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Handheld Augmented Reality Application for 3D Fruits Learning

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***Abstract*—The purpose of this study is to look into the use of augmented reality (AR) technology in education materials of fruit and its nutrition. AR is the primary technology used in proposing this project. AR is a real-world interactive experience in which real-world items are augmented with computer-generated perceptual information. The idea of this research is to use AR in complementing the traditional learning method by using the AR markers as flashcards to improve user experiences. Because schools are closed during the Covid-19 outbreak, traditional learning is not available. This study proposes the use of 3D animation integrated into augmented environment to illustrate each of the fruits such as the nutrition information, the suitable period to consume the different fruits and the benefits of the different fruits' combination to overcome and improve traditional fruit's nutrition's learning among students. The proposed application outperforms the 2D illustration method in terms of student understanding by adding richer user interactions. Furthermore, the proposed application can be used as an alternative to determine the best way to teach and learn about fruits and nutrition. To achieve the objectives of the proposed application development, there are 4 main phases to be went through. The first phase is focusing on studying and learning the interaction features in handheld AR context besides studying about the concept and technical information about AR development. The second phase is designing process along with the development of the proposed application. The third phase is to integrate the AR application along with the interaction features and some other additional elements such as quizzes to test the user understanding after the learning process. The final phase is to evaluate the user experiences after trying the proposed AR application. The project's expected outcome was evaluated using data collected from the user during the final phase.**

***Keywords*—Augmented reality, fruit learning, nutrition, learning; interaction**

I. INTRODUCTION

Augmented Reality (AR) is a game-changing technology that offers a direct or indirect real-time view of an enhanced real-world environment with virtual computer data [1]. AR is utilized for numerous objectives, including education, professional and consumer applications in commerce, education, entertainment, communication, business, and medical sectors. AR applications in education help teachers explain and envision learning content to improve students' understanding and productivity. For example, a mobile device can be used to scan an image on a flashcard treated as AR marker to register virtual content that allowing students to access the AR-based learning content [2].

Teachers and students can use AR as a powerful tool in their teaching and learning processes. Visual representations make learning more interesting for students. AR can make a learning process more exciting and immersive by allowing teachers to display virtual models of concepts or include game components to supplement handbook materials [3]. As a result, students can easily understand and improve their knowledge. Aside from that, AR can ease the access towards the existing learning materials at any time anywhere, especially during the Covid-19 pandemic situation where students must learn from home, and it can make it easier for parents to teach their children from home with interactive AR learning materials [4].

II. LITERATURE REVIEW

A. Augmented Reality

The breakthrough in AR technology has occurred in recent years. Because of its extensive use, it has gone from theoretical to practical applications. In current life, AR technology can be applied and is not confined to a wide range of applications.

AR technology differs from Virtual Reality (VR), in that the user enters a virtual (computer generated) environment completely without seeing the real world. AR, on the other hand, is characterized integrating a portion of the three-dimensional (3D) virtual content with the real world in real-time [5]. Comprehensively, AR is defined as a computer technology that blends real-life images, scenes, and clips with the virtual world using 3D computer graphics in real-time, equips with interaction features to enhance user AR experiences [6].

According to Cohen *et al.* [7], AR is a technology that combines 3D virtual items with the actual world, allowing users to interact with both virtual and real-world objects simultaneously. AR is a sort of technology that employs computer-generated content to enhance the actual environment. Users can effortlessly incorporate digital content into their vision of the actual world. In addition to audio, video, animation, and/or text, it is possible to include 2D and 3D shapes. These upgrades assist individuals obtain a deeper awareness of their surroundings.

Alternatively, AR as a system that blends virtual and real-world settings using specialized techniques and approaches [6] also have the vary possibilities in practical tasks such as illuminating airplane landing pathways in actual airports and providing virtual information to a surgeon during surgery that indicates the areas that must be excised. According to Dunleavy and Dede, AR is a technology that enables the realistic synchronization of digital content from computers and software with the physical environment [8]. It is feasible to merge real and virtual experiences and relevant information from the external environment contrasted with a simulated digital world. In overall, AR aims to bridge the gap between the user's sense of reality and AR content.

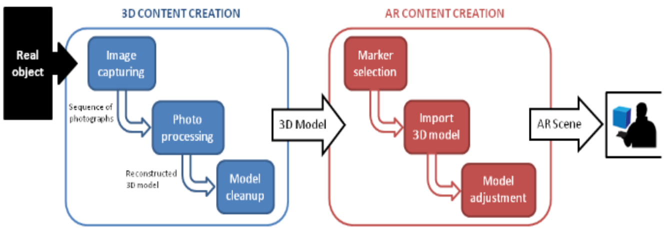

Fig. 1. Stages in Augmented Reality [10]

AR as a contemporary technology system in which virtual things are added to the real environment in real-time [9] should mix actual and virtual items in a real environment. This is done by registering virtual content either markerless or marker-based. According to Camba and Contero [10], the construction of an AR's interactive features is a visually intuitive procedure. First, an AR marker is selected and printed from the ID menu to visualize the scene while it is being constructed interactively. Fig. 1 depicts the process of developing AR content.

Next, the camera must be turned on, and the marker must be pointed. After the AR marker is recognized by the AR system, the user can interact with the 3D content/model registered on the particular AR marker. Usually, the AR marker is a printed marker and the 3D content/model is placed above the marker. For markerless AR application, GPS-based or natural AR marker such as the real-world item like painting, floor map or even 3D sculpture are used as AR markers that is not deliberately printed.

For desktop-based AR system, the controller on the main panel is used to perform 3D content/model interaction such as rotation, translation, and other advance manipulations. In handheld AR context, the touching inputs are usually been utilized for the same purpose.

1) Handheld Augmented Reality (HAR)

Smartphones and tablets are small and lightweight, with a display, camera, graphics, GPS compass, and accelerometer, it is potential for the use of an AR system. HAR usually been used for variety purposes such as gaming, interactive marketing, education [11], and navigation. HAR must resolve several technical issues before reaching its full potential. Interacting with virtual objects in augmented scenes on handheld devices is difficult since it is limited such as single hand interaction and touching input sensitivities. Fig. 2 show example the uses HAR devices in project.

Fig. 2. Uses a smartphone, a PDA, and a tablet PC

2) Handheld Interaction

Direct manipulation involves tangible interaction [12] such as hand gestures and AR marker movements. When entering the AR environment, the user can physically move the recognised object through the direct manipulation towards the AR markers or performing hand gesture interaction. The disappearance or appearance of a visible object, changing an object's direction, altering the proximity of two or more objects, or movement are some tasks that can be triggered by performing tangible interactions [13]. Tangible AR interaction could not assume both hands were free since one of the user's hand may be used for gesture inputs or moving an AR marker in HAR-specific system. In head-mounted display (HMD) based AR, you must touch the screen while holding the device and this type of AR system suffering dizzy and eye tireness issues. Refer to Fig. 3 of the example of HAR interaction.

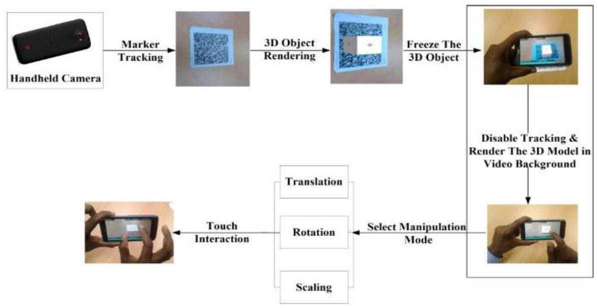

Fig. 3. Interaction of HAR

3) AR Flashcards

AR flashcards are a recently introduced product. AR flashcards surpass regular paper and digital flashcards as instructional tools that treated as AR markers. By physically holding AR flashcards, learners can have the same experience as with regular flashcards, playing without the AR features. Additionally, they can scan the flashcards with a mobile device to activate the AR content [14]. After the mobile device identifies the flashcards, the appropriate 3D virtual graphics can be superimposed on the flashcards [1]. Learners can interact with the registered virtual objects. Users can manipulate the virtual objects by touching the mobile device's screen, touching inputs are the commonly used interactive features for the users to interact with the virtual objects. Based on this context, some benefits of using AR in education are concluded:

Firstly, AR displays 3D learning content that enhance traditional learning. Second, AR-based games, models, and simulations facilitate situational, collaborative, and ubiquitous learning which are more adaptable with the new era learning mechanism. Third, AR systems moderate children's perceptions of presence, immediacy, and immersion by combining real and multimedia content. Fourth, AR systems allow you to see the unseen. Lastly, AR can bridge the gap between formal and informal learning.

TABLE 1. COMPARISON PREVIOUS WORKS [15, 16]

Previous work	Research focus	Type of AR
The Fargoes Fruits Augmented Reality Flashcards [15]	AR was used to find out about a good source of carbs, vitamins, minerals, fibres of tropical fruits	HAR Interaction that only allowing users to tap onto button provided for informative explanation, no interaction with the virtual objects allowed
AR Recommend Fruit Nutrition [16]	AR was used for explaining the fruits' nutrition	HAR Interaction that only allowing users to tap onto button provided for informative explanation, no interaction with the virtual objects allowed

In the context of producing the proposed AR application for fruits and nutrition learning, some previous similar works were studied (refer Table 1). AR Fargoes [15] is an application concentrates on the used AR to learn about a valuable source of carbohydrates, vitamins, minerals, fibres of tropical fruits. Meanwhile, AR Recommend Fruit Nutrotion [16] is focusing on explaining fruit nutrition using AR technology. Both applications are more concerned with explaining fruits' nutrition but less concerned about the interaction among the user with the application.

After conducting extensive research, the proposed application is meaned to improve on the interaction part. The proposed application is HAR-based with several interaction features and additional quizzes to enhance user learning experiences.

III. METHODOLOGY

As indicated in Fig. 3, this section explained the methodology of the proposed application. A flow chart is constructed to provide a deeper insight of project flow to achieve the objectives as below:

i. To analyse the applicability of AR technology for learning the content of fruits and nutrition.
ii. To develop interactive learning AR application based on fruits nutrition learning content.
iii. To evaluate the efficacy of the proposed AR learning application in enhancing students' understanding of fruits' nutrition.

To achieve the objectives stated above, 4 phases involved as stated on Fig. 4. Each phase is explained thoroughly in the following sub-sections.

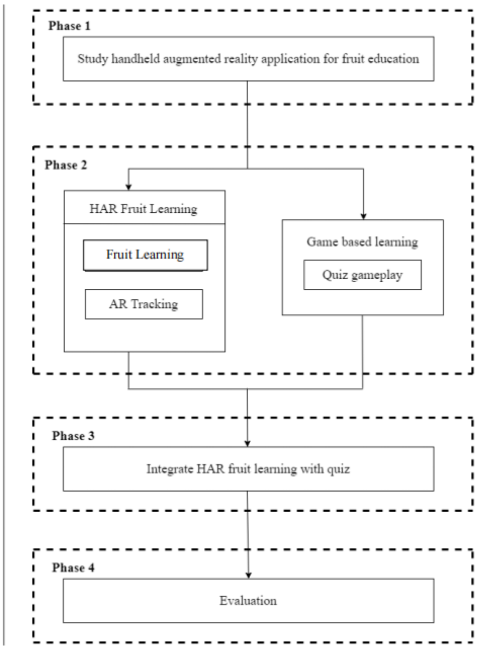

Fig. 4. Phases of project framework

A. Phase 1: Study handheld augmented reality application for fruit education

Firstly, the authors investigated the viability of using AR in developing the proposed application. Apart from that, authors also learnt about the particular learning content such as the composition of fruits and their nutritional value to integrated into the proposed application.

This phase is crucial since it is the fundamental tasks that support the next phase that basing on the information and skills gathered in this phase. Through the study, the data and learning interaction of fruits and nutrition are collected. This phase clarifies the basic concept of AR technology including the definition of AR and AR utilization in education. All the information in this phase is used in the next phase.

B. Phase 2: Develop HAR application for fruit learning

Based on the data collected in the previous phase, this phase is focusing on the design and construction of the AR applications for 3D fruits and nutrition. First, the flashcards that were served as the AR markers were created. Each of the flashcards is designed to suit the learning theme, and the features of the particular flashcard' images are generated to allow the markers to be detected by the camera of the HAR application. Then, the cards were used to register 3D fruits into the physical world after tracked by the built-in camera through the user's handheld devices. Other than that, users can interact with the 3D fruits that appear and get to know the nutrition of the fruits. The interaction features also been designed to integrated in the proposed AR application in orfer to interact with it such as combine two flashcards with tap or drag to combine 2 different fruits for further explanation. The AR application is developed using Unity software with the integration of Vuforia SDK.

C. Phase 3: Integrate HAR fruit learning with quiz

After the development of AR tracking system and other elements, the HAR application is integrated with fruit nutrition learning materials. This HAR application consists of two parts: an AR fruit learning content and user understanding testing content in quiz mode. Before answering the series of quizzes, the user needed to learn about the fruit's nutrition through first by interact with the virtual fruits in AR mode. After went through all the learning process, the user can proceed to the built-in quizzes to test their understanding.

D. Phase 4: Evaluation

The final phase is the evaluation of the proposed HAR application for fruit learning. During this phase, usability and user acceptance testing is conducted to collect feedbacks based on the comments and suggestions made on this application. In this context, fifteen preschoolers are selected to test the prototype. Each respondent was provided with a pre- and post-test questionnaire to evaluate the proposed HAR application for fruit learning. The preliminary questionnaires both pre-test and post-test is attached as Appendices A and B. In addition, this phase also including the data analysis process with discussion on the results received.

IV. SYSTEM IMPLEMENTATION

HAR application for 3D Fruit Learning can be divided into two sections: AR learning process and knowledge assessment process through quizzes. The UML diagram in Fig. 4 depicts the two primary use cases used for this project with included functionality. The project methodology discussed in the preceding section served as the foundation for the implementation phase.

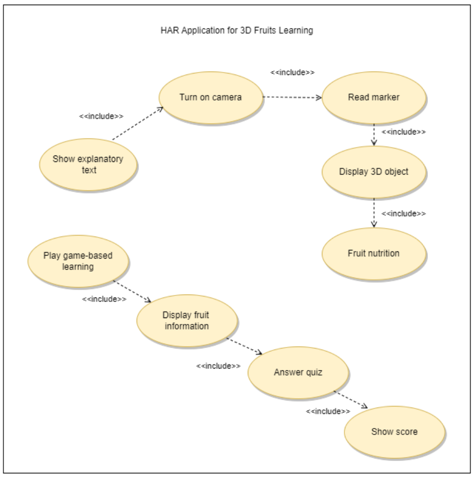

Fig. 5. Use case of HAR App for 3D Fruit Learning

A. Implementation of AR Fruit Learning

The application of AR Fruit Learning focuses on how users may utilize augmented reality to learn about fruits. This phase also focuses on AR user interaction. Fruit learning provides information on the carbohydrate, protein, fat, water, and sugar contents of each fruit. It also includes the recommendation of when to consume the fruit, either during the day or at night, and the benefits of the fruit. This interface will be shown when user tapping on 3D fruit that appear when user scan the flashcard. When a user taps the 3D fruit appeared on the device's screen, the nutrition information appears as shown in Fig. 6.

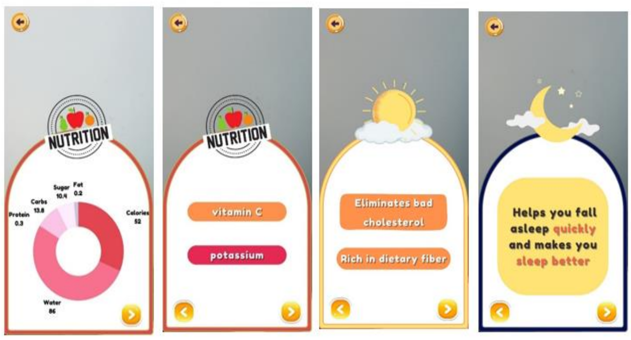

Fig. 6. Learning fruit nutrition information with recommendation

B. Implementation of AR Tracking

In this project, marker-based AR tracking is utilised for detecting the marker on the mobile device. Thus, Vuforia AR SDK is imported into the HAR 3D Fruits application. After successfully imported, App Licence Key is obtained from Vuforia portal and Vuforia Configuration setting is added. As demonstrated in Fig. 7 depicts the set of markers used in this research.

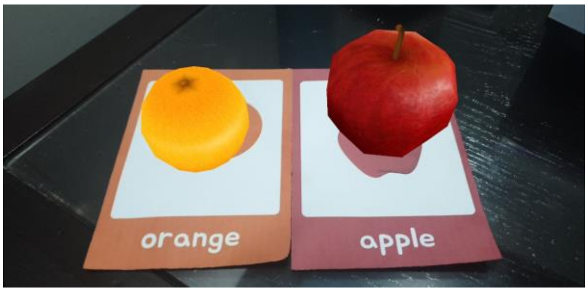

Fig. 7. Multiple image target

C. Implementation of quizzes

The quizzes were used to assess students' understandings after they have learned about fruits and its nutrition. As illustrated in Fig. 8, a quiz interface is developed and produced by using Unity3D.

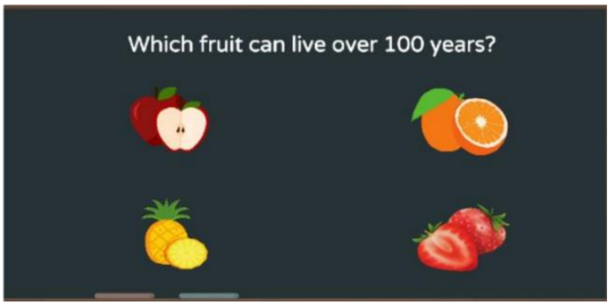

Fig. 8. Example of a quiz question

V. Testing Design

A. Respondents

A total of 15 preschoolers have participated in the experiment. 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.

As stated by [17][18] for usability test that aims to find problem that easy to discover, 5 participants already enough for this purpose. Based on [17][18], 5 participants would expect to find 85% of the usability problems. It is discovered that the critical value between 0.32 and 0.42 were found that indicated that 80% of the usability problems in a test could be detected by 4 or 5 participants.

However, based on some other studies [19], 10 participants is a better number that be able to find 95% of the application or system problems with a lower bound of 82%.

Another study done by [20], 12 participants were needed to find a slightly harder-to-find problems (p=0.15) and wanted to be 85% of finding them. In those previous studies [18-20], the researchers also stated that the testing aim of finding the issues within an evaluation process is not depending on the large numbers of participants that is because repetition may occurred and mostly participants would discovered same problem or issue. As stated in study [20], the research done a likelihood of discovery for various sample sizes and found out that 10 participants could be expected to find nearly all of frequently occurring problems (p=0.25, 94%), and could find out less than half of more rare problems (p=0.05, 40%).

Due to the research and time constraints, thereby this research is stick to 15 participants is believed is an acceptable number for the evaluation stage.

B. Experimental Setup

To begin with the experiment, an AR marker with a card - like size is placed on the table with appropriate position and area. To achieve a better outcome, the location of the mobile device and the user's hand must be aligned. The camera of mobile device which is used to track and display the AR experiment is also need adequately positioned to the suitable position from the marker about 45 cm. The student needs to hold the mobile device with one hand only, while the other hand is for interacting with the HAR Fruit Learning Application through touchscreen input. Then with allocated time of 25 minutes, the student can start the exploration of the application. When exploration was finished, the student needed to answer the questionnaire regarding the application. 5-point of Likert scale with value ranking starting from 1 (strongly disagree) to 5 (strongly agree) has been used to rate the application.

VI. RESULTS AND ANALYSIS

A statistical analysis was applied to the results of user acceptance testing (UAT) and usability testing conducted on the HAR Application for 3D Fruits Learning. Direct observations and questionnaires were used to collect data. The questionnaire is divided into two sections: (a) the pre-test questionnaire and (b) the post-test questionnaire. The pre-test questionnaire asks about past experience with AR besides collecting background information. While post-test questionnaire asks feedback and comment after exploring and testing the application.

A. Usability Testing

According to Fig. 9, 73.3% of participants have reached post-test result point 5, and 26.7% have reached point 4. Utilizing the fruit learning test has increased students' interest in utilizing it. According to the students' responses to the questionnaire, majority of the participants said that after trying the application, their reading skill were improved.

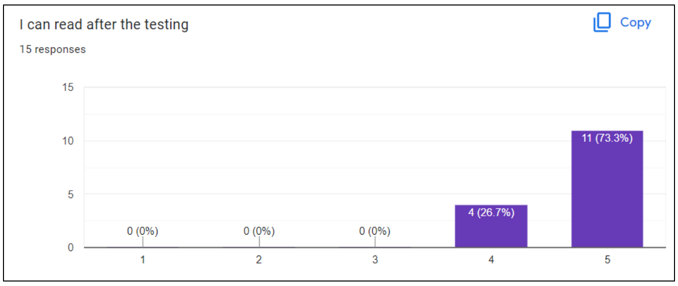

Fig. 9. Reading ability after using application

The following question tests participants' knowledge of fruits and their nutritional value after using this app. 80% of respondents indicated that they knew more about fruits than before. As depicted in Fig. 10, nearly all respondents indicated that they had gained substantial fruit knowledge.

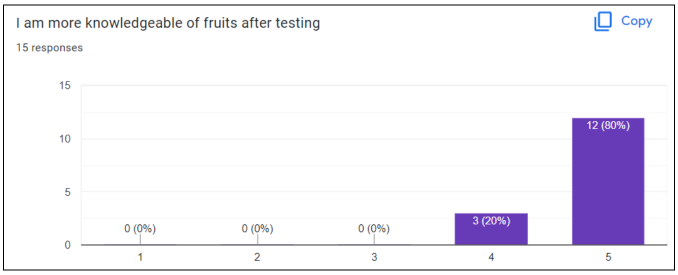

Fig. 10. Knowledge of fruit and nutrition after using the application

According to Figs. 11 and 12, the majority of preschool students were unaware of AR technology before. After using the proposed application, the findings show an increase in the proportion of preschoolers using AR technology in their learning process.

Students' interest in AR technology also increases after using the fruit learning app, with the majority of participants (93.3 %) reporting high levels of interest (Figs. 11 and 12). They are interested in AR fruit-learning applications.

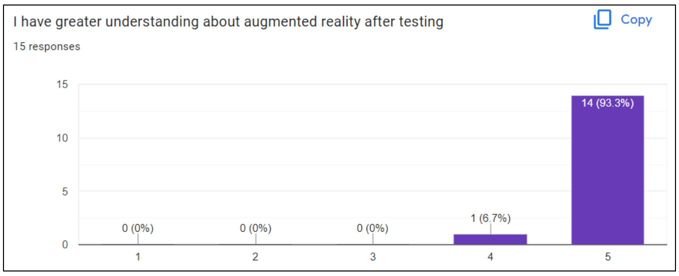

Fig. 11. Student's knowledge of AR

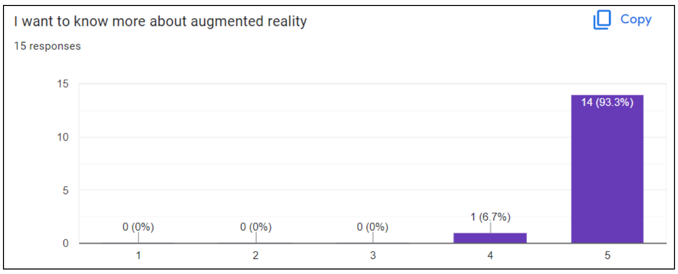

Fig. 12. Student's interest in AR technology

When asked about is it the proposed application is easy to use, 80% of respondents strongly agree with the statement. While the remaining of 20% respondent also agree with the statement as illustrated in Fig. 13. Fig. 14 showed that 86.7% of respondents are strongly agree the application is user friendly and 13.3% also agree with the statement. This question is greatly related with the use of strategically color and texture for the UI, realism of 3D models and the rendering on screen.

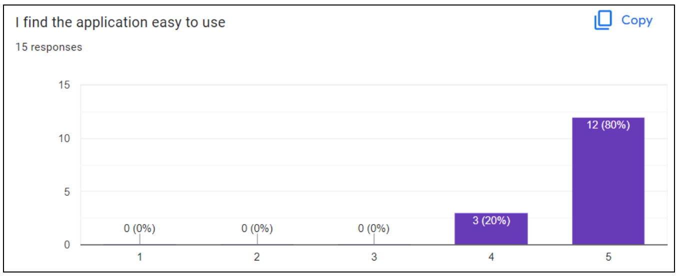

Fig. 13. Students are very easy to use this application

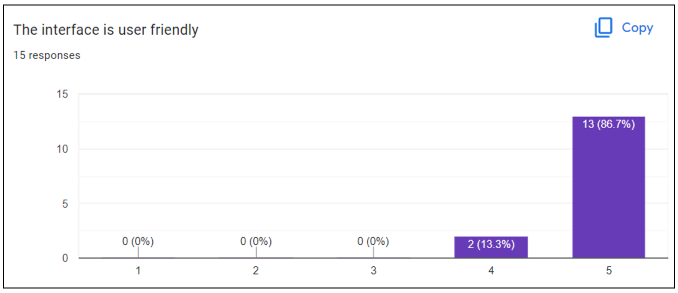

Fig. 14. The interface is user friendly

Users' perception were mostly favourably to the application. Based on Fig. 15, almost respondent (86.7%) strongly agree followed by 13.3% of them also agree the learning objective of the application is clear enough. This is because the instruction provided was able to help them to act accordingly in order to achieve goal of the playtime.

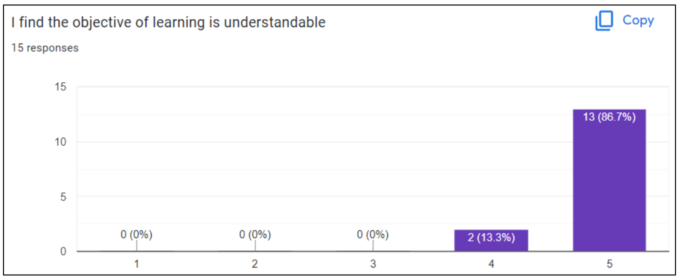

Fig. 15. Students understand the learning objectives

The respondents were also asked about effectiveness of the application in aspect of knowledge. Majority of the respondents with 93.3% strongly agree that they want to know more about fruit nutrition. The remaining (6.7%) of respondent agree with the statement. This is because almost of the respondents had try all of the experiment being provided and want to remake again the experiment. Fig. 16 depict the data.

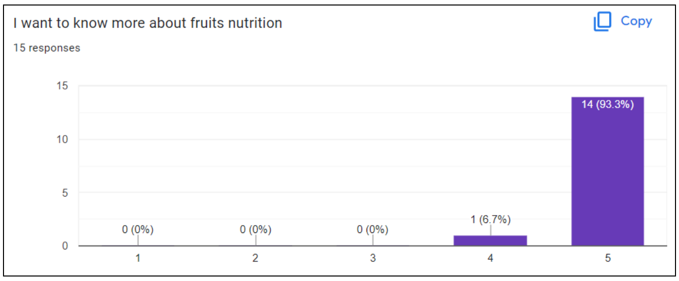

Fig. 16. Student's knowledge increases after playing the quizzes

VII. CONCLUSION AND SUGGESTIONS

In conclusion, this application successfully meets all of the three objectives of this project. The application also well integrated and able to help the students to learn fruit in an interactive and fun ways.

The next thing that can be done is making the user interface more responsive. More interactive features can be added and more learning content can be integrated such as both the portrait and the landscape views are available for perusing its contents. When the user rotates their mobile device, so does the program's user interface will also rotate. Additionally, because ARCore is compatible with iOS and Android devices, it has the potential to be utilized in the near future to solve the issue of insufficiently supported device platforms.

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