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Design and Development of Augmented Reality (AR) Solar System Learning Application

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Abstract: Using conventional learning materials to learn Solar System topics in Year 4 primary school is less interactive on concept learning, and required consistent focus, motivation and imagination. Hence, the project aims to design and develop a Solar System mobile learning application named Solar System World by using Augmented Reality (AR) as a medium and to test for bugs, discrepancies of the proposed application, and feedback from Year 4 primary school students. The proposed application is designed for the AR solar system learning application with an interactive AR module, mini quiz (2D), and mini learning game (2D) module to increase the interaction and motivation with the students. The development of augmented reality (AR) solar system application is based on the Multimedia Mobile Content Development (MMCD) methodology, which consists of 5-stage procedures, which is application idea creation, structure analysis, process design, main function development, and testing stage. Based on user testing results, 83.8% of the respondents left positive feedback on the proposed Solar System World. Development with additional languages, increased quiz module difficulty and a reward system and health-improving mechanism for the game module are some of the future works of this AR-based application.

Keywords: Augmented Reality, Solar System, Marker-Based

1. Introduction

The solar system is one of the sub-topics in science that is being taught to Year 4 primary school students in Malaysia. However, learning about the solar system in Year 4 of primary schools is less interesting because the information and description on the topic are only theoretical and usually presented in 2D images, through textbooks, videos, and/or physical models of the solar system [1]. However, this traditional method is limited in delivering the visualization complexity of this topic to students [2]. This is because the traditional learning method always involves more rigid hardware equipment or tools that limit the visualization, interaction, and motivation while learning [3]. All tools as mentioned above (textbooks, 2D figures or images, and videos) lack interactivity and only assist students in learning the foundation concept about the solar system. By applying AR, students may have a different immersion and experience when learning about this topic.

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If the method of learning and teaching is less interactive, student's attention would be drifted when being taught with a stream of dry concepts and figures [4]. Most of the recent studies reported that AR applications lead to better learning performance (53.3%) in educational settings, increase learning motivation (28.1%) and improve student engagement (15.6%) [5]. These results demonstrate that AR is a promising technology in improving the student's learning performance and may induce motivation levels in the students [5]. Additionally, according to Mohamad Bilal Ali and his team's research in 2015, on average, a regular student can only remember about 30% of what they hear and around 20% of what they observe [6].

With the inspiration to bridging the gap between the virtual and the real world, Augmented Reality (AR) may provide a new paradigm in teaching and learning [7]. AR is a technology that allows for added sensations, visibility, and information, generated by a computer to the normally perceived reality [8]. On special visors worn by the individual, images, writings, and virtual objects could be reproduced, thus providing additional information on the real environment. Applying AR in learning, particularly for the topic of the solar system, students are expected to have immense experience in visualization and therefore may help them understand this topic better.

Hence, to overcome this, an Augmented Reality (AR) Solar System learning application is proposed. The project aims to design and develop a Solar System mobile learning application with the Android platform by using Augmented Reality (AR) and test the developed augmented reality (AR) system to Subject Matter Experts (SME) and target users. The SME of this project is Year 4 primary school science teacher named Ms Nur Fareha Binti Husin and the target users are Year 4 primary school students in Batu Pahat.

All the essential information about the solar system is designed and displayed, together with audio synchronization to let students be immersed in this 3D virtual experience. This application is designed in dual languages, which are Malay and English, to especially cater to Year 4 primary school students in Malaysia. Few sets of 2D quiz and mini-games are developed as part of the learning module of this application. The proposed application is expected to have a planet's information broadcasting function in dual languages in the AR module, over 15 questions of question sets and answer feedbacks in the quiz module, and a mini-game module with a move up or down control system to avoid collision to the obstacles to get a higher mark.

2. Related Work

2.1 Solar system topic in Year 4 primary school

The solar system is a topic in chapter nine under the theme of "Earth and Space Science". Based on the Year 4 Science and Technology World textbook, there are a few sections under this topic such as rotation and revolution of the earth, direction and duration of rotation and revolution of the earth, and effects of the rotation of the earth on its axis. At the end of this session, students should be able to describe the components in the solar system (sun, planets, natural satellites, asteroids, meteoroids, and comets [9].

In addition, there are two experiments and one simulation model activity under this topic. The first experiment activity is aimed to investigate the effects of the rotation of the earth on its axis. Students should be able to define planets based on their axis and how they are orbiting the sun and later on build a model of the solar system based on their comprehension [9]. The second experiment is aimed to learn about the direction and duration of rotation and revolution of the earth. The student is required to prepare some materials such as a paper plate, plastic plate, 5 cm-pencil, marker pen, ruler, and adhesive tape to experiment. A procedure is provided to guide the experiment. Last but not least, the student is required to produce a simulation model of the earth using a used box, nuts and bolts, two polystyrene balls in different sizes, and adhesive tape. The model is produced based on the given steps.

By the way, the learning methods under this topic which is solar system has required the materials and tools to make student better understanding how solar system works. So, by applying AR to this topic, it will more focus on interactivity using an image, animation, sound, and interaction mechanism, to make the concept easier to comprehend [10]. So, students can better understand the operation of the solar system without using tools or props and have a better visual and learning experience. Lastly, based on the subject of Science Year 4, the subtopic of the solar system is more to the description of the elements and components contained in space. Thus, the use of digital (AR) should have a positive effect on the learning environment [11].

2.2 AR Marker-Based Technology

Marker-based AR allows an augmentation to be triggered by a marker [12]. In the real world, such markers can be paper-based or physical objects that exist. Markers are images that can be seen by a camera and are used to place virtual items in a scene using the software. Typical types of markers include all print media that can be read by the camera, such as logos, pictures, banners, or clear images. However, the software imposes restrictions on the kind of augmented reality markers that can be utilized, where particular algorithms are needed to extract features from the marker. They can encompass a vast range of distinct images while being very straightforward for error correction. Black and white representations of two-dimensional (2D) barcodes are the most basic sorts of augmented reality markers. Refer to Figure 1 below.

Figure 1: A simple marker [12]

2.3 Comparison of existing applications

Three existing applications are described in this section, with techniques that include marker less detection technique, marker-based detection technique, and non-augmented reality element. These applications are SolarSystem AR+, AR Solar System, and Kids Solar System - Children's learn planets. Table 1 shows the comparison between existing applications.

(a) (b) (c)

Figure 2: (a) SolarSystem AR+ (b) AR Solar System (a markerless-based application) (c) Kids Solar System - Children's learn planets (a non-AR application)

The proposed application (Solar System World) proposed three types of modules, which are the AR module, learning module, and game module. To improve the entire experience, features such as background music, sound effects, and narration is provided, together with appropriate instructions at the beginning of each module. The AR marker is provided via a link to cloud storage. The application is designed with a fitting font type that is suitable for primary school students (target users) with the type of lowercase 'a' will get the ball-stick type [13] design as well.

Table 1: Comparison between existing applications

Element	*SolarSystem AR+*	*AR Solar System*	*Kids Solar System - Children's learn planets*	*Solar System World,* proposed application.
Types of Augmented Reality	Marker-based.	Marker less-based.	Non-AR (2D).	AR Marker-based & 2D.
Weaknesses	- Inconsistent design. - Instruction is insufficient. - No exit pop-up. - No Application's name or logo. - Only cover solar system planets.	- No main interface - No exit pop up - Instruction is insufficient. - Not stable when calibrating.	- Not all are free to use. - Instruction is insufficient. - No exit pop-up. - When the user selected the sun under the Japanese language mode, but the system will read out but display the wrong planet name with the description which is "水星" (Mercury) but not "太陽" (sun).	- Only cover 3 constructs (AR solar system, mini quiz, mini-game).
Strengths	- Free to use. - Provide detailed planet information.	- Free to use. - With interactive function.	- Consistent button. - Pleasing audio. - Suitable font.	- Free to use - Consistent button - Instruction is sufficient. - Pleasing audio. - Suitable font. - Broadcasting planet's audio information is included.

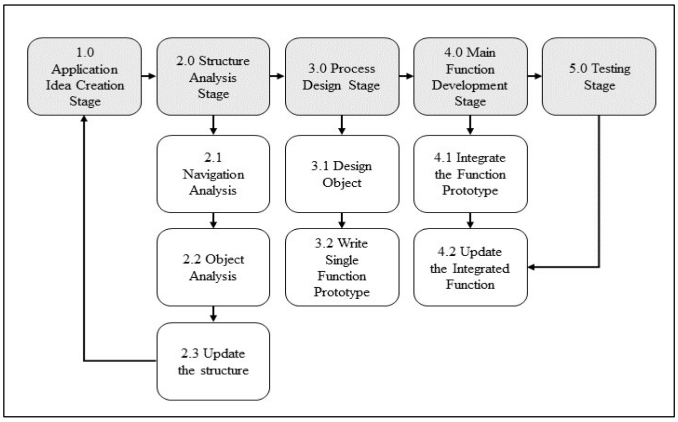


Figure 3: Multimedia Mobile Content Development (MMCD) [10]

3. Methodology

In this section, the methodology used in developing Solar System World, an educational AR-based solar system learning application is discussed. The methodology model for this project's development process has been chosen as Multimedia Mobile Content Development (MMCD) and mainly for the model's rapid stages within a short duration of the establishment. Figure 3 shows the stage of Multimedia Mobile Content Development (MMCD) [14].

3.1 Application Idea Creation Stage

The application idea creation stage is the first stage of the MMCD methodology. Two activities are implemented in this stage, which is the analysis stage mainly to identify user requirements and also application requirements. Table 2 shows the list of application idea creation stages and Table 3 shows the user analysis of Subject Matter Expertise and target users.

Table 2: Application Idea Creation Check List

Item	Description
Application type	• Mobile
Target user	• Year 4 primary school students
Target device	• Smart Phone (Android)
Unity2019	• Version: 2019.4.12f • Resolution: Free aspect
Adobe Illustrator CC 2020	• Design 2D background and 2D object in quiz and mini-game, buttons and AR marker
Adobe Photoshop CC 2020	• Design game graphic assets
Adobe Audition CC 2020	• Create and edit audio
User Interface	• Background (main page, sub, page)
Pictures	• 2D images (homepage, info page)
Application Synopsis	• Solar System World is an AR-based mobile learning application for Year 4 primary school students in Malaysia. This application serves as a supportive learning material for science subjects. It uses multimedia elements in the teaching and learning process. The application is designed with an interactive AR module, mini quiz (2D), and mini-game (2D) module to enhance the interaction and motivation about this topic to the students.

Table 3: User Analysis

Stakeholder Category	Role in product	Design implications	Actions Needed
Subject Matter Expertise (Year 4 primary school science teacher)	Content consultant expert in the related field.	Based on the interview, Simple user interface design	• Instead of text, an icon-based button shall be used. • The same theme font which is Berlin Sans FB is used in the whole application and the size will be bigger than 50pt. • All the button shapes are circle shapes and consistent sizes.

Table 3: User Analysis

Stakeholder Category	Role in product	Design implications	Actions Needed
		Easy to learn.	• The back button shall bring the user back to the previous page while the setting page shall lead the user to the setting page. • Clear instructions are given, narrator and textual. • The calibration site is provided to let the user easily calibrate the marker. • A marker with text instructions is provided through the drive link. • Two languages which are English and Malay are provided to the user.
		Reliable content, simple word choice, better with one syllabus word.	• Different planet model sizes should easily be distinguishable. • The colour selections of the solar system are altered to a slightly vivid colour mode but there are no colour selection errors. • Provided correct information on the solar system. • The sentence structure is simple and easy to understand.
General User (Year 4 primary school students)	End-user of the system	Based on the questionnaire, Can be used anytime, anywhere with user preferences.	• It shall be accessed in the school computer laboratory or classroom, and on the parent's mobile phone. • The application is developed in offline mode which allows user use at anytime and anyplace. • The application shall develop on a mobile device.

3.2 Structure Analysis Stage

The second stage of the MMCD methodology is Structure Analysis. In this stage, two components are analysed, which are navigation analysis and object analysis. As mentioned in Section 3.2, navigation and objects are the two key characteristics of a well-structured MMCD. If these two components are not properly analysed, it might cause problems at a later design stage and even affecting the rest of the development process. Figure 4 shows the navigation structure of Solar System World and Table 4 shows the object checklist of content structure.

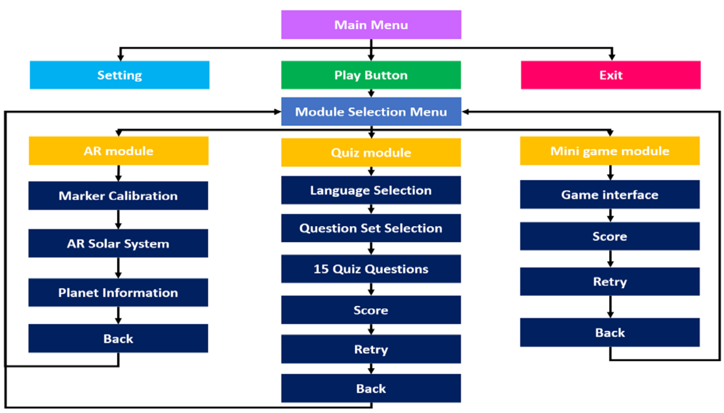


Figure 4: Navigation structure of Solar System World

Table 4: Object checklist of content structure

Item	Description
Number of main GUI (Graphical User Interface)	• Application logo
2D Graphic	• Static image information, button icon
3D Graphic	• Solar system, planets
Audio	• Background music (mp3) in the home page, AR module, quiz module, and mini-game module. • Sound effect of planet's information, quiz correct and wrong answer feedback, mini-game move and collision.
Writing	• Berlin Sans FB • The selection of text font is intending to attract the attention and interest of the target user.
Colour	• Colour selections of the solar system are altered to a slightly vivid colour mode compared to its originally natural colour.
Animation	• Revolving planets around the sun, planetary rotation, and revolution, animation of rocket flying (within a mini-game).

3.3 Process Design Stage

Preparing all the items listed in Table 2 (the content structure checklist) is the main goal of the process design stage. The design process would include two sub-components, which are object modelling and prototype scripting. Some tools such as Adobe Photoshop, Illustrator, Audition, and Unity are being used to develop certain objects in this stage. Hence, flow chart (main flow chart), button design, audio, object modelling and single function prototype of the Solar System World is discussed in this section.

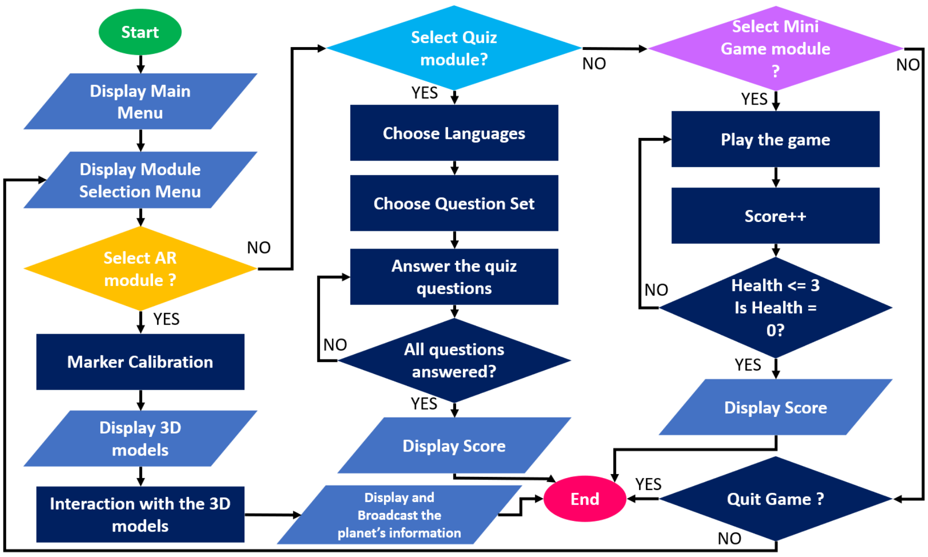
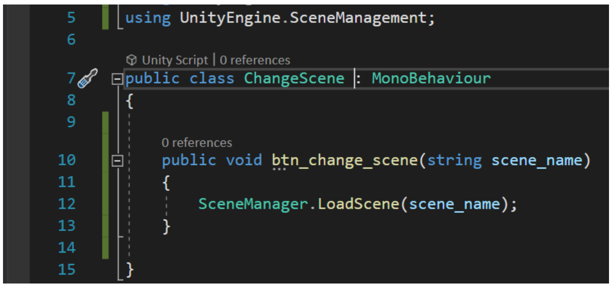


Figure 5: Main Flow Chart of Solar System World

Based on the flowchart shown in Figure 5, the Solar System World application is a 3 in 1 learning application that has 3 modules. There are AR modules, quiz modules, and mini-quiz modules in this application and each module have a different structure and will have its process.

Table 5: Button design

Button	Function Description	Button	Function Description
	This is the AR module button.		This is the exit button.
	This is the quiz module button.		This is the reset button for quiz, mini-game, and highest score.
	This is the mini-game button.		This is the home button for navigating to the module selection menu.
	This is the play button to start the application.		This is the next page button.
	This is the setting button.		This info button is to show instructions and credits.
	This is the back button.		This is the close button.



```
5   using UnityEngine.SceneManagement;
6
    Unity Script | 0 references
7   public class ChangeScene : MonoBehaviour
8   {
9
        0 references
10      public void btn_change_scene(string scene_name)
11      {
12          SceneManager.LoadScene(scene_name);
13      }
14
15  }
```

Figure 6: Single function prototype of Solar System World

The changing scene is a significant function in Solar System World to change the scene between modules. Based on Figure 6, in line 4 and line 5 of the code snippet, there is one library that needs to be added for writing a single function prototype, which is `UnityEngine.SceneManagement`. This library handles the object `SceneManeger` in line 12, where it involves the behaviour of `LoadScene` with a parameter named `scene_name`.

3.4 Main Function Development Stage

The implementation of application development is discussed in this section. There are two major stages which are application assets development and integration in Unity with scripting in this section to make the application functioning with the game assets as well. Table 6 shows the application assets development in Solar System World.

Table 6: Application Assets Development

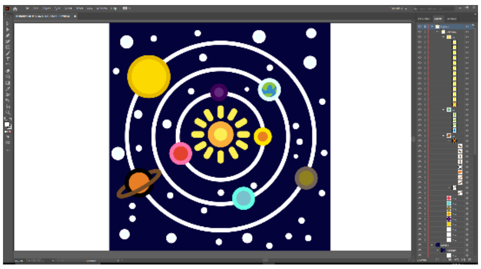
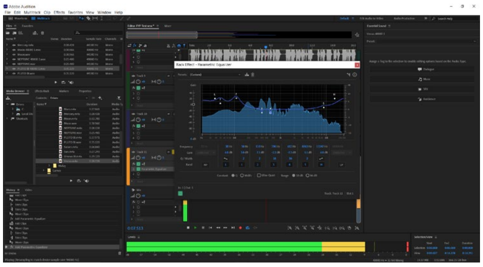
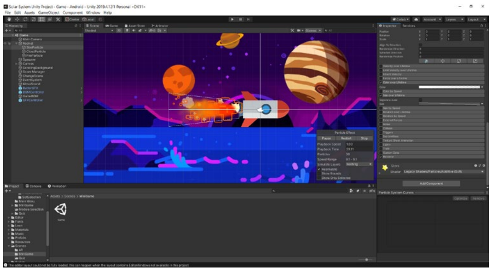
Assets	Development	Description
AR Marker		The AR marker is designed by using Adobe Illustrator with a simple shape and colours. Planets and stars and orbits are designed consistently with the circle shape. Different colours are applied to the planets to make the marker looks more attractive, and increase the number of stars is helped to increase the detail of the AR marker to enhance the AR stability while the user is scanning and displaying the AR object on the marker.

Table 6: (continued)

<table>
<tr><th>Assets</th><th>Development</th><th>Description</th></tr>
<tr><td>3D Models (Planets)</td><td>
</td><td>The Solar System models are created by using Unity 3D with the 3D sphere object provided in Unity. Next, texturing is very important to the planets, it makes the planets look more realistic. Before the texture is applied, the material is required to create and assign with texture.</td></tr>
<tr><td>Background Music and Sound Effects</td><td></td><td>The audio clips were recorded using mobile phone broadcast by the apps called “Bahasa Voice to Text”, and then being transferred into the computer for editing purposes. The recording time of each audio clip is between 25 seconds to 35 seconds. To make the audio clips sound more nicely, the editing also includes noise removal, adjusting to a higher pitch, and amplifying the amplitude by using Adobe Audition.</td></tr>
<tr><td>Special Effects</td><td></td><td>The smoke sprites, and stars sprite, and flame particle effect make the rocket-like fly in space. Since the 3 particle effects are applied as the child of the rocket game object, thus the particle effects will move its position with the parent position as the rocket game object.</td></tr>
</table>

Some important functions are used in the integration with scripting development of Solar System World modules. Such functions of change language, update quiz score, and health reduction and game over is described in Table 7.

Table 7: Integration in Unity with Scripting

<table>
<tr><th>Functions</th><th>Scripts</th><th>Description</th></tr>
<tr><td>Change Language (AR)</td><td>

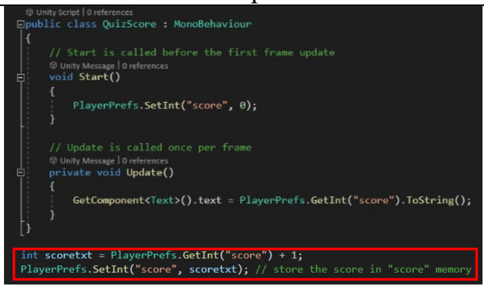
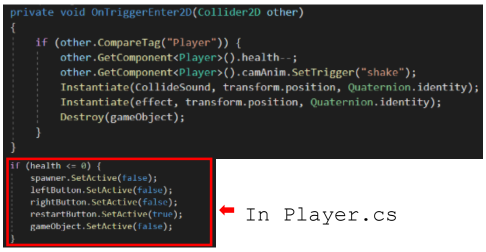
```
public void SetEnglish()
{
    for (int i = 0; i < 11; i++)
    {
        PlanetLabel[i].text = Input[i].EngPlanetName;
        DescriptionLabel[i].text = Input[i].EngPlanetName;
        Description[i].text = Input[i].EngPlanetDescription;

        EngMusicBtn[i].SetActive(true);
        MalayMusicBtn[i].SetActive(false);
    }
}
0 references
public void SetMalay()
{
    for (int i = 0; i < 11; i++)
    {
        PlanetLabel[i].text = Input[i].MalayPlanetName;
        DescriptionLabel[i].text = Input[i].MalayPlanetName;
        Description[i].text = Input[i].MalayPlanetDescription;

        EngMusicBtn[i].SetActive(false);
        MalayMusicBtn[i].SetActive(true);
    }
}
```

</td><td>A script called <code>ChangeLanguage.cs</code> is created for this function. A few public game object array variables are declared in this script to run the function such as <code>PlanetLabels</code>, <code>DescriptionLabel</code>, <code>Description</code>, <code>EngMusicBtn</code>, and <code>MalayMusicBtn</code>. Next, since there are two languages is applied in Solar System World, thus there are two functions named <code>SetEnglish()</code> and <code>SetMalay()</code> in this script and with a for-loop function inside of it to loop every assigned UI when the <code>SetEnglish</code> or <code>SetMalay</code> functions is being called.</td></tr>
</table>

Table 7: (continued)

<table>
<tr><th>Functions</th><th>Scripts</th><th>Description</th></tr>
<tr><td>Update Quiz Score (Quiz)</td><td></td><td>Once the quiz is started, a memory called `"score"` with an integer value 0 is declared. Then, the "score" value is added by 1 if the user selected the correct answer, and assigned it to `scoretxt` integer variable. Lastly, update the score to text UI with the latest memory value in string mode.</td></tr>
<tr><td>Health Reduce and Game Over (Mini-Game)</td><td></td><td>In `Obstacle.cs`, `OnTriggerEnter2D` is a special function for detecting whether the game object has collided with the other collider game object or not. In this case, the health value is reduced if a game object with the `"Player"` tag has collided and some other effects such as camera shake and collide animation, collide sound effects is implemented. Once the health variable value in `Player.cs` becomes 0, the obstacle spawner, left and right buttons and the player is disabled, then the restart button is enabled.</td></tr>
</table>

3.5 Testing Stage

In this section, the implementation of application assets and scripting integration is discussed. Alpha testing is to test and check whether the function of the Solar System World is the same as the actual result or different from it and use some effective action to correct it. In addition, beta testing is also conducted with the target user by using Technology Acceptance Model (TAM) [16], which measure user acceptance towards the application based on the constructs verified. TAM includes the survey items such as perceived usefulness, perceived ease of use, user satisfaction, and attribute of usability [17]. Table 8 shows the results of alpha testing while the results of beta testing are discussed in section 4.

Table 8: Results of alpha testing

Test	Expected Result	Actual Result	Correction Action
Play Button	Navigates to Module Selection Scene.		
AR Module Button	Navigates to AR Module Scene.		
Quiz Module Button	Navigates to Quiz Language Selection Scene.		
Mini-Game Button	Navigates to Mini-Game Scene.	Works well as expected.	Not needed.
Home Button	Navigates to Module Selection Scene.		
Setting Button	Display the Setting Panel.		
Exit Button	Display the Exit Panel.		

Reset Button	Reset the quiz and mini-game.		

Table 8: (continued)

Test	Expected Result	Actual Result	Correction Action
Back Button	It navigates to the previous scene.		
Broadcast Audio Button	Broadcast the description in audio when clicked.	Audio clips will keep playing.	Add stop playing command to close button.
Answer Option Buttons	Show the correct or wrong feedback.	While being clicked many times, the score continues to increase.	Add a cover to avoid double-clicking the answer option.
Movement Control Button	Move the player up or down.	The player game object is moved out of the screen.	Set a minimum and maximum Y-axis to the player via scripting.

4. Results and Discussion

For the beta testing, the test was conducted by involving the target users by using Technology Acceptance Model (TAM). The questionnaire items were measured by using a “yes”, “no” or “not sure” to scale the questions asked. The questions according to TAM are listed in Table 9.

Table 9: Technology Acceptance Model (TAM) for evaluating application quality

Constructs	Evaluation variables	Measured Items
Perceived of usefulness (PU)	Learning Outcome Acquisition	PU1: I can recognize the planets when playing this game. PU2: I can understand the planet's description. (AR Module) PU3: I know how to speak and read properly the planet's name. (AR Module) PU4: I get more information about planets when playing quizzes. (Quiz Module) PU5: I know what transportation takes to go to space. (Mini-Game Module)
Perceived ease of use (PEOU)	User acceptance level (Usability)	PEOU1: I think the props and models in Solar System World are beautiful and colourful. PEOU1: I enjoy playing the game as it is easy to learn.
User satisfaction (US)	Overall performance	US1: Question 1: I can see and read the instructions, descriptions and questions in the game. US2: Is everything in Solar System World working properly with no errors and does not lagging while playing?
The attribute of usability (AU)	Functionality	AU1: I can understand the use of the buttons in Solar System World.

A set of Google Form questionnaires was prepared for the target users, so the data analysis can be done easier since the data is generated by figures and charts and is more efficient without human factor error while calculating data in the analysis process. The questionnaire has 12 questions and it is divided into 4 sections which, learning outcome acquisition, user acceptance level, functionality, approximate time of playing apps. The target users are required to give feedback via the prepared questionnaire after tested the Solar System World. In addition, the user testing was also carried out with Subject Matter Expert (SME) on 30 June 2021, which is a science teacher named Ms Nur Fareha Binti Husin from SJK(C) Tongkang, Batu Pahat, Johor and the given comments was recorded. Since user testing is carried in early June of 2021 which is during the Covid-19 outbreak and the period of Movement Control Order

(MCO), so it is quite hard to get more target users to participate, but there were still 15 target users (9 male and 6 female) involved in the beta testing. The results of testing are discussed in the next section which is results and discussion.

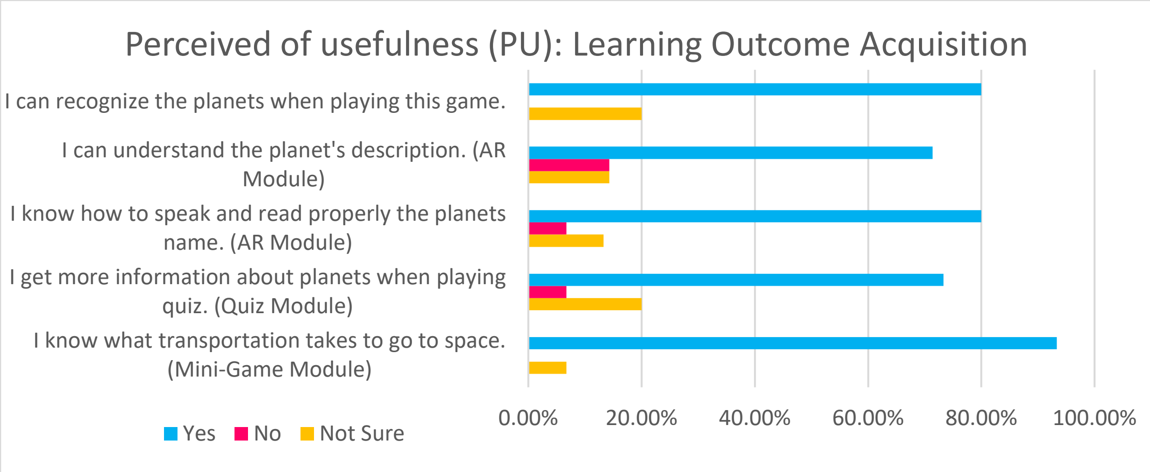


Figure 7: Analysis of learning outcome acquisition

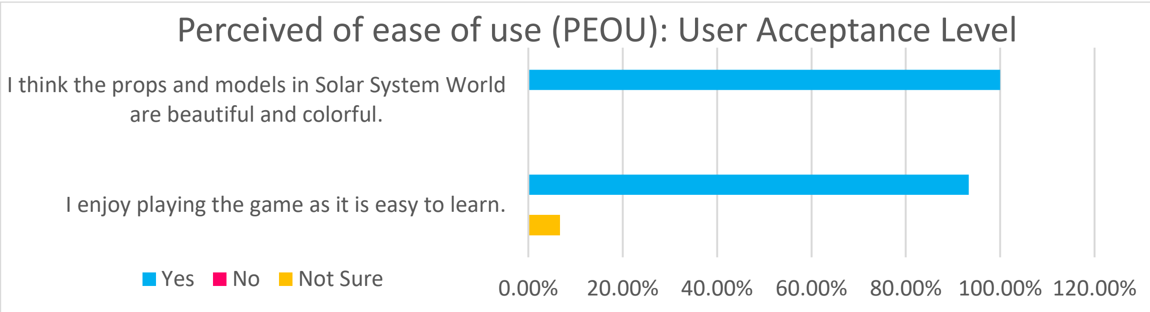


Figure 8: Analysis of user acceptance level

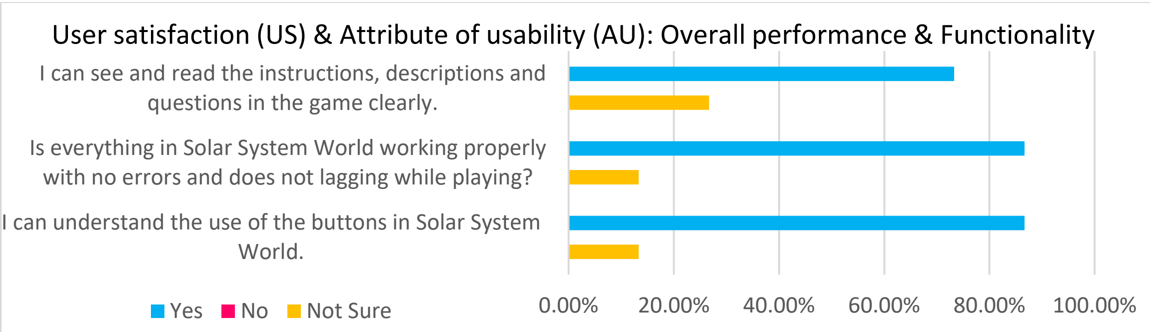


Figure 9: Analysis of overall performance and functionality

Based on the presented results in Figure 7, 8 and 9, an average of 83.38% of respondents is satisfied with the learning outcome, graphics, overall performance and functionality that provided in Solar System World. Even though Solar System World has obtained a high level of satisfaction, but few respondents gave negative feedbacks and were not sure to read, speak, and understanding the information in Solar System World. This is because read and understand the planet's description might be a challenge for their age since some professional terms may be awkward or infrequently used in their daily life. Thus, the simpler terms and learning in graphical can be the solution as the future work. Overall, the numbers of positive are much higher than negative, so it can be considered the objective of this project is achieved by applying an interactive and motivative AR learning application to the learning of the Solar System topic.

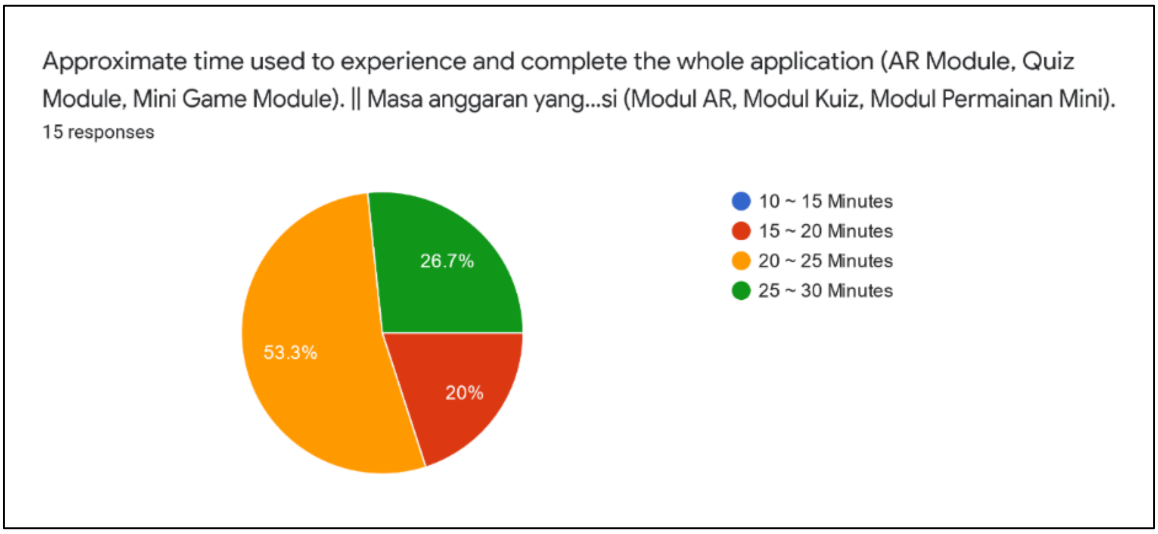


Figure 10: Time taken to experience and complete Solar System World

Figure 10 shows the time taken for the respondents to experience and complete Solar System World. Most of the respondents (53.3%) take 20 to 25 minutes to experience and complete all of the modules in Solar System World while 26.7% take 25 to 30 minutes and 20% take 15 to 20 minutes to experience and complete all the modules.

According to the comments from the Subject Matter Expert (SME), which is a science teacher named Ms Nur Fareha Binti Husin, from SJK(C) Tongkang, Batu Pahat, Johor, she loved the design, reliable content and appearance of Solar System World. She also agreed with the Solar System World have achieved the aim of interactive and motivating learning via AR and quiz module, and the mini-game module can be activities that allow students to relax in their learning spare time. However, she hoped that Solar System World can provide more graphical elements such as pictures and videos to replace the text description in the AR module because text description might confuse students when they seeing some strange terms or sentences. Besides, the approximate time she used to experience the AR module is 8 minutes, 15 minutes for 2 sets of quiz questions, and 5 minutes to experience the mini-game. Thus, she agreed that Solar System World can act as new interactive learning material and it is suitable to apply in-class learning because the time to experience Solar System World only takes about 28 minutes.

Lastly, according to the latest Primary school PdPR Timetable in 2021, allocation of time to study science subjects for year 4 students in primary schools is 90 minutes for SK school while for SJK is 120 minutes a week [17]. Thus, Solar System World is practical and implementable for in-class learning programs and home-based teaching and learning with a demonstrated beneficial learning outcome since the time taken used to experience and complete the whole application is less than 30 minutes.

5. Conclusion

Based on the user testing results, some advantages and limitations of Solar System World have been found and shows in Table 10. In conclusion, Solar System World is suitable for target users to use as a learning material to enhance their learning experience of Solar System Topic. To sum up, Solar System World Augmented Reality (AR) learning application is giving a whole new learning experience by applying the AR approach to make learning Solar System topics more interactive and motivating. Not only that, the quiz module and mini-game module in the proposed application is enhanced their learning efficiency from the questioning and gamification approach. By following a well-planned Multimedia Mobile Content Development (MMCD) methodology, Solar System World was designed and developed within a specific time constraint, and valuable and an average 83.8% of positive feedback was obtained through user testing. Thus, from the results of user testing, it can be said all three objectives of this project have been achieved. Last but not least, providing simpler terms, graphical elements, provide language selection function, increase additional language such as Chinese in Solar System World, increase the difficulty of quizzes, and develop a reward system for both quiz and mini-game modules and a health-restoring system for mini-game module is suggested as future work to expect and improve the inadequacy of the current version of Solar System World.

Table 10: Advantages and limitations of Solar System World in the current version

Advantages	Limitations
Provide positive results, high user acceptance level, and high multimedia interactivity in user acceptance testing.	Some professional terms have been used in the planet's description and quiz module, which might increase the difficulty to understand the meaning of the sentences.
Successfully described planets in text or audio form and provided 2 sets of questions in quiz module and enhanced learning interactivity via mini-game.	The quiz module does not have a reward system, which may reduce the user's desire to play when playing the test.
Can be used as an exercise whether it's participating in the school's physical teaching	There is no auxiliary item such as health-restoring items in the mini-game module, so it might reduce the interest level of play.

Acknowledgement

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Appendix A

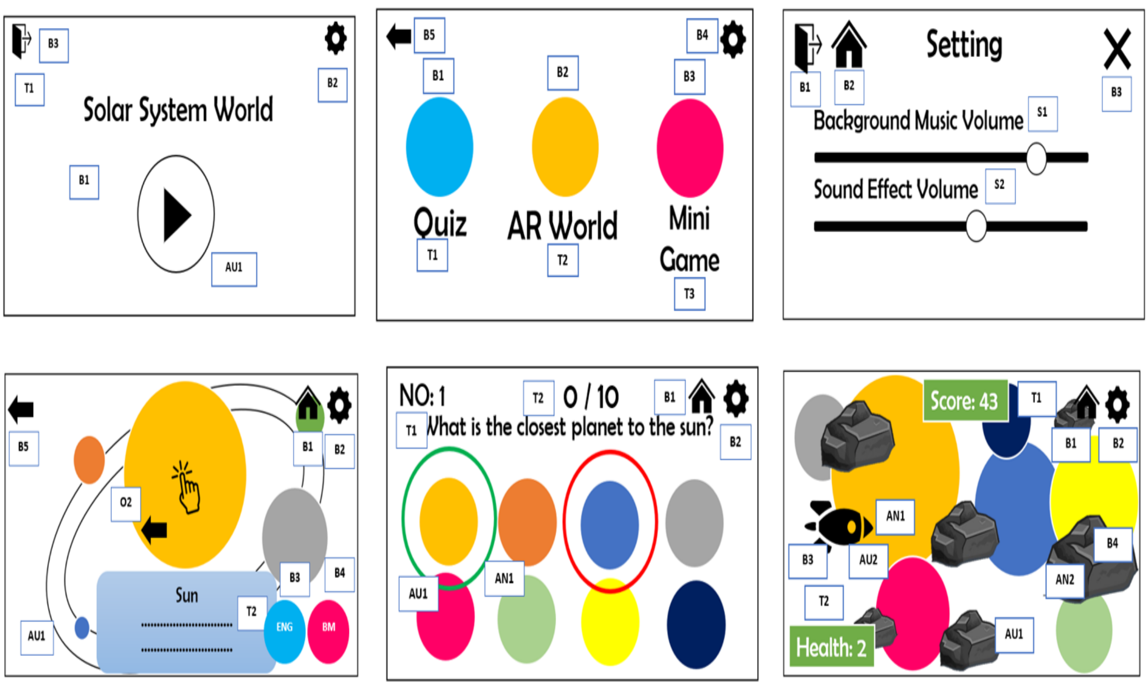

Figure 11: Sample storyboard of proposed application - Solar System World

Appendix B

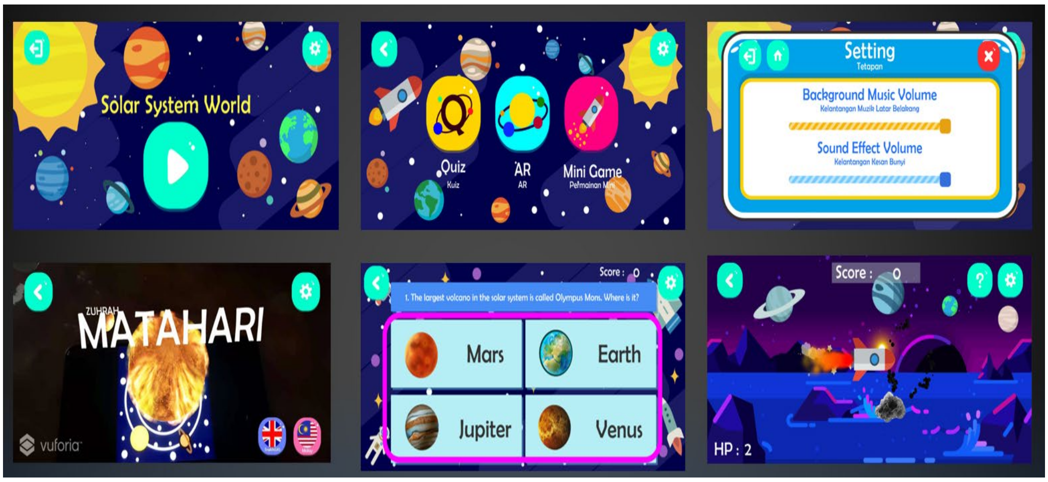

Figure 12: Sample output of proposed application - Solar System World

Appendix C

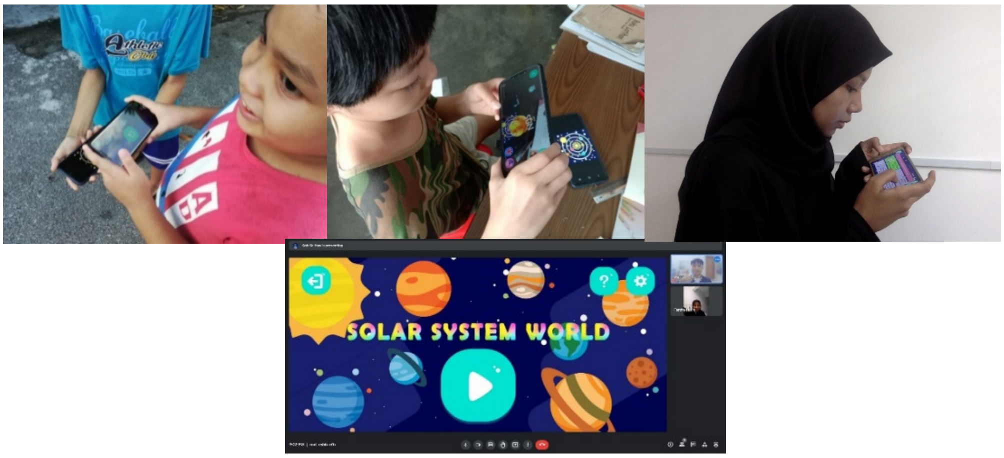

Figure 13: User testing with SME and target user

References

[1] P.A. Rhyco and K. Chandra, "Rancang Bangun Aplikasi Pembelajaran Tata Surya 3D Berbasis Augmented Reality," pp. 137-148, 2012.

[2] S. E. Higgins and A. A. Y. Al-Qahtani, "Effects of traditional, blended and e-learning on students' achievement in higher education," Journal of Computer Assisted Learning, vol. 29, no. 3, pp. 220–234, 2013.

[3] H.-Y. Chang, H.-K. Wu, and Y.-S. Hsu, "Integrating a mobile augmented reality activity to contextualize student learning of a socioscientific issue," British Journal of Educational Technology, vol. 44, no. 3, pp. E95–E99. 2013, doi:10.1111/j.1467-8535.2012.01379.

[4] E. Bondarik, "How Augmented Reality in Education Could End Traditional Teaching," Iflexion, [Online]. Available: https://www.iflexion.com/blog/augmented-reality-education. [Accessed Nov 10, 2020].

[5] J. Bacca et al., "Augmented reality trends in education: A systematic review of research and applications," Educational Technology and Society, vol. 17, no. 4, pp. 133–149, 2014.

[6] A. M. Bilal, A.H. Noor Dayana, and N. AIL E. P. Danakorn, “Teknologi Augmented Reality dalam Pembelajaran Sains.v Satu Terhadap Penyelidikan Lepas,” Universiti Teknologi Malaysia, 2015.

[7] H.-K. Wu et al., “Current Status, Opportunities and Challenges of Augmented Reality in Education,” Computers & Education, vol. 62, pp. 41– 49, 2013.

[8] I. Mustaqim, S. T. Pd, and N. Kurniawan, “Augmented Reality (ز سعلما هاج تا و ليصتح في للآا ز سعلما عقاولا ت ينقت مادختسا) Augmented Reality (بسالحا ر رقم نم ةدحو في ينيسحلا دمحم معنملا دبع تنب اهم رثأ هاج تا و ليصتح في للآا بسالحا ر رقم نم ةدحو في ت يونا ثلا تلحرلما ثابلاط ة بلاطلا دادعإ ين. 2018,” Fourth International Conference on Computing Communication Control and Automation (ICCUBEA), pp. 36–48, 2016.

[9] A. M. Ramadhan et al., “Unit 9: Earth,” SCIENCE YEAR 4 TEXTBOOK (2020 Edition), 2019.

[10] S. E. Okawa and C. Kirner, “Development of an Educational Environment based on Multimedia and Augmented Reality,” University Federal de Itajubá, UNIFEI Itajubá, Brazil, pp. 137-148, 2013.

[11] L. Phipps et al., “Conserv-AR: a virtual and augmented reality mobile game to enhance students’ awareness of wildlife conservation in western Australia,” In: Proceedings of the 15th world conference on mobile and contextual learning (mLearn 2016), Sydney, Australia, , vol 1, pp 214–217, 2016.

[12] S. Fleck, M. Hachet, and J. M. C. Bastien, “Marker-based Augmented Reality: Instructional-design to improve children interactions with astronomical concepts,” Proceedings of IDC 2015: The 14th International Conference on Interaction Design and Children, vol. 2, no. 5, pp. 21–28, 2015, https://doi.org/10.1145/2771839.2771842.

[13] McCullough, “What is the easiest font for kids to read,” Quora.com, 2017. [Online]. Available: https://www.quora.com/What-is-the-easiest-font-for-kidsto-read. [Accessed Nov 28, 2020].

[14] W. S. N. Saifudin, S. Salam, and M. H. L. Abdullah, “Multimedia Mobile Content Development (MMCD) Framework and Methodology for Developing M-Learning Application,” J. Tech. Educ. Train., vol. 4, no. 2, pp. 15–22, 2012.

[15] F. D Davis, “Perceived usefulness, perceived ease of use, and user acceptance of information technology,” MIS quarterly, pp. 319-340, 1989.

[16] H. M. Abu-Dalbouh, “A questionnaire approach based on the technology acceptance model for mobile tracking on patient progress applications,” J. Comput. Sci., vol. 9, no. 6, pp. 763-770, 2013.

[17] Tchercollection, “Jadual Waktu PdPR Sekolah Rendah: Terkini 2021,” Tchercollection.com, 2021. [Online]. Available: https://www.tchercollection.com/jadual-waktu-pdpr-sekolah-rendah-terkini/. [Accessed June 6, 2021].