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# Educational science game for early primary school

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**Abstract.** Learning is a process to extend the knowledge, but learning science helps to understand the world. Science education is important due to the relevance in human's lives and the universally applicable problem-solving and critical thinking skills it uses and develops. It is a foundation of education for student. When it comes to student, science education gives them the skills and knowledge that are required for their problem solving and critical skills. Science is the best subject that can be learn by experimenting and experiencing. Nowadays, technology had taken part in many domains. Same goes to education, technology had contributed many improvements to make the learning process more attractive. Hence, in this modern era, the implementation of video games in education can be the effective way for student to learn while having fun in learning. Therefore, this project aims to develop a science game for student to play while experiencing the new method of learning process. The game is developed by using Unity3D game engine.

## 1. Introduction

Educational game can be applied in many subjects taught at school. For this project, science subject for student Standard 1 is chosen. The game created can be a platform of new learning method since the subject requires student to explore their environment and nature. Hence, with the game version, students are able to play and learn science interactively without neglect the education elements. The content of the game is appropriate for the Malaysian education system which following the syllabus from new curriculum which is Kurikulum Standard Sekolah Rendah (KSSR).

Nowadays, there are many methods to improve the way of study in school. Over the years, educators had provided various way to help students gained a long-lasting interest in study because it has the potential to enhance the student's attention to stay focus and the learning quality [11]. Since the development has rapidly growing, the evolution of learning method changes in a modern way. One of the approaches to increase the quality of learning is by using a computer and games as a medium [9]. Game-based learning can be considered as the mix of education and games. Education game design must have a balance between fun and educational value [6]. Game can be said to be successful in help student to encourage problem solving and decision-making skills. It also helps to increase student understanding and time engagement in learning.

This paper contains six sections as follows: Section I presents the introduction of the paper. Next, Section II describes about the literature review that had been done for this project. Section III presents

the methodology used for the project. The implementation of Science subject into the educational game is described in Chapter IV. Then, Section V described the test conducted and the evaluation of the result. Lastly, Section VI contains the conclusion of the project development.

## 2.  Literature Review

### 2.1  Game and Education
Computer games have become immersed in our society and cultural environment. The advantages of computer games become the reason by many parties to use it as attraction especially in learning process. Game has unique perspectives of teaching and learning differ from any platform [10]. Computer game gives a new method and approach for educators to apply it in learning process. The games also have to be balance in entertainment and academic aspects. In addition, playing online games may be something which can enhance a child's learning and development. It also has potential in improving on the perceptual and motor skills [3]. In other research, there are four domains which of the positive effects in playing video games, i.e. cognitive, motivational, emotional, and social [2].

### 2.2  Game Based Learning
Game-based is an approach to learning while exploring the suitable aspects of games in a learning context. For example, teaching history with simulations. When the learn processed in groups, the finding shows that the students achieve better experience, learning performance and satisfaction [4]. There are many aspects of education which contributes to active learning. As stated by Pivec and Dondi, [9] the first aspect of educational role-play is the immersion and reasonable experiences in learning process. Other than that, the development of personal understanding about the topic that gains from the resources and lessons. Next, the personal method of understand the lesson with other person by testing and challenging each other knowledge. Lastly, the reflection of someone's achievement to put it as a self-benchmark. Based on the research, game-based learning enables the learners to understand better and helpful in improving the achievements and learning attitudes [13]. Green and Bavelier [3] stated that serious game motivates and trigger them to use their skills and ability in critical thinking. Collaborative learning environment has been studied by [13] and online teaching using mixed reality for telepresence [14].

### 2.3  Science Education
For this game development, the subject referred is Science for Grade 1. The syllabus applied following the latest curriculum in Malaysia education system which is Kurikulum Standard Sekolah Rendah (KSSR). The aim of the science education is to provide opportunities for pupils to learn about themselves and environment through experiencing and investigating [7]. In the other hand, it acquires knowledge and skills to enable pupils to apply it to make decisions and solve the problem in everyday life. As what had mentioned above, science requires more skills and knowledge by experimenting the things around them. Researcher stated that student's interest and willingness to study science is diminished since they require to rote [1]. Johnson and Mayer [5] review that digital game helpful in improving spatial cognition, perceptual-motor skills, problem solving skills and visual attention processing. Science is wide and many more can be discovered. The basic of science are taught since earlier of the age. Its knowledge can be gained through direct or indirect approaches. As usual, direct knowledge comes from the lesson at school or home. Meanwhile, indirect knowledge comes from the things happened in our surrounding. It also can be gained when something influenced and triggered us to solve the problem. In this project, the topic used in this subject for the game development is living things and non-living things.

### 2.4  Selected Topic
The selected topic chosen in this subject is from Chapter 3 which is Benda Hidup & Benda Bukan Hidup. There are four sub-sections under this chapter which are (1) Benda Hidup & Benda Bukan Hidup, (2) Ciri-ciri Benda Hidup, (3) Kecil dan Besar, and (4) Keperluan Asas Benda Hidup.

In overcoming the problem of quality consistency of science education, many experts called for inventing the approaches of science education. Game and simulation for science education are the suitable approach since it already a part of nowadays norm of community [1][7]. Furthermore, game provides better way in attracting student's attention and has different method in learning process. There are many digital games that can be obtained from internet or play store. Playing digital games not only limited in classroom but student also can play it at home as self-learning time. Below is some example of existing science games for kids. There are no existing games for Science Standard 1 from Malaysia. Hence, the example below shows the Science Games for Grade 1 from abroad schools which are (1) Science Game for Kids, (2) First Grade Learning Game and (3) Hermione 1st Grade Science Learning Education Game. Below is the table that describes the comparison of the existing games.

**Table 1**. Comparison of existing applications.

|  | Science Game for Kids | First Grade Learning Game | Hermione 1st Grade Science Learning Education Game |
|---|---|---|---|
| Operating System | Android, iOS | Android, iOS | iOS |
| Rating | 3.0 | 4.8 | 1.0 |
| Price | Free, additional fee to unlock other games | Free, additional fee to unlock other games | Fee required |
| Curicculum Based | Curriculum from worldwide syllabus | Curriculum from worldwide syllabus, includes another subject | Next Generation Science Standard (NGSS) Curriculum |
| View Based | 2D | 2D | 2D |
| Features | -colourful image<br>-attractive graphic<br>-sound, music | -colourful image<br>-attractive graphic<br>-animation<br>-sound, music | -colourful image<br>-animation<br>-sound, music |

## 3.  Methodology
This section explains the methodology used in this paper. Methodology is essentially a systematic procedures and act as a guide to ensure the development process is on the right track. There are four phases includes in the methodology to develop this research.

*3.1  Phase 1 Preliminary investigation of the requirements for educational game*
In this phase, the studies on Science subject for Standard 1 was conducted for the assigned topics. The studies were made to ensure the information is right based on the syllabus. Next, a research was made to investigate the effectiveness of the learning method through the game and the elements required to enhance the game appearance. The interview was conducted with the teachers from primary school and preschool to collect related information and idea for Science educational game development.

They had given their opinion about the application of game in learning method. Both interviewees are strongly agreed with the statement because the method can make the students more understand about what they had learned. Madam Noridayati had thought that the game can enlighten the learning environment and easy to stimulate the students thinking. Due to that, Madam Saodah shared that she had applied various physical game such as playing teng teng while counting. The students had given great response since they had enjoyable moments while learning with their friends. In addition, the teachers also agreed that the digital educational game can be a part of learning method. Madam Saodah shared that the digital game can attracts more attention of the student. Meanwhile, Madam Noridayati stated that students nowadays are more attracted to the gadget. Hence, the game can be one of the platforms for them to enhance their knowledge from what they had learned at the school.

*3.2  Phase 2: Science Education Game Design*
The game was designed based on the ideas and the requirements obtain from the previous phase. The game concept and game elements were designed to match with the suitability of the educational game.

To create a playable game, the game mechanism was designed based on the suitability for the target user. The game has three categories which represents the subtopics of the chosen topic which is living thing and non-living thing. The educational content of the game is based on the KSSR curriculum as discussed previously.

*3.3   Phase 3: Science Education Game Design*
They had given their opinion about the application of game in learning method. Both interviewees are strongly agreed with the statement because the method can make the students more understand about what they had learned. Madam Noridayati had thought that the game can enlighten the learning environment and easy to stimulate the students thinking. Due to that, Madam Saodah shared that she had applied various physical game such as playing teng teng while counting. The students had given great response since they had enjoyable moments while learning with their friends. In addition, the teachers also agreed that the digital educational game can be a part of learning method. Madam Saodah shared that the digital game can attracts more attention of the student. Meanwhile, Madam Noridayati stated that students nowadays are more attracted to the gadget. Hence, the game can be one of the platforms for them to enhance their knowledge from what they had learned at the school.

*3.3   Phase 4: Development*
To develop this project prototype, a suitable game engine was selected as it provides many functions and tools to create the Science educational game. Unity provides a tool to develop the games and interactive designs or experiences in 2D or 3D. For this game, the project was built on Windows PC platform so the players can play the game through their PC. To make the game functional, there are several game mechanics used in this game such as drag and drop, randomization, move player, timer, and scoring.

*3.4   Phase 5: User Acceptance and Usability Testing*
Usability Testing is a useful testing methodology to test and evaluate the usability aspects of an application. It is vital in improving the quality of user experience as usability testing emphasizes aspects such as ease of use, efficiency, and satisfaction, based on the research done by [15].

## 4.  Implementation
This section explains the implementation of this paper based on the methodology of this paper.

*4.1   Game Concept*
The concept of the Science educational game for Standard 1 is to develop a 2D game based on the Science subject for the subtopic in Chapter 3; 'Living Things and Non-Living Things'. The game is a computer-based game which has three mini games indicates the subtopics. The first subtopic named living-things and non-living things. Next subtopic is the characteristics and basic need of living things and the last subtopic is small and big. Players are freely to choose which game that they want to play. The target audience of this educational mobile game is student in Standard 1.

*4.2   Game Mechanics Design*
In this game, there are three categories of game according to the subtopics of the Science subject. Each game has three levels and the difficulty is increase by the level. The player needs to follow the instruction given before they can start playing the game. In the first game, players are forwarded to the next level once they succeed with current level. Players are able to gain the award or feedback once the game is done. The total marks of the players were displayed too once the game is over.

    The same thing goes to the second game and the third game. Each game has three level and the players proceed to the next level when the current level is done. In the second game, players must collect the basic need items as much as they can to get the highest marks. Each collected item contributes to 10 marks. The players must control the character's movement by using left and right key. The game is done when the player hits the non-basic need item. Once the game stop, the marks will be displayed, and the players can choose whether to replay the game or return to the main menu. The difficulties of the game

increases by adding the speed of the falling object, so that the player need to take the fast action to avoid the unnecessary item.

Lastly, the third game requires player to drag the objects and sort them according to the size. The boxes are provided with the number listed. However, there is a time limit to complete the task. Hence, the players need to complete the task within the time given. As the level increases, the time limit is also getting shorter to increase the difficulty. The time taken will be recorded once the player succeeds the task and the players also can replay the game if they are failed to do so. The concept of the Science educational game for Standard 1 is to develop.

*4.4   Game Level*

Each mini game has different type of difficulties. For example, in the first game, the players need to drag the objects based on category of living things and non-living things. As the level increases, the objects are varied and changed. Next, in the second game, the players need to collect the basic need item that are falling randomly. They must avoid the non-basic need item to stay survive. When the level increase, the time duration between the two objects to fall are short, so the player needs to response quickly as the falling objects are increased. Lastly, for the third game, players need to succeed the task within the time given. As the level increases, the limit time given is shorter. Hence, players need to be quick in order to proceed to the next level.

**5.   Graphical User Interface**

A properly designed Graphical User Interface (GUI) of the game enable the player to start the game easily.

Start page has two buttons to start the game or to quit the game. Main page has four buttons, while Login page allows user to enter their name. After the user logins to the game, it has three options. When user picks Information button on the Main page it will give the information on how to play the game and user also allowed to get into game setting. The game is able to on or off the audio. While the Dialogue System appears to check whether the user has learnt from the game especially about Chapter 3; 'Living Things and Non-Living Things'. There are three stages the user needs to complete. Figure 1 (a) shows the scoring board and Figure 1 (b) shows the Panel Note. It was for the user to do reading.



(a)                                                            (b)

**Figure 1.** (a) Scoring board (b) Panel Note

A list of interfaces include in this project are listed in Table 2 below.

**Table 2.** User Interfaces with Game Elements.



The implementation of code in game development is important to build the logic of the game. There were several classes implemented to ensure the game was functioning well. The game mechanics used are explained below.

*5.1   Drag and Drop Interaction*

Each mini game has different type of difficulties. For example, in the first game, the players need to drag the objects based on category of living things and non-living things. As the level increases, the objects are varied and changed. Next, in the second game, the players need to collect the basic need item The handler used was IPointerDownHandler, IBeginDragHandler, IEndDragHandler and IDragHandler. To detect the mouse clicks until it was released, the method used was OnPointerDown. The function applied when the mouse clicked on the object. Next, IBeginDragHandler and IEndDragHandler were used to detect when the objects are started to be dragged. When the player starts dragging the object, the OnBeginDrag method called to unblock the ray cast on the canvas. Otherwise, the ray cast is blocked once the player ended the drag using OnEndDrag method. Then, OnDrag function was called to enable the dragging objects move around the canvas. Meanwhile, in Drop class, the handler used was IDropHandler. The method called was OnDrop.

*5.2   Randomize and Timer*

In creating the questions for the game, it must generate randomly every time the player starts the game. In the first and the third game, the objects had been created to spawned randomly by switching its place or object. In second game, the objects are spawned randomly and falling within the assigned duration. Each object assigned with box collider and rigid body components. Box collider used to detect the hit between the object and rigid body used to apply the mass on the object.

In Kecil & Besar game, timer was applied to every level. Player has to complete the task within the required time. The game is over once the timer stopped. The timer applied in Update function to enable the timer decrease whenever the frame looped. Time.deltaTime was added to round the time per second. The time required was declared first according to the level. Timestart variable hold the timer required in the gameplay.

*5.3   Movement and Scoring*

Moving the player provided in the second game which is Ciri-ciri & Keperluan Asas Benda Hidup game. The inspector of the player was applied with Rigidbody 2D which enable the character to move horizontally in XY plane rotate on perpendicular axis. Vector2 was used to represents velocity of the object. The input received only required horizontal movement which is left and right.

Each correct answer was rewarded with 10 points. The score triggered when the objects were collided with the same tags. In first game, the dragged objects and dropped objects were declared based on the living things and non-living things categories. Meanwhile, in second game, the character was tagged with "need" to allow the scoring added when it is collided with the basic need objects

## 6.   Evaluation and Results

*6.1   User Acceptance Testing*

The test was done as to determine whether the application can be accepted or not. The evaluation was done using Blackbox method. The feedback of the result was compared between the expected outcome and actual outcome. The testing was performed on the 10 respondents from age range between 7 to 10 years old. The respondents were selected randomly from the nearest community. The flexibility in selecting respondents from different age ranges was due to the COVID-19 pandemic which limiting the testing process. There are 3 target users aged between 10-12 years old and 10 non-target users aged between 23-30 years old are involved in user acceptance testing and usability testing. The table below shows the result of Beta testing using Blackbox method.

Table 4 shows the result of Beta testing by using Blackbox method. From the result, the events done by the respondents were mostly were successfully functioning. All the buttons that available in the game were work well and can be switched to the assigned scenes. The respondents also can view the score after they had done playing the game. The game mechanics such as drag drop and player movement are functioning well instead of a bit problem about the inertia of the character's movement. However, there were some problem in score when the respondents played the game. The score sometimes may be correct, and it can be negative value when the respondents were wrong at the beginning of the game.

The error might be from the mistakes in code itself. But overall, the test give positive feedback from the respondents as the flow of the game is works well and working as expected.

**Table 4.** User Interfaces with Game Elements.

| Event | Expected Outcome | Actual Outcome |
|---|---|---|
| The users click on the setting menu | The setting menu is displayed | Can easily displayed setting menu |
| The users enter the dialogue menu | The dialogue menu displayed with button to proceed the dialogue | The dialogues are run smoothly and easily to proceed |
| The users click on the home button | The home interface displayed | Can easily displayed home menu |
| The players win or lose the game | The feedback panel displayed with score, home button and restart button | The feedback panel displayed with home button, restart button but the score sometimes displayed wrongly |
| The score added and deducted | The score added and deducted correctly | The score added correctly but deducting can be negative value |
| The users click on the audio button for mute/unmute | The audio is mute / unmute | The audio mute and unmute only works in home scene. |
| The users click on the pause button | The pause panel displayed with home button and resume button | The pause panel displayed with home button and resume button |
| The users click the items to drag and drop | The drag and drop activities are functioning | Can easily drag and drop the items |
| The users click on left and right keys to move the character | The character can move left and right | Can easily moves the character but the inertia is little bit over. |

### 6.2  Usability Testing

Usability testing was done as to get the feedback from the respondents about their experience and satisfaction. The questionnaire contains two sections to be answered which are the first section required the information about the respondent and the second section provides post-test related questions. The post-test related questions are categorized into several factors such as efficiency, satisfaction, and learnability.

The first section in the questionnaire was asked about respondent's information such as gender and age. Besides, the experience in learning the topic and the experience in playing digital game using PC also had been asked. The test done on 10 respondents which consists of 5 males and 5 females from different age range. There were 4 respondents aged 7 years' old which is in Standard 1. Meanwhile, there were 1 respondent aged 8, 3 respondents age 9 and 2 respondents age 10. The respondents were selected in different age range due to the limitation during Restrictions Movement Order (RMO). Most of the respondents had learned the selected topic during Standard 1 and familiar with it. In the other hand, 6 respondents stated that they have no experience in playing digital game using PC while 4 respondents had experienced it.

From the results of non-target users as shown in Figure 2, most of the non-target strongly agreed that this game prototype was satisfying to use as 60% of non-target users choose "Strongly Agree" and 40% of non-target users choose "Agree" for the question related to the satisfaction. The non-target users felt satisfied to use the game prototype to learn English words. For the memorability of the game prototype,

most of the non-target users able to understand the function of interface elements such as buttons and input controls as well as gameplay of mission at each level of the educational mobile game prototype.
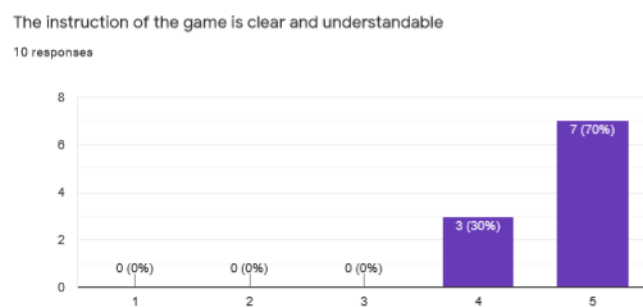
*(a)   Efficiency component*

There are three questions asked to determine the effectiveness of the game flow when the respondents play the game. It is also determined their understanding about the system.
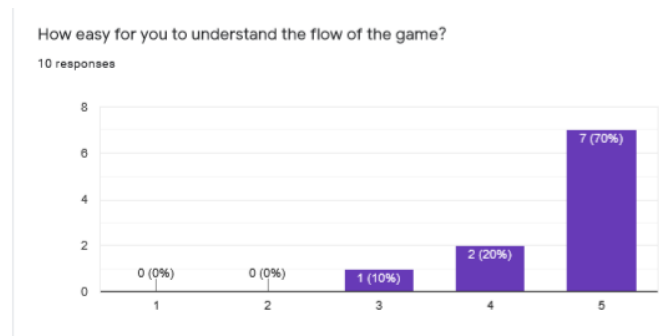


(a)
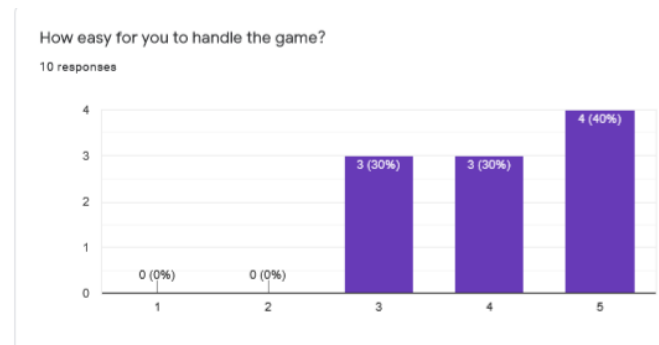


(b)



(c)

**Figure 2.** Efficiency elements

 The result from the tests above shows different outcomes based on the respondent's understanding about the game flow. Figure 2 (a) illustrates the bar chart result of the respondent's understanding on the game flow from the scale 'very hard' to 'very easy'. There was 70% of respondents scaled that the game flow was easy to understand. However, one respondent scaled neutral because the lack of skill in playing game. Figure 2 (b) illustrates the graph about the respondent's skill in handling the game. The scale from 'very easy' to 'neutral' were chosen averagely because most of the respondents never experienced in playing the game using PC. Most of them were good in control the game but not efficiently as expected. Figure 2 (c) shows the result of how the respondent's feedback on the game instruction. 70%

of them were strongly agreed that the instruction was clear and understandable, and the rest was agreed with the statement.

*(b)   Satisfaction component*
There were two questions asked about the respondent's feedback on the game design including game theme, fonts, colors, and interfaces together with sound effect and music background.
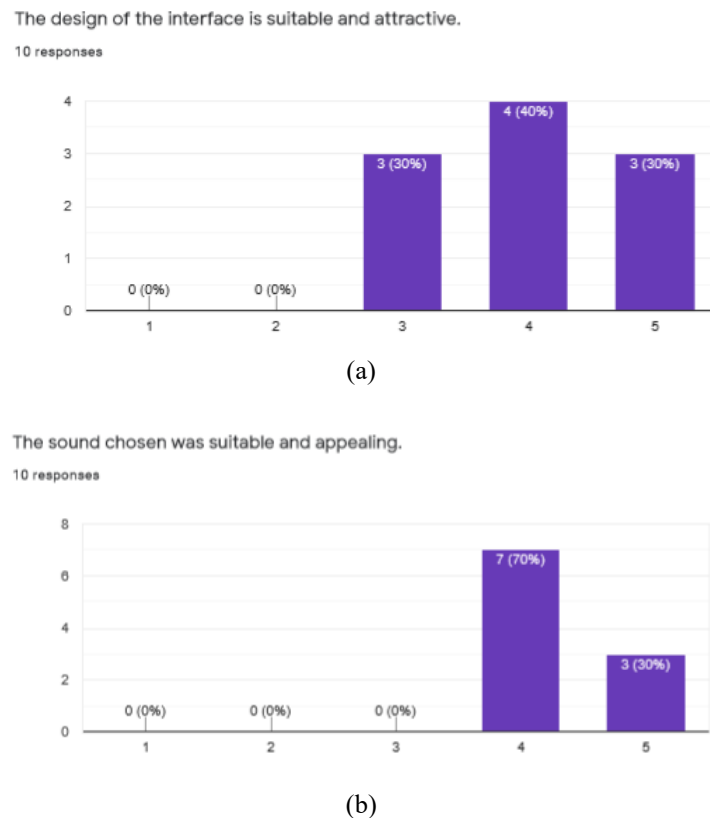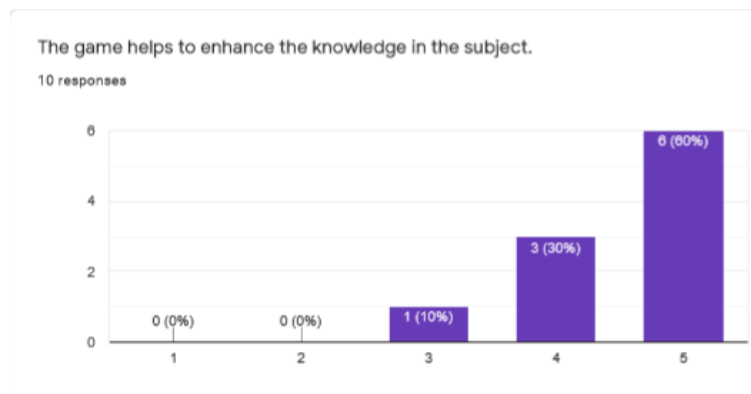
The design of the interface is suitable and attractive.

10 responses



(a)

The sound chosen was suitable and appealing.

10 responses



(b)

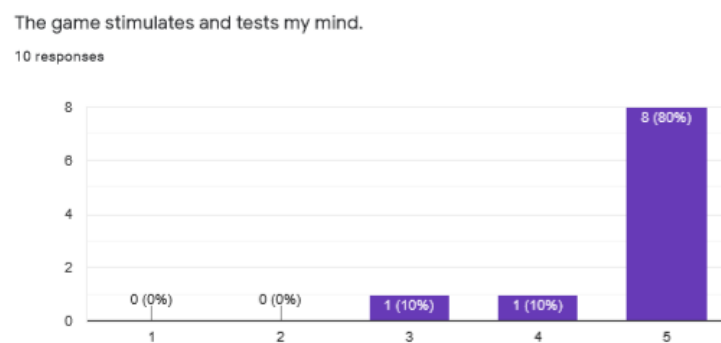**Figure 3.** Game design factor questionnaire

Figure 3 (a) illustrates the graph of the feedback of the respondents regarding to the design of the game application. From the figure, most of them agree that the design of the interface was suitable and attractive. Meanwhile, the number of respondents that chose 'strongly agree' and 'neutral' was equal which is 30%. The suitability of the design was considered based on the age of the user and the type of the game which was educational game. In the other hand, Figure 3 (b) demonstrates the result of the feedback for the audio used in the game. The audio includes sound effect and music background. From the result, 3 respondents were strongly agreed that the sound was suitable and appealing. Meanwhile, the rest of the respondents were agreed to the statements. Overall, the audio used in the game was attractive and suitable according to the content of the game.
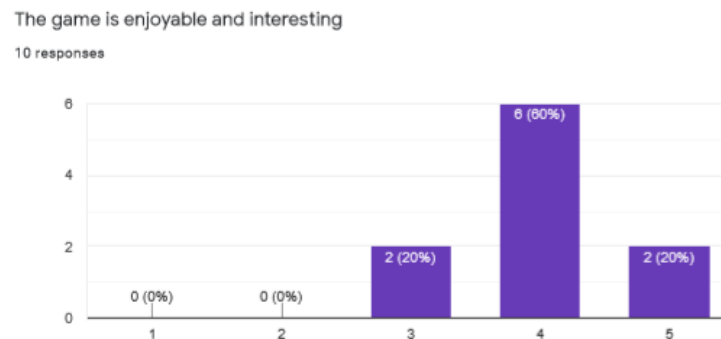
*(c)   Learnability component*
There are three questions asked about the respondent's feedback on the game effect on them while playing the game. The effects include the respondent's reaction and respondent's knowledge.

The game helps to enhance the knowledge in the subject.

10 responses



(a)

The game stimulates and tests my mind.

10 responses



(b)

The game is enjoyable and interesting

10 responses



(c)

**Figure 4.** Game effect factor questionnaire

The figures above illustrate the results of the testing for the learnability on the respondents in terms of respondent's reaction and knowledge. Figure 4 (a) asked about the opinion of the respondent regarding to the statement as stated. 6 respondents were strongly agreed that the game helped them to enhance their knowledge on that topic. 3 of them were agreed and 1 respondent just feel neutral. This is due to the age of the respondent that was already 3 years older than the target respondent (7 years old).

Next, Figure 4 (b) asked the respondent's opinion about the game that can stimulates and tests their mind. From the result, it can be said that most of the respondents were strongly agreed that the game had stimulated and tested their mind. Meanwhile, 1 respondent was respectively agreed and feel neutral to the statement. That effect on the respondents was because of they must think how to strive the missions in the game. They had to revise what had they learned in the class while playing the mission in the game. The last question asked to the respondents is whether the game was enjoyable and interesting. 60% of the respondents agreed to the statement that the game was enjoyable and interesting

while 20% respondent respectively agreed and feel neutral to the statement. Overall, the respondent's feedback is good, and they had felt satisfied playing this game

## Acknowledgments

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