Augmented Reality Application for Solar System Learning

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***Abstract*— The purpose of this study is to investigate the applicability of Augmented Reality (AR) technology to solar system learning content. AR is a real-world interactive experience in which real-world items are augmented with computer-generated perceptual information and is used as the main technology for this study. AR in solar system learning provides a way to study natural phenomena of solar system that are impractical to see directly due to their location, duration, and scale in virtual 3D visualization. There are several existing problems of the previous AR solar system learning applications such as users are not allowed to interact with the virtual learning content and the users only can view the 3D animated visualization. Some existing applications were built only for users to learn the fact of the solar system without any quizzes for users to test their understanding. Besides, in the existing systems, only one marker is used for the entire solar system which is less interactive. Thus, in this study, the application was designed and developed to allow users to interact with the virtual 3D content by using touch-based inputs. Different card combinations also allow users to perform vary card interactions to expel different learning content. Also, quizzes are included to boost the users' understanding. Preliminary testing results based on the identification of applicability of AR technology to solar system learning content showed that the proposed application could be used as an alternative to adequately identify the best method for teaching and learning process on solar system topic.**

Keywords*— *augmented reality, solar system, science, learning

I. Introduction

The solar system was chosen as the learning content in this study because of the teacher's ambition to bring faraway worlds up near and personal in a 3D scenario. When the knowledge of the solar system is given through text or 2D representation, students frequently struggle to comprehend spatial concepts and phenomena of the solar system especially when the concepts are getting more complex for secondary students to learn. This also means that secondary students are suppose to understand the basic of solar system concept before they can understand complex concept of the phenomena. Lack of basic knowledge may cause students to easily bored, unmotivated to learn the topic and sometimes may lead to misunderstanding in the learning process as they cannot interact and see clearly on how solar system works. Apart from that, teaching and learning system that only use text and 2D illustration as learning materials is very common in learning process as well as limited to represent the real phenomena to secondary students. Hence, teachers find it less interesting and difficult to attract students’ attention.

Thus, Augmented Reality (AR) has the potential to solve the challenge of spatial learning [1]. AR may be utilized to improve students' comprehension, critical thinking abilities, and conceptual understanding. The use of 3D animations assist students in better understanding the looks and features of the planet built using oblique and double-curved surfaces. Aside from that, study also showed that 3D space learning could improved visual comprehension for pupils [1]. It is obviously useful when the learning content involving complexity of the topic itself. For example, in the solar system learning purpose, when each planet is built with complex characteristics [1]. Due to the potential of the AR technology in the solar system learning, this study is proposed to provide more comprehensive learning experience using AR. Additional features are added to enhance students’ understanding after learnt and in more interactive mode.

II. Literature Review

AR as the creation of a digitally enhanced representation of the real physical environment using digital visual elements, audio, or other sensory stimulation made available by technology. Companies interested in mobile computing, especially business applications, are increasingly following this trend [2]. AR is a reality where everything has been enhanced with interactive digital elements [3]. The most popular AR applications in current period depend on smartphones to show the AR environment, in which users need to turn on their smartphone's camera, display the actual world around them on the screen, and view the virtual content that created by an AR software to improve the real environment in various ways such as superimposing photos, adding real-time directions, inserting labels, changing colors, and modifying the look of the user or their environment using 'filters' on Snap-chat, Instagram, and other applications.

AR is not only used for gaming, but this immersive technology is becoming popular nowadays where various industries such as education, health and business are investing in AR to increase customer engagement and remain competitive especially during this unprecedented time where everyone needs to stay at home during Covid-19 pandemic. The goal of AR is to employ 3D virtual components as tools to increase user experience and engagement in comparison to the real world. In marker- based AR, the device search for a particular target such as printed marker or real world objects such as bottles or human hands which known as Image Target. When an AR application detects a target using the camera, it analyses the image and augments virtual material such as a 3D model, video, picture, or other material [4]. For example, users can see the 3D model of a bag by positioning their camera to the printed product catalogue.

There are three (3) steps in AR development process with real-time video stream which are recognition, tracking and mix [5] (refer Fig. 1 and Fig. 2). The recognition process comprises identifying an image, an object, a person's face, or their body. The real-time localization of an image, object, human face, or body in space is a component of tracking. Last but not least, the mix process entails projecting media, such as 3D objects, images, or videos, on top of images, objects, human faces, or bodies.

The procedure of these 3 processes takes less than 40miliseconds to match the human eye's fluidity of 25 pictures per second. Powerful algorithms must be used, and research is always being conducted to further enhance each of these 3 processes, which are being aided by the increasing performance of equipment and gadgets. Computer Vision is a heavy CPU consumer in and of itself, but the more available power, the more sophisticated the algorithm for a really enhanced user experience. Furthermore, with the fast increasing usage of captors such as GPS, Compass, Gyroscope, thermometers, and speedometers, the total of information gathered may be utilized to further enhance and increase users' experience in a present situation.

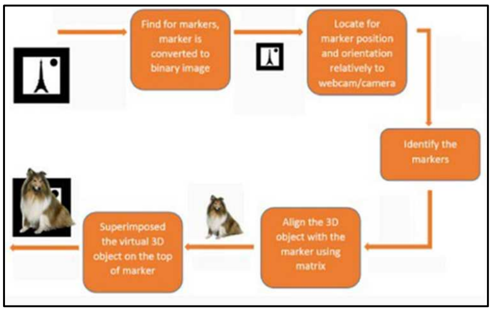

Fig. 1. AR Development Process [5].

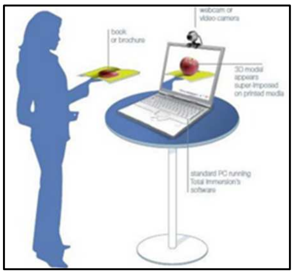

Fig.2. Real-time video stream with AR [5].

A. AR Tracking Technique

Tracking, the technique of identifying a user's location and orientation in an environment, is crucial to AR as precise registration of real and synthetic objects provides more realistic results [6]. Tracking techniques are necessary for AR to properly display visuals depending on the changing position of the viewer. Furthermore, tracking is required for effective AR registration and the accurate alignment of virtual and real-world objects [7].

Physical world objects along with the exact synchronization of virtual data are done in three phases for realistic mobile AR: location, rendering, and merging. Virtual data is changed based on the smartphone's location during the positioning phase. At the rendering stage, the 3D models that hold virtual data are converted into 2D pictures [8]. Coordinating those three phases demands precisely tracking the 3D positions of Tracking Point of Interest (POI). The POI may be monitored using commonly utilized vision and sensor-based approaches [9].

Marker-based and marker-less tracking systems are two types of vision-based tracking systems. A static picture, also known as a trigger image, is required for marker-based AR experiences, which a person can utilize AR software to scan using their mobile device [10]. A variety of additional extra materials (video, animation, 3D, or other) are made available on top of the marker after the smartphone scan (refer Fig. 3).

Rather than detecting markers, marker-less AR [12] inserts virtual 3D objects in the physical world depending on the realistic features of the surroundings. As a result of this difference, object tracking systems are no longer necessary. Marker-less AR experiences are now possible because to advancements in cameras, sensors, CPU, and algorithms capable of accurately recognizing and mapping the actual environment.

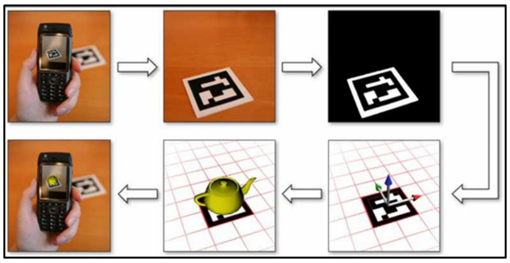

Fig. 3. Basic Workflow of an AR Application Using Marker-based Tracking Method [11].

The sensor-based technique is a technique for detecting a target that makes use of a different types of sensors. Magnetic, inertial, optical, and mechanical sensors are among the sensors that are used. Sensor-based tracking systems usually have a high processing speed, but to fix concerns due to physical issues, calibrating and matching activities are conducted [8]

B. Solar System Learning Concept in Technology

In learning science subject, particularly solar system topic, students are given instanced learning content that must be understood. Understanding the solar system is made more difficult by the fact that not all of its elements and events, such as the movement and structure of each planet and the process of lunar and solar eclipses, can be directly investigated. [13]. For a solar system topic, it is desirable to employ technology such as simulation or AR to make the teaching-learning process more efficient and effective. Virtualization in science provides a way to study natural phenomena that are impractical to see directly due to their location, duration, and scale [13].

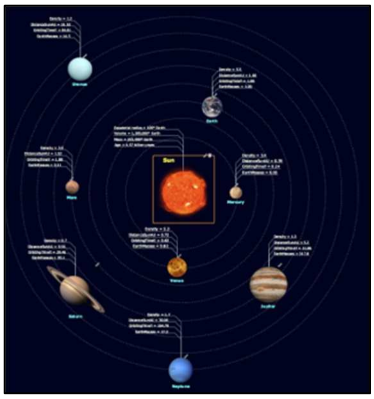

Fig. 4. Mind Map of Solar System Learning Concept [15].

By using virtual planetarium surroundings, students can get understanding of a phenomena or situation that appears to be really complex and difficult to observe directly in real life [14]. Planetarium software, one of the most intriguing instances of Virtual 3D Contents, provides various chances for learners to understand the solar system in novel and beneficial ways, as the program displays the structure, characteristics, and complexity of the solar system in 3D representation. The solar system software program (refer Fig. 4) can aid in the technical discovery and study of solar system topics. The solar system software application is a tool that can be used to aid students in viewing the solar system as exploration learning may be used as a learning technique in comprehending the solar system.

III. Research Methodology

This section discusses the study methodology in detail along with suitable approach to develop the proposed application. Flow chart diagram are used to represent the stages included in the system development by using Waterfall method (refer Fig. 5).

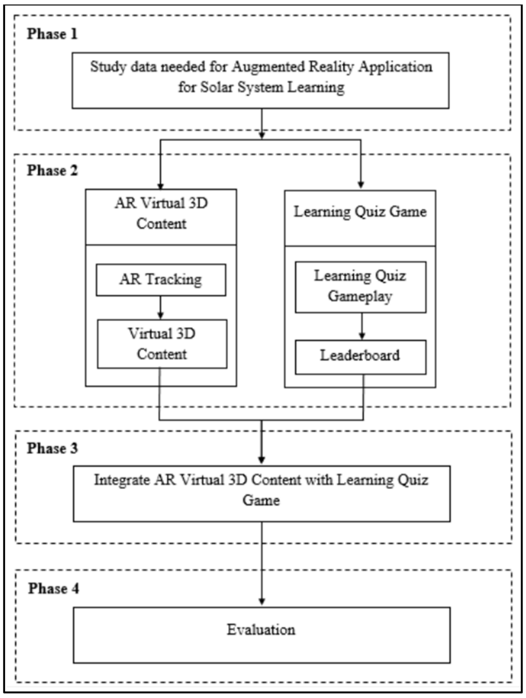

Fig. 5. Flowchart of the project using waterfall approach.

A. Phase 1: Study the Data Needed for AR Application for Solar System Learning

The first phase of this research includes the study of AR applications for solar system learning. This phase is crucial and must be carried out as the next phase only can be conducted based on the information gathered in this phase. Through the study, the data of AR technology and the concept of solar system learning are collected. This phase clarifies the basic concept of AR technology including the definition of AR, stages involved in AR development and the requirements to develop AR application. Other than that, this phase also studies the suitability of the implementation of solar system learning with AR technology. The information collected through this phase is used in the next phase.

B. Phase 2: Development of AR Application to Learn Solar System

In this phase, designing process along with the development of AR application for solar system learning are conducted using the data collected from the previous phase. Firstly, the AR markers are designed and the features of the images are generated in order for each marker to be tracked using the camera of user's device. After an AR marker is tracked through the user's device, it is used to project the 3D virtual solar system environment in the physical world. Other than that, the gameplay for the quiz game are designed and developed at this phase to fulfil the objective of the project. Furthermore, the leaderboard are also added to to encourage the user to get the highest score and to climb up the leader board. The AR application are developed using Unity software with the integration of Vuforia SDK. Multiple card interactions are designed to show the different combination of planets and the relevant learning content.

C. Phase 3: Integrate the AR Virtual 3D Content with Learning Quiz Game

This phase focuses on the integration of the AR Virtual 3D Content with learning quiz game based on the concept of solar system learning. This application has two modes where the first is the AR virtual solar system learning environment that consist of AR tracking and virtual 3D content, and the second mode is the learning quiz game to evaluate the students' understanding on the solar system topic through the quizzes. This phase concludes the development of the proposed application and ready to be tested and evaluated by the user which conducted in the next phase.

D. Phase 4: Evaluation

The last phase is conducted to evaluate the fully developed AR application for solar system learning. This phase is important to ensure the objective of the development of AR application is achieved as well as detecting and fixing any bug found in this phase. Usability testing along with user acceptance are conducted in this phase to gather information, feedback and suggestion from the users regarding the application effectiveness. The evaluation procedure is based on the guides from [16, 17]. Pre and post experiment questionnaire will be given to each of the user to evaluate the AR application for solar system learning.

IV. Implementation

This section covers the implementation of the AR virtual 3D content as well as the integration of AR marker tracking. This section also discusses the development of Learning Quiz Game as a form of game-based learning as well as describe how the AR virtual 3D content and the Learning Quiz Game are linked.

A. Implementation of Virtual 3D Content

There are two (2) types of tasks that are focused on during the phase of implementing virtual 3D content which is the process of creating a list of planets included in the solar system and the information and movement of each of the planets in the solar system. Basically, there are two (2) sets of interaction that can be conducted by the user. First, the 3D content of the planet is displayed based on the marker used. There have ten (10) markers and each marker represent each planet which are the Sun, Moon, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. Next, the animation of movement for the planet around the sun is displayed if the user places the Sun marker together with the other markers. This multiple card interactions show the different movement of planets. To ensure the exact knowledge related to the solar system, brief research is performed to collect the data on the information of each planet and the movement of each planet such as the speed, distance of the planet with the sun and the mass.

B. Implementation of AR Marker Tracking

The marker on the mobile device is detected using marker-based AR tracking in this study. Hence, the Vuforia AR SDK is added to the proposed Solar System AR application. The main camera prefab is then deleted and replaced with the AR camera so that the AR camera may be fully utilised in this application. The App License Key obtained from the Vuforia portal is added to the Vuforia Configuration setting, and the marker database obtained from the Vuforia portal is also imported for tracking purposes.

Following that, the image target of the marker was added to the application project, and the database, along with the image target, was also configured for the marker's implementation.

Instead of using a single image target, a multiple image target is used to make the marker interactive. When two or more markers, such as the Sun and the Earth, are merged, a new object is created. As a result, the set of markers is designed in the manner (refer Fig. 6). Next, all of the game objects being used are dragged as children of the specific image target to ensure the marker is recognised and tracked by the camera. This means that each game object has its own image target or marker that appears on the display devices.

Fig. 6. Collection of multiple image target.

To allow the detection of multiple image target, the size of max simultaneous tracked images and objects need to change according to the quantity of marker being used. The changes are made at Vuforia Configuration settings.

Thus, the marker needs to always be changed according to the user's desire. For example, if user want to display the earth movement around the sun, the user need to put both the Sun marker and the Earth marker on the table and scan the cards using phone camera (refer Fig.7).

Fig. 7. Interaction Between Sun Marker and Earth Marker.

C. Implementation of learning Quiz Game

The second stage contain a set of quizzes as a game-based learning. This quiz game has ten questions, all of which are relevant to the AR solar system exploration. The user must first enter their name to indicate their identification as well as the ranking. After filling in their name, the user must click the start button, which is linked to a logic that saves the user's name and class using playprefs. This data is eventually used to display in the leader board page. This leader board is integrated using Tenenet to save the player's information in the database. The information will be used to display the ranking automatically. To do this, add the game to Tenenet and set up all required information. Next, to integrate Tenenet with Unity, Tenenet Unity package is imported. Lastly, the data of API system is changed based on the information set up from Tenenet. After the user has finished responding to all ten questions, the results panel will appear on the screen. If a user selects the leader board button, their ranking will be displayed depending on the data that was stored using the InsertPlayerActivity method and the playerprefs. In this part of the quiz game, the gamification component is being put into action. The rating is going to urge users to achieve the greatest possible point total so that they can be on the top list of the ranking. On the other side, this result panel also features two additional buttons that have been designed with the names retry and back. These buttons are displayed here. The user is given the opportunity to restart the learning quiz game whenever they click the "Retry" option. When the back button is used, the user will be brought back to the main screen.

V. Evaluation

This section covers the workspace setup used to carry out the testing for the proposed application.

A. Respondents

The evaluation involves total of 10 respondents. Since it is the preliminary evaluation, small number of participation is enough for this purpose [18, 19]. These respondents are among secondary school students with age range 13 to 17 years old. Aside from that, all of them have different level of understanding on solar system topic from beginner to expert. Some of the respondent have experience with AR and some of them are not. All of them own smartphones, but only 2 of them had to borrow from other respondents due to the software limitation which is only available for the Android operating system. The variety of respondent's background provide different data to be analyzed for this research study.

B. Evaluation Setup

First, the respondents received a brief introduction to the project and instructions on the individual tasks that needed to be completed. Next, a pre-test questionnaire must be completed by each responder in order to collect background information. These respondents started interacting with the AR Solar System App after completing the survey. Each respondent had 25 minutes to test out and explore the application. The setup of the AR workspace for this project involves an AR marker with a card-like size placed on the table in the proper location and region (refer Fig. 8).

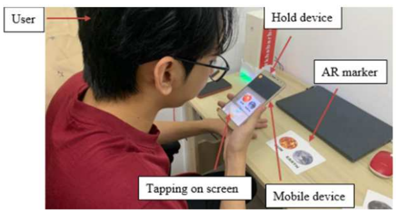

Fig. 8. Vuforia Configuration Setting.

The user's hand and the location of the mobile device need to be in alignment for optimum results. The mobile device's camera, which is used to track and display the AR experiment, is also properly positioned at a distance of around 45 cm from the marker. After the testing is complete, the post-test questionnaire is given to each respondent to collect feedback and comments from users regarding the application.

VI. Results and Discussion

The usability testing that was done to evaluate this application is described in this section. This testing consists of a number of questionnaires. The pre-test questionnaire and the post-test questionnaire are the two portions of the questionnaire. The respondents are from ten secondary students that participated in the testing. In addition to gathering background data, the pre-test questionnaire asks about prior AR experience. After investigating and testing the application, a post-test questionnaire requests feedback and comments about the application. The following subsections provide and discuss the acquired data.

A. Usability Testing

The findings of the post-test questionnaire are presented in the form of column charts. The first 2 questions asked regarding the easiness of the user interface in order to accomplish a given task during the used of the application. After explore the application, majority of the respondents (50%) strongly agreed and the remaining (40%) also agreed that the application is easy to use. However, only 10% of respondents neither agree nor disagree the application was overall easy to use (refer Fig.9). This was because 50% and 30% of respondents strongly agreed and agreed respectively the user interface is easy to understand. However, 20% of respondents neither agreed nor disagreed that the user interface was easy to understand (refer Fig. 10).

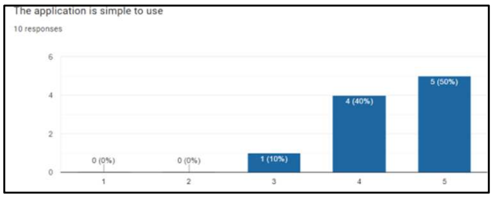

Fig. 9. The result on the easiness of this application.

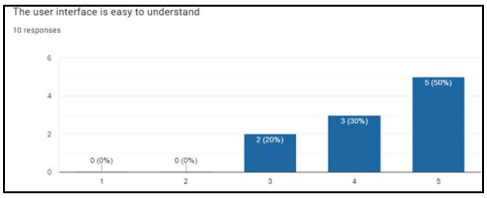

Fig. 10. The result on user interface.

While in term of the learnability aspect of the application, the result of the information provided in the application was clear and easy for them to learn or understand the learning content (refer Fig. 11). Majority of the respondents with 50% strongly agreed and the other 40% agreed with that statement. However, 10% neither agreed and disagreed and another 10% disagreed that the information provided in the application was clear and easy for them to learn. This was because some of the respondents were in beginner level of solar system knowledge. This also can be seen from the next question (refer Fig. 12) where majority of the respondent with 60% strongly agreed and 30% agreed respectively that the application improved their knowledge regarding the solar system topic. However, the remaining respondents with 10% neither agreed nor disagreed with the statement.

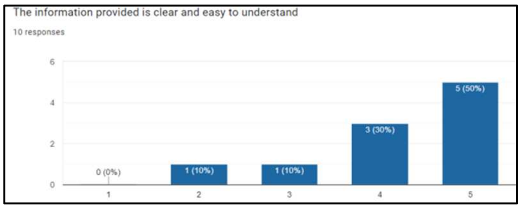

Fig. 11. The result on the information provided.

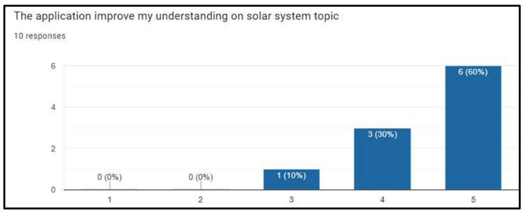

Fig. 12. The result on understanding improvement.

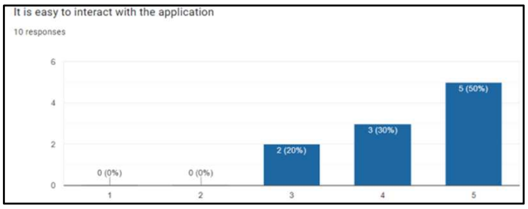

Fig. 13. The result on easiness to interact with the application.

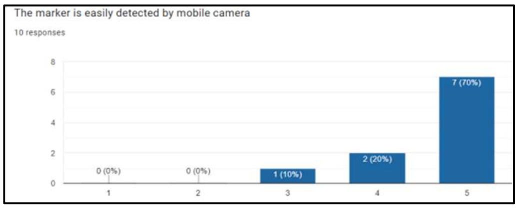

Fig. 14. The result of the easiness to detect the marker.

In terms of suitability of the learning content with the targeted audience, the respondents' feedback regarding the suitability of the learning content and difficulty level for secondary school student (refer Fig. 15). Most of respondent with 50% strongly agreed and 30% agreed that the learning content is suitable for them to learn. The remaining of 10% respondents however remain neither agreed or disagreed and another 10% disagreed the learning content is not suitable for them. This is because the information might be difficult for lower secondary student which is for Form 1 and Form 2 student. This also can be seen on the next result (refer Fig. 16) where 40% of the respondents strongly agreed and 30% agreed that the application. The remaining of 30% respondents however remain neither agreed or disagreed that the application has all functions and capabilities they expect to have.

Next, the respondents' feedback whether they would use the application often or not (refer Fig. 17). Most of the respondents with 50% strongly agreed while the remaining of 30% respondents agreed that they would use the application frequently. However, the remaining 10% of respondents neither agreed nor disagreed and another 10% disagreed with the statement. In terms of recommendation to others, 60% of respondents strongly agreed and 30% of respondents also agreed the application is worth to try by others. However, the remaining 10% of respondents neither agreed nor disagreed with the statement (refer Fig. 18).

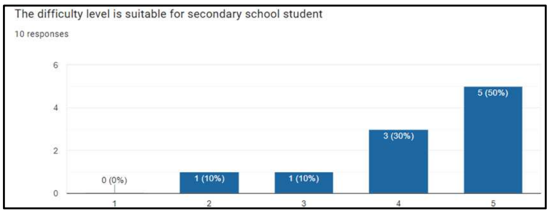

Fig. 15. The result on the suitability of difficulty level.

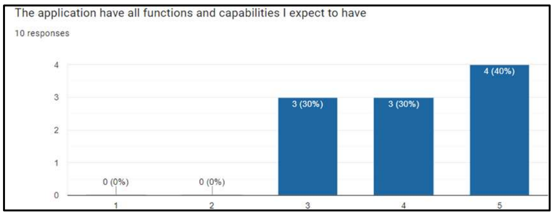

Fig. 16. The result on the user expectation of the application.

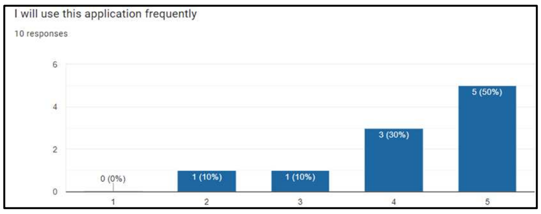

Fig. 17. The result on frequently use of the application.

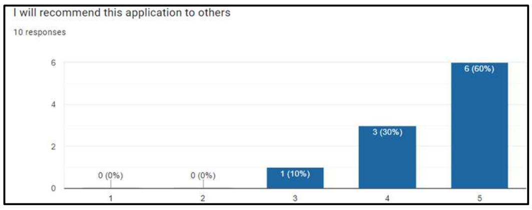

Fig. 18. The result on recommendation to others.

VII. CONCLUSION AND SUGGESTIONS

As conclusion, all three objectives are predicted to be met throughout the development of this project. First is to analyse the applicability of AR technology to solar system learning content. Next, for the second objective, to design and develop a system to improve students' understanding on solar system topic using AR technology and lastly, to evaluate the performance of the proposed AR learning in enhancing students' learning experience on solar system topic.

Even though the project was successfully carried out and all three goals were met, some restrictions have been discovered. Firstly, sometimes it's difficult to display the game object when a marker is detected. Next, the limitation is that the app only supports portrait view and may only be used with Android devices that have at least API level 26. API Level is an integer number that uniquely identifies the framework API revision provided by an Android platform version. The Android platform provides a framework API through which the apps may communicate with the Android system. The last limitation is the application only support one single user.

Some of the suggested improvements in this section can be used to enhance the project in the future. First, modifying the setting on the AR camera can fix the flickering of AR game objects. Next, by making the user interface responsive coming ahead, it can also be improved. Lastly, he application only supports single users, therefore adding multiplayer users may be considered an enhancement.

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REFERENCES

[1] S. Cai, X. Wang, M. Gao, and S. Yu, "Simulation teaching in 3D augmented reality environment". in IIAI International Conference on Advanced Applied Informatics, pp. 83-88, 2012.

[2] A. Hayes, "Augmented Reality Definition," Investopedia. Retrieved from https://www.investopedia.com/terms/a/augmented-reality.asp, 2022.

[3] H. Ben Houston, "The Future of Customer Engagement and Experience," Retrieved from https://www.the-future-of-commerce.com/contributor/ben-houston/, 2022.

[4] R. Palmarini, J. A. Erkoyuncu, R.Roy, H.Torabmostaedi, "Asystematic review of augmented reality applications in maintenance". Robotics and Computer-Integrated Manufacturing, vol.49, pp. 215-228, 2018.

[5] S. Prabhu, "Augmented Reality SDKs in 2018: Which are the best for Development," Retrived from http://www.arreverie.com/blogs/best-augmented-reality-sdk-in-2018/, 2017.

[6] E. Bostanci, N. Kanwal, and A.F. Clark, "Augmented reality applications for cultural heritage using Kinect". Hum. Cent. Comput. Inf. Sci., vol.20, 2015.

[7] D.W.F. Van Krevelen, and R. Poelman, "A survey of augmented reality technologies, applications and limitations. International journal of virtual reality". vol.9, pp. 1-20, 2010.

[8] M.J. Seong, and D.H. Lee, "Design and implementation of cultural property learning contents using augmented reality". Journal of Digital Contents Society, vol.18, pp. 831-837, 2017.

[9] F. Zhou, H.B.L. Duh, and M. Billinghurst, "Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR". in 2008 7th IEEE/ACM International Symposium on Mixed and Augmented Reality, pp. 193-202, 2008.

[10] A. Cīrulis, K. Brigmanis-Briģis, and G. Zvejnieks, "Analysis of suitable natural feature computer vision algorithms for augmented reality services". Baltic Journal of Modern Computing, vol.8, pp. 174-181, 2020.

[11] D. Wagner, and D. Schmalstieg, "ARToolKitPlus for pose tracking on mobile devices". in Conference: Proceedings of 12th Computer Vision Winter Workshop CVWW07, 2007.

[12] J. Chun, and B. Lee, "Dynamic manipulation of a virtual object in marker-less AR system based on both human hands". TIIS. 4. pp. 618-632. 10.3837/tiis.2010.08.010, 2010.

[13] Y.C. Chen, "Learning protein structure with peers in an AR-enhanced learning environment (Doctoral dissertation), 2013.

[14] M. Dunleavy, M., and C. Dede, "Augmented reality teaching and learning". Handbook of research on educational communications and technology, pp. 735-745, 2014.

[15] L.L. Guglya, M.I. Orlyuk, M.I. Ryabov, A.L. Suharev, and I.M. Orliuk, "Sun and solar system daily and short-period changes dynamics of the Earth's magnetic field in the 24-th cycle of solar activity according to magnetic observatory Odessa". Odessa Astronomical Publications, vol.26, pp.263-267, 2013.

[16] E.S. Goh, M.S. Sunar, A.W. Ismail, and R. Andias, "An inertial device-based user interaction with occlusion-free object handling in a handheld augmented reality," International Journal of Integrated Engineering, vol.10(6), pp.159-168, 2018.

[17] E.S. Goh, M.S. Sunar, and A.W. Ismail, "Device-based manipulation technique with separated control structures for 3D object translation and rotation in handheld mobile AR," International Journal of Human-Computer Studies, vol. 2020(141), https://doi.org/10.1016/j.ijhcs.2020.102433, 2020.

[18] H. Shu, "Pretesting," in: A.C. Michalos (Eds.). Encyclopedia of Quality of Life and Well-Being Research, pp.5048–5052, 2014.

[19] V.P. Thomas, S.C. Delphine, M.H. Patricia, and A. Gayet-Ageron, "Sample size for pre-tests of questionnaires," Quality of Life Research, vol. 24(1), pp.147-151, 2015.