.

Table 4. Steps in building the environment

Process creating environment
(a) Setting pixels
(b) Choosing the tile map
(c) Creating the terrain
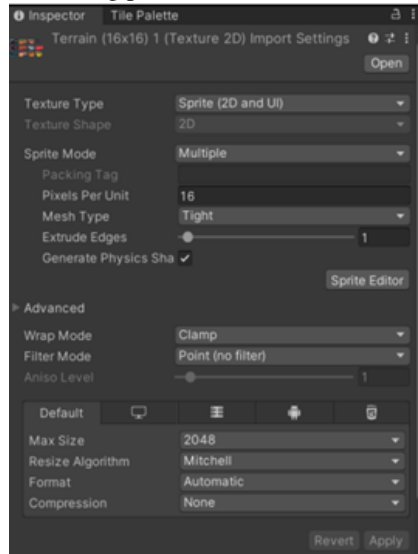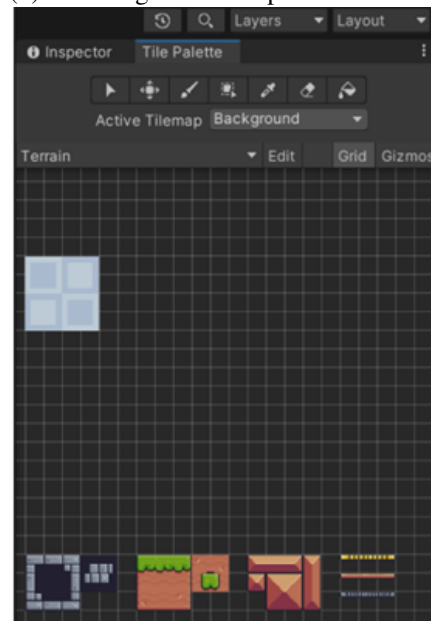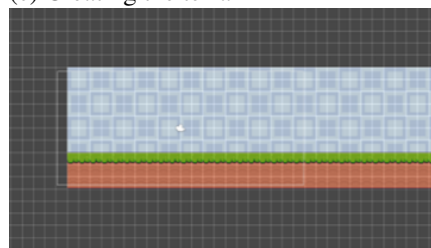
3.4 Character, Animation and Animator

The chosen character for this game is a virtual guy as shown in Figure 6, who has an ability to jump and move to the left and to the right. The implementation of the animation is created to suit the character such as jumping, running, falling and death. Animation editor is used to preview and edit the created animation.
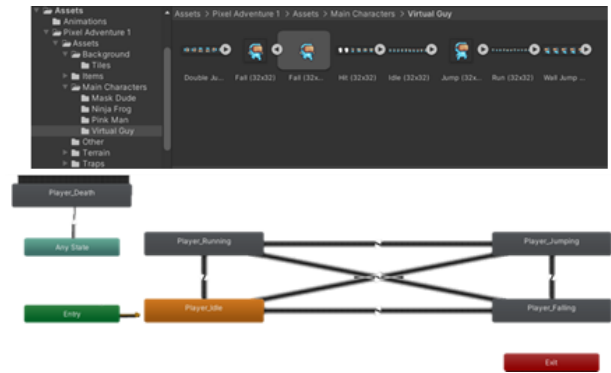
Figure 6. Character in the game game with its animator in the animation editor

3.5 Collect and Count Items

The objective of this game is to collect the banana. Therefore, the game needs to count the game to achieve the objective. The number of collected items is display at the top left corner as shown in Figure 7 to acknowledge the player.

3.6 Screening Test

The development of the screening test is following questions setup for screening the dyslexia condition. Ten questions are created in each level. Overall, this game has three levels. In each level the students are permitted to only make a total of 4 mistakes out of 10 questions correct to be identified as not having dyslexia [5]. The rule of thumb for next screening is more than 60% probability of having dyslexia. The formula to calculate the probability of having dyslexia as below:

$$\textbf{probability have dyslexia} = \frac{\text{number of mistakes}}{\text{total number of questions}} X 100\%$$
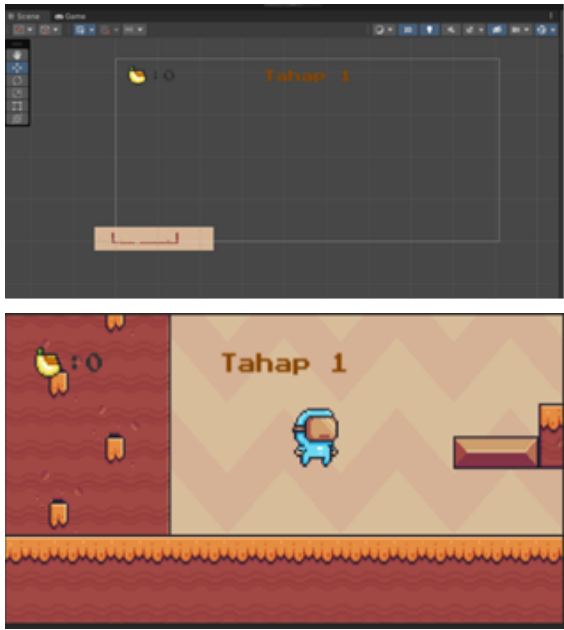
Figure 7. Counting item with and without character

## 4. Evaluation and Discussion

During evaluation two activities were performed in measuring the effectiveness of the game-based screening for dyslexia. The activities include survey to 30 responded from teachers and students, whereas for observation involves 6 students (3 students at risk and 3 normal students). All of the respondents were asked to play with the game first. Then, they need to answer survey questions using Google form. The questions use 1-5 Likert scales generally evaluates the usability and efficacy of the game application. Based on the survey as shown in Figure 8, 20 responded with 66.7% rated they are strongly agree in favour of using the game application. The remaining 33% or 10 responded agree that they like using the game. The responded also rate similar scale for question related to enjoy playing the screening test game.

In addition, the survey also asks on their agreement towards whether the game helps students and teachers or not. As a result, 83.3% rated strongly agree and 16.7% rated agree. The survey also asks whether the respondent would recommend the game application to other people who might have a risk to do the screening test. From the survey, 20 respondents rated they are strongly agree to recommend others using the game application. The remaining 10 respondents choose agree to recommend to others. As conclusion, the game application managed to give enjoyment without stressing the student even though they are actually being screened through the game approach. Majority of the responded agree the application have a good potential in helping students, teacher as well as the parents for early screening. Despite having a positive comment, a few improvements need to give attention. Some of the comments includes to add more element on writing exercise during screening, to have a multiple games types such as puzzle, crosswords and mix & match activities. Some of the responded stated to questions is too limited. They are suggesting to have 20 questions to screened
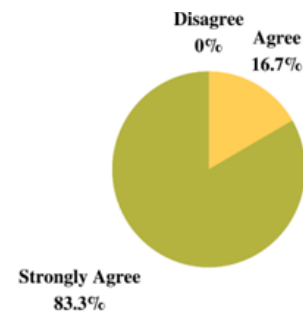
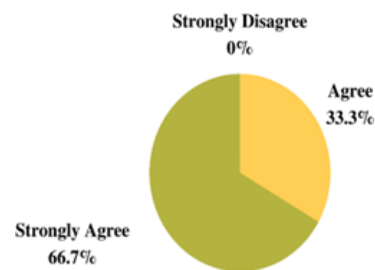the students in more accurate and details.
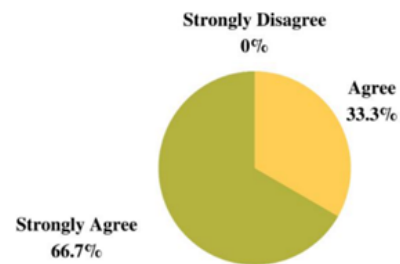
(a) Do you like Game-based dyslexia pre-screening test?
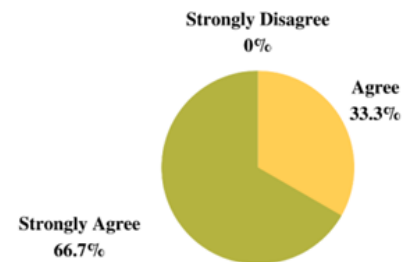
(b) Do you enjoy playing the game-based dyslexia pre-screening test?

(c) Do you think the game-based dyslexia pre=screening test can help student in learning?

(d) Would you like to recommend the game-based dyslexia pre-screening test to the people that might have dyslexia to do the screening test?

Figure 8. Evaluation using survey to 30 respondents.

During the observation, we use observation form as shown in Fig. 13 to record the behaviour of the students while playing the game. Observation data is used as triangulation data in confirming the students enjoyment and engagement towards the game application. The on-task and off-task be-

haviour as in the observation form is suitable approach to measure student engagement [15]. On-task time was calculated when the student start playing the game until the students either exited, surrendered, or finished the game.

Figure 9. Observation form

Result from the observation showed the students is in favour with the game. The students (normal and at risk) smile when successfully finish each level. Some of the students clapped their hand and say yes when accomplished the mission (finding all bananas) and overcome obstacles during games episode. The students also read the questions out loud without ashamed even in front of their friends who also attentive with the games. Some of the students shake her head following the game background music. Other students who surround the game player also give supports and they are hive-five with each others when success. This creates a supportive and collaborative learning among peers.
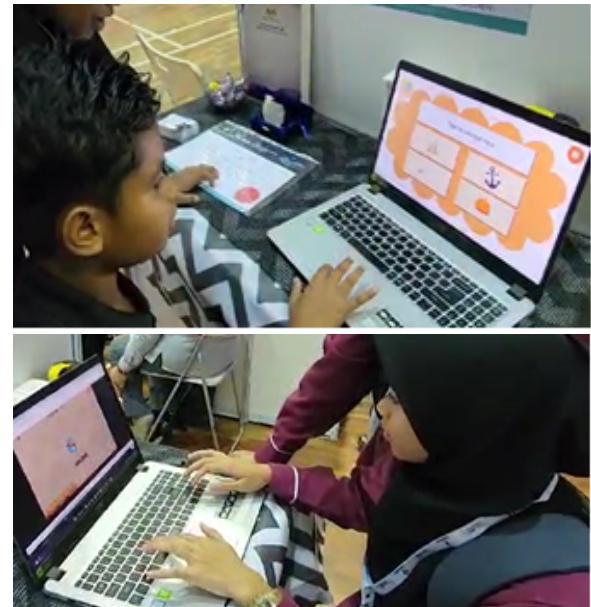

Figure 10. Students interact with the game-based dyslexia pre-screening test

5. Conclusion

In summary, this paper describes the development of the game-based pre-screening test for dyslexia students. The process begins with the analysis of the traditional screening approach which is ISD, interview session with teachers and a few surveys to understand more on the current process and to get idea on the proposed game. The next process was design which create a context diagram and flow chart to visualize the game application. After the design process was finish, the development of the game is begun. Unity application and Canva is used in the development stage. Free assets in the Unity application helps to ease the development process. The development is important to determine the project success. Thus, comment and input from the teacher during analysis helps in translating the conceptual idea to a working prototype. After development, the game was published in the unity group as a platform to conduct evaluation process. Finally, the evaluation which involved teachers and students in answering surveys after using the game and observation with 6 students while playing the games.

Based on the survey result, all 30 respondents agree that the game is suitable to be used as an early intervention to pre-screen students with dyslexia. The students feel enjoy and fun playing the game without noticing they are actually being measured or screened. Despite of the that, a few lessons were experienced. The first lesson is changes of behaviour. Dealing with the students requires preparation on the changes of their behaviour. A longer time (with a maximum of 30 minutes) is not recommended because the students can easily get de-motivated. Finally, the students limitations where it requires great sensitivity and patience to understand the students capability. Some of the students are hyperactive and need supervision and some of them are too soft-spoken which require us to ask if they have a problem. Nonetheless,

the game application can be a good early screening tools for dyslexia students in Malaysia.

Acknowledgment

Data Availability Statement

Raw data for our dataset are not publicly available to preserve individuals privacy, especially children with special needs. In addition, we respect their request not to share the raw data publicly.

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