DEVELOPMENT OF AUGMENTED REALITY APPLICATION AS A LEARNING TOOL IN BIOLOGY EDUCATION

BY

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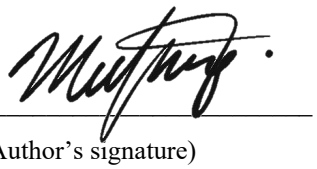

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It is hereby certified that ***YONG MEI TING*** (ID No: ***21ACB05921***) has completed this final year project entitled *"Development of Augmented Reality Application as a Learning Tool in Biology Education"* under the supervision of Dr. Lim Ean Heng (Supervisor) from the Department of Information Systems, Faculty of Information and Communication Technology.

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ABSTRACT

This project presents the development of an Augmented Reality (AR)-based mobile application designed as a learning supplement specifically for secondary biology students in Malaysia. Although many countries have widely adopted AR technology in the education field, AR technology in education in Malaysia remains in its start-up and trial stage. There **is** a lack of dedicated applications that fit the school syllabus in Malaysia, and most schools still teach biology using traditional methods such as textbooks. While some biology-related AR applications **exist** on the market, their scope is typically general and may not serve as effective learning tools for students. To address these issues, this project aims to develop a Markerless AR mobile app that enables students to learn abstract concepts in a more engaging way by interacting with biological models virtually in the real world, without the need for markers. Additionally, to maximize the app's effectiveness, a gamified quiz module **is** integrated to reinforce learning through interactive assessments, promoting student engagement and retention. The app has undergone comprehensive system testing, expert evaluations, and user experiments to assess its effectiveness in improving educational outcomes. This project contributes to the modernization of biology education in Malaysia, offering a more immersive, interactive, and enjoyable learning experience for students.

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APP	Application
AR	Augemented Reality
UI	User Interface

CHAPTER 1

Introduction

This chapter will thoroughly explore the background of the chosen topic of Augmented Reality and its implementation in education especially in the Biology field, carefully identifying the underlying issues and defining the motivation driving this project. Additionally, this chapter will also delineate the project scope and objectives as well as highlight the contribution that is going to be established by this project.

1.1 Background of the Project

In Malaysia, students in science stream will generally start to study Biology subject during their secondary education. It is especially crucial to ensure that they have a strong basic of fundamental Biology knowledge before they are involved in higher education which Biology topics become more advanced and complex. However, without a clear strategy of learning, aids from visual representations or hands-on practicals, Biology is often perceived as abstract, overwhelming and difficult to understand by high school students as they often need to use their imagination by only referencing from their textbooks [1]. For instance, it would be hard for them to imagine the exact structure of a cell or an organ by just looking at the 2-dimensional and non-interactive figures from their notes. Such difficulties in understanding the Biology concepts hindered students' interest and motivation in studying Biology, causing the learning to become more ineffective [2].

With the awareness of such challenges faced by the students, traditional Biology teaching methods had improved to demonstrate concepts by using physical models such as 3D printing models of human organs, systems as well as cells. This improvement indeed has helped students to visualize and understand better, promoting higher engagement and interaction in the classroom [3]. However, such models are usually costly and with limited availability [4]. Students are only able to use the models in the laboratory and need supervision from teachers or lab assistants. Moreover, the physical models provide limited details, thus, students will still need to refer to their textbooks

or lecture notes to look for more information in order to have a thorough understanding of the concepts.

To address issues related to the ineffectiveness of traditional teaching methods of Biology, technologies have been introduced tremendously into the education sector and started to become a norm, especially in developed countries. For example, the use of Augmented Reality (AR) technology in illustrating objects in 3-dimensional virtually in real space. AR is defined as a system that merges the physical and virtual environments, allowing for real-time interactions through precise registration of virtual and real objects [5]. In the context where the real world is blended with the virtual world, AR brings immersive experiences facilitated by technology to its users which also drastically promotes the users' engagement and interactions [5], [6]. Due to its ability to effortlessly demonstrate abstract contents virtually in a real environment, AR has been widely used in many fields, especially for educational purposes in recent years, in subjects such as Physics, Chemistry, Biology and so on. Studies have shown that AR is able to facilitate the students' learning experience and effectiveness [7], improving their academic achievement in some subjects such as Biology [8] and Physics [9]. While the implementation of AR in education in Malaysia is still in the start-up and trial stage, therefore it is worth investigating and exploring the effectiveness of the application of AR in education. In this project, the study of the effectiveness of the developed AR application in Biology education for Malaysia secondary Form 4 students will be focused.

1.2 Problem Statement

1.2.1 Ineffectiveness of Traditional Teaching Methods in Biology Education

The traditional teaching methods in Biology education such as studying from textbooks or physical models from the laboratories are ineffective as students could have difficulties in visualizing or imagining some abstract concepts or structures [1]. This challenge faced by the students led to the decline of their interest and motivation and an increase in their negative attitudes towards learning Biology. Due to the lack of effective tools that could help them to be more engaged in the learning process, they

often perceived studying Biology as hard, boring and largely depended on memorization from the textbooks rather than understanding [1].

1.2.2 Lack of Dedicated AR Learning Application that Fits to a Specific Syllabus

By observing the existing mobile applications available in the app marketplace, there is a lack of dedicated AR Biology Applications that can serve well as learning supplement for secondary school students. Most similar applications that are publicly available in the market are too general and have limited content depth to fit into a specific syllabus [10]. Some similar apps with richer coverage of biology topics would generally need expensive subscriptions for access and the contents have no guarantee of helpfulness for a student that follows a designated curriculum. Other than that, most development of AR educational applications are mainly involved in the engineering and medical field at the tertiary level while secondary level education is less focused [11].

1.2.3 Ineffectiveness of Existing AR Biology Learning Applications

In overview of the existing applications that openly available in the current market, there exists multiple deficiencies that hinder the effectiveness of the applications in facilitating biology learning experiences. Some applications have poor navigation design [12] which could lead to steeper learning curve especially for novice users that have limited experience with the similar applications. Other than that, most applications provide only standalone AR features and without feedback mechanism, which may lead to insufficient engagement and hinder the effectiveness of the learning application. To enhance the effectiveness of educational apps, the apps should not only deliver educational content but also actively engage users to promote learning outcomes effectively. Research suggests that successful educational apps should combine elements such as autonomous learning, motor skills, task structure, engagement, language demand, and personalization [13].

1.3 Motivation

This project aims to develop an AR-based mobile application that acts as a learning supplementary tool that improves the effectiveness of the learning process by secondary school students in the Biology subject. The proposed application is expected to be enhanced from the existing similar applications in terms of its functionalities, content design as well as interface design, providing students with an application that is easy to use and can learn Biology interactively and engagingly, boosting their learning interest and effectiveness. Most importantly, this project hopes to provide a meaningful application that is integrated with the curriculum rather than for general usage only.

1.4 Project Scope and Direction

At the end of this project, a Markerless AR-based mobile application will be developed to serve as a supportive tool in Biology education for secondary Form 4 students. This application will encompass two major modules, which are the learning module and the quiz module. In the learning module, a few topics from the Form 4 Biology syllabus that would need visualization for better understanding will be covered. The users will be able to interact with the biological 3D objects virtually in the real environment by zooming, rotating, moving and selecting model's part to view the information displayed on screen. The purpose of the quiz module is to reinforce students' knowledge and serves as a feedback mechanism to ensure that their learning from the AR illustrations is effective. To maximize the learning experiences, the quiz module will also adapt the gamification learning approach to enhance the user retention and motivation in learning through features such as point scoring, competition with other users and leaderboard.

1.5 Project Objectives

The overall goal of this project is to develop an improved AR-based educational mobile application in the Form 4 Biology context that can address the ineffectiveness of conventional teaching methods and current existing solutions. The detailed objectives are as follows:

1. To investigate the current teaching methods used in secondary Biology education in Malaysia.
2. To propose the development of an AR-based mobile application as a learning supplement that is integrated with the secondary Form 4 Biology curriculum.
3. To verify the effectiveness of the developed application as a supportive tool in secondary Biology education.

1.6 Contributions

The development of the application that tailored to the biology students could potentially create a transformative shift in the way students learn the complex biological concepts by providing an immersive and interactive learning platform, minimizing the gap between theoretical knowledge and practical application of AR technology. The impact of this project is significant as it overcomes the limitations of traditional teaching methods, facilitating deeper understanding of the abstract concepts through visualization and interaction. This initiative converges technology and education, offering an effective solution that allows Biology to be more accessible and engaging for students across diverse learning environments.

1.7 Report Organization

This project is structured to have seven chapters, beginning with the first chapter on the introduction of the selected topic and an overview of the problems, motivation, objectives, scope and contributions. Chapter 2 focused on the literature review of the prior works, comparing the strengths and weaknesses of the existing similar applications to provide a foundation for the proposed method. The following Chapter 3 and Chapter 4 delineated the project's design specifications, methodology and planned

timeline for the project development. System Implementation in Chapter 5 reported on the development and implementation phases followed by Chapter 6 which assessed and evaluated the functionality, usability and effectiveness of the developed product. The last chapter summed up the key components involved in this report and proposed several recommendations for future work.

CHAPTER 2

Literature Review

This chapter provides a comprehensive review of the technologies relevant to the development of an AR-based biology learning application and discuss the differences between marker-based and markerless AR systems. Following this, the chapter reviews previous works on AR mobile applications for biology learning, providing a comparison of these applications. Based on the findings from the literature, the chapter then focuses on user requirement gathering and concludes by outlining the proposed solution, addressing the gaps identified in previous studies.

2.1 Review of Technology

2.1.1 Augmented Reality (AR) in Education

Augmented Reality augments what we see from the digital devices such as smartphones and tablets by superimposing digital contents such as text, images and 3D objects onto the real environment, enhancing users' perceptions of reality with the interactive and immersive experiences that due to the blending of virtual objects with the physical world. The implementation of AR usually can be realized using hardware devices such as smartphones, tablets, and AR glasses, which are equipped with cameras, sensors and capabilities to render AR content.

In the educational context, AR has been applied in various subjects, transforming traditional learning methods by replacing dull 2D contents on books with dynamic and interactive contents that not only engage students but also enhance their understanding of complex and abstract subjects. For example, in science subjects, abstract concepts are brought to life by enabling students to explore with the science structures and elements in their 3D forms in real-world environment, allowing immersive observation and interactions with the elements for better retention and comprehension. Another example would be overlaying historical elements and artifacts onto physical locations in history lessons to allow students to have a tangible connection to the past, better understanding and experiencing the historical events.

Several studies have shown that AR technology possesses numerous advantages when used in educational settings. For instance, from the study by Chang and Hwang [14], it is found that with the help of AR guiding mechanism, there are significant improvements in students' learning performance and learning motivation due to the engaging and interactive nature of AR that helps in better retention of concepts as well as immersive experience provided by AR that promotes students' active participation in learning process. Another study [15] had shown that the use of AR application in the educational environment improves students' spatial abilities as they were able to interact with the digital object in real time and visualize how these objects fit and function within their environment, developing comprehensive understandings on the spatial relationships and dimensions of complex structures.

2.1.2 Virtual Reality (VR) in Education

Unlike AR that blends virtual digital elements with real environment, Virtual Reality is another technology that immerse users in a fully virtual environment generated by computers, providing a complete sensory immersion experience which is dynamically controlled by the actions of the user [16]. There are two common types of VR, which are non-immersive VR and immersive VR. Non-immersive VR generally requires only digital screen for users to look into virtual world while immersive VR has to be done with VR headsets and motion controllers in order to enable the user to immerse into the virtual world and interact with the virtual elements.

There are wide range of applications of VR in education. For instance, in the medical education, VR provides a virtual environment that simulates the real-life scenarios, allowing the medical students to carry out medical trainings and experiments in a safe and risk-free environment, improving their hands-on skills and preparing them for real-life practices [17]. Other than that, VR also able to help in visualizing the complex subjects such as space technology and mathematics, demonstrating the concepts such as solar system and geometric shapes with dynamic 3D models to allow students to explore and interact with the virtual models [17].

The advantages of VR in education are similar to AR. For example, immersive VR provides engaging, interactive and immersive learning experiences for students and

help them in visualizing abstract concepts and simulating events that are not perceivable in real life, facilitating better comprehension and retention of learning [18].

2.1.3 Comparison of AR and VR in Education

In terms of immersive experience, although both AR and VR offer immersive learning experiences, there are different extents of immersive level depending on the type of technology used and the context of using. AR overlays virtual elements onto the real world, combining virtual content with the physical environment, making the abstract concepts more tangible and providing contextual learning experiences that enhance engagement and retention without isolating them from their physical environment [19]. The application of this technique can be realized simply with the mobile devices. In contrast, for VR, it is often work better with the aid of VR headsets or high-end computers to fully immerse the user into the virtual world. However, the cost of these VR hardware is still higher than most people can afford in the current market [20]. Hence, AR is more accessible than VR in view of their cost and hardware requirements.

Since AR typically requires only mobile devices such as smartphones and tablets, it is more cost-effective, convenient and easier to implement and use than VR that often used along with expensive headsets and high-end computers. In addition, wearing VR headsets often cause disorientation or motion sickness for some users, limiting the duration and effectiveness of the learning sessions [21]. Thus, AR seemed to be a more practical choice in educational settings due to affordable budgets and lower entry barriers.

2.1.4 Marker-Based AR

Marker-Based AR is one of the types of the augmented reality techniques commonly used in various applications, especially in educational settings. It works by detecting predefined markers such as printed images or objects that with visual features that can be easily extracted to trigger and overlay the 3D digital contents in the real environment through a device's camera. Despite this approach is popular due to its high reliability as well as ease of implementation and use [22], it has weaknesses such as

limited flexibility due to its dependency on physical markers, which means that the application will not function if without the materials containing the markers or the markers are obscured or damaged.

2.1.5 Markerless AR

Markerless AR is another AR technology that can overlay digital contents onto the real environment through a device's camera without the need for physical markers. The placement of the 3D augments is done by simply capturing and scanning surfaces and grounds in the environment; therefore, it offers greater flexibility and stability as it is not confined to any predefined markers, allowing implementation of more dynamic applications. However, it suffers from the challenge of potential accuracy issues due to environmental factors [23].

2.1.6 Comparison of Marker-Based AR and Markerless AR

Table 2-1 Comparison of Marker-Based and Markerless AR

Criteria	**Marker Based AR**	**Markerless AR**
Flexibility	Limited flexibility. Requires markers to trigger digital contents.	More flexible. Does not require markers and can function in most environments. Free to move around the 3D models.
Accuracy	More accurate in controlled environments.	Potential accuracy issues due to environmental variations.
Stability	Relatively lower. Greater distance between camera and the markers, greater	Relatively higher [23].

	magnitude of shake of the 3D models [23].	
User Experience	Lesser freedom and immersion as the camera must be pointed to the physical markers to interact with the models.	More freedom and immersion due to the absence of physical markers. Can interact with the models at any angle and position.
Educational Outcomes	Highly responsive to students' learning demands. Improves students' learning outcomes more than traditional learning methods [24].	Effective in responding to students sensorimotor learning demands. Improves students' learning outcomes more than traditional learning methods [24].

In short, marker-based AR and markerless AR have respective pros and cons. While in educational settings, both technologies are proven to be able to improve students' learning experiences and achievements. For marker-based AR, it is known for its high accuracy in controlled environments. However, it has limited flexibility, stability and user freedom due to the need of physical markers to trigger the functionalities and these markers could sometimes be subjected to damage—such as getting wet, which can cause blurriness, or tearing apart—the app will be unable to detect the markers [25]. This will render the app unusable until new, undamaged markers are obtained. In contrast, although markerless AR might face accuracy issue due to environmental variations, it provides greater flexibility and user freedom as it does not require markers to trigger the functionalities, allowing user to interact with the contents at anytime and anywhere. Despite the various benefits and limitations, the suitability of the technology to be used would depend on the educational requirements and designs as well as user preferences in later sections.

2.2 Previous Works on AR Mobile Application in Biology Learning

2.2.1 Science AR

General Introduction of the Application:

Science AR is an augmented reality app that contains 3D models in science subjects such as Physics, Chemistry, Biology and Maths. It is a free educational application developed by Imran Khan [26] to help students visualize abstract scientific concepts from different perspectives as well as get to interact with the models in a way that is far more engaging than 2D images can. After opening the app, a home page (Figure 2-1) is displayed with 3 buttons, explore models, search models and notifications. Inside the explore models screen, the subjects are divided into 4 respective science categories (Figure 2-2), this review will be only focused on the biology module (Figure 2-3) which consists of models such as brain, hand bone, heart, deoxyribonucleic acid and so on.

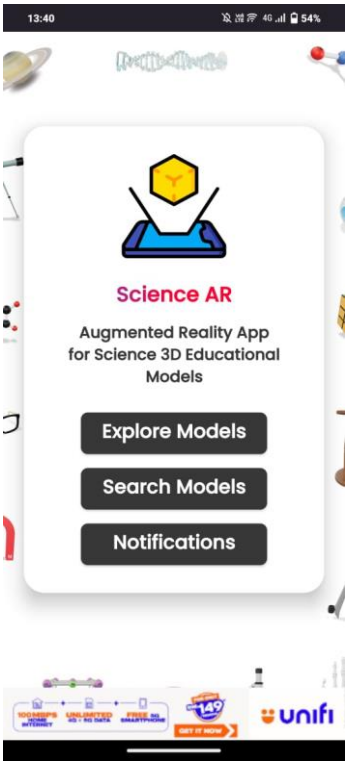


Figure 2-1 Home Screen of Science AR

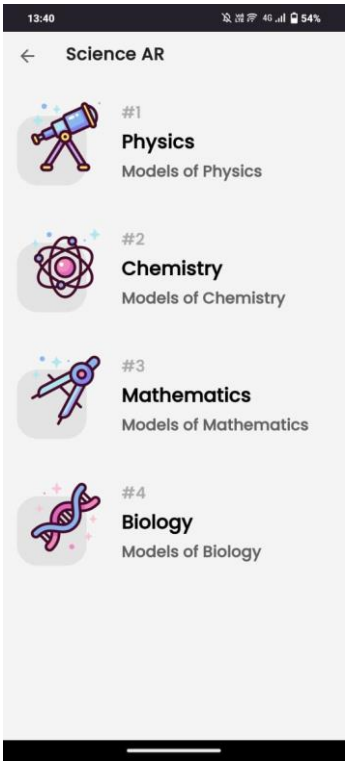


Figure 2-2 Explore Models Screen

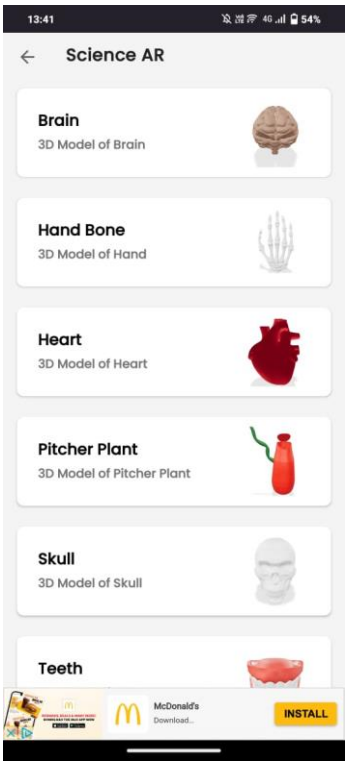


Figure 2-3 Biology Models

Features of the Application:

By selecting a model, a detail page of that particular model (Figure 2-4) will be displayed, and users can choose to view the model in their space. Before viewing the model, a user can also choose to share the model to their friends by clicking the share button and the model link can be shared through various social media channels. To view the model, there are 2 options for the users. They can choose to view the model virtually in virtual space or their real environment through their devices' cameras. The app would require them to scan a empty space then the model will be displayed on the space (Figure 2-5) (Figure 2-6). A user can observe the model by zooming in and out and also by 360 degrees rotating the model. A user can view the model from different angles as well by moving their devices around and they can take a picture of the model and the picture will be saved into their devices' gallery. If the users are not likely to view the model in their real space or when their physical environment conditions are not desired, they can always choose to view the model on a blank white background (Figure 2-7). Other than that, this app provides helpful tips for users (Figure 2-8) when scanning the environment for a better user experience.

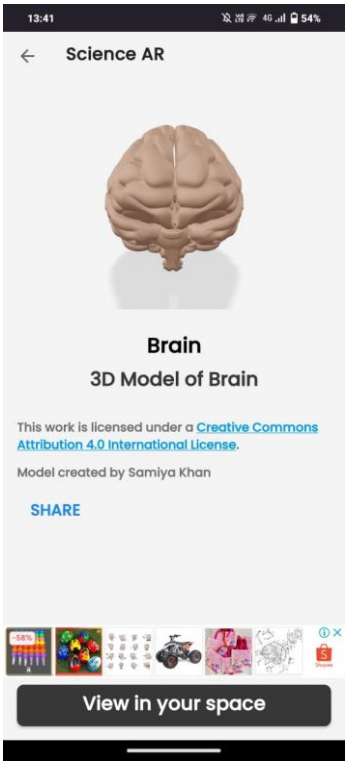


Figure 2-4 Model Detail Screen

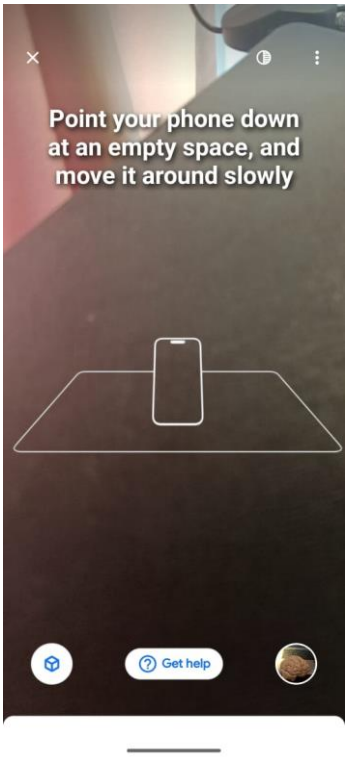


Figure 2-5 Scanning the Space

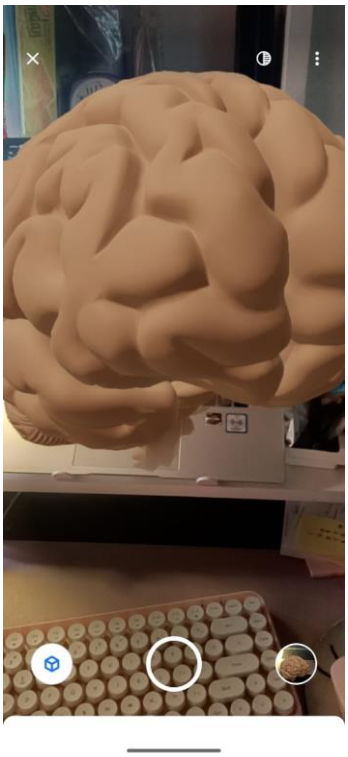


Figure 2-6 Model Display

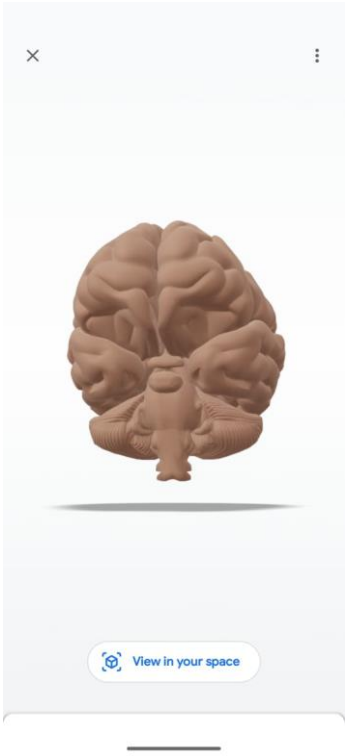


Figure 2-7 View Model in Virtual Space

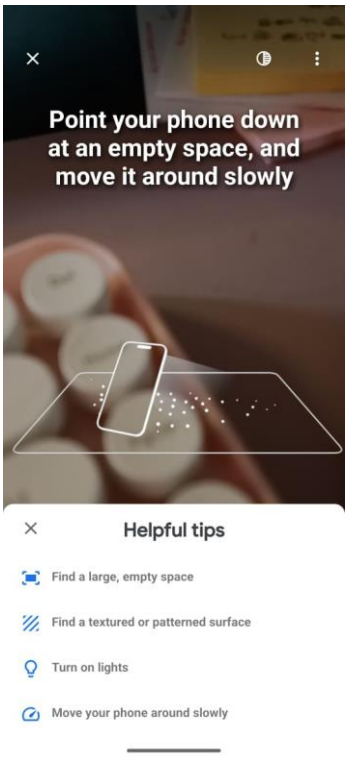


Figure 2-8 Helpful Tips for Space Scanning

Strengths of the Application:

Science AR provides an effective design of the user interface and the navigation itself is clear, user-friendly and intuitive as users can learn to navigate around the app within a short time. The well content organization by categories and search models function (Figure 2-9) further enables users to locate their desired models quickly and easily, increasing the effectiveness of their self-learning process using this application. Assistance is also available by providing instructions overlaying on the camera screen to aid users in their scanning process before displaying the model. The photo-taking feature enables users to record certain model's parts for their own future reference or to share with their friends for easier discussion. Furthermore, the interactions such as moving rotating and zooming of the model are easy and smooth.

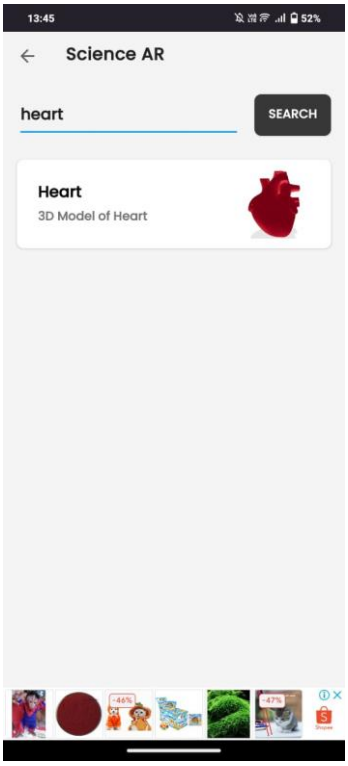


Figure 2-9 Search Model

Weaknesses of the Application:

This application is considered a very general supportive tool for educational purposes as it is not informative enough. There are no texture labels or information associated with the model, thus the students are not able to have a deeper insight into the concepts behind the model and might need to refer to alternative resources to have

further understanding. Furthermore, this application lacks some action buttons such as the interaction buttons and a button that enables the zoomed or moved model to go back to its original view. The lack of these buttons might decrease the user-friendliness of the app as some users might not be familiar with the operations to interact with the models. Moreover, this app does not provide instructions or tutorials for navigation which might be a bit troublesome for a first-time user when exploring the application.

2.2.2 High School Anatomy 21

General Introduction of the Application:

High School Anatomy 21 [27] is an AR-based educational app developed by Virtual Medicine for secondary school students to study human body systems such as skeletal, muscular, nervous system and so on with multiple interactive functions such as combine, layer, highlight and so on. The models will be displayed in real-world environments through devices such as mobile phones and tablets in their 1:1 actual size. The information regarding the anatomy parts will be displayed along with the model.

Features of the Application:

The model will be displayed straightaway after the app is opened and the user can start to interact with the model by moving, rotating and zooming as well as selecting the parts to view the details (Figure 2-10). In the textual information section, users can click on the audio button on the right side to listen to the pronunciation of the selected part of the anatomical model. There are four buttons below to let users choose either to only view or focus on the selected part (Figure 2-11). Other than that, users can click on the AR button in the middle of the screen to display the model in actual size in their real environment.

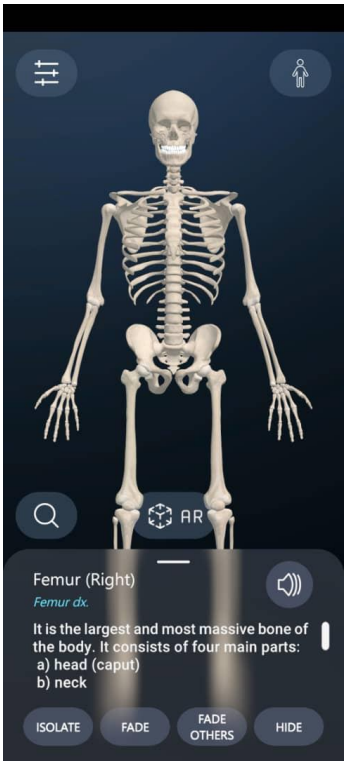


Figure 2-10 Information Display

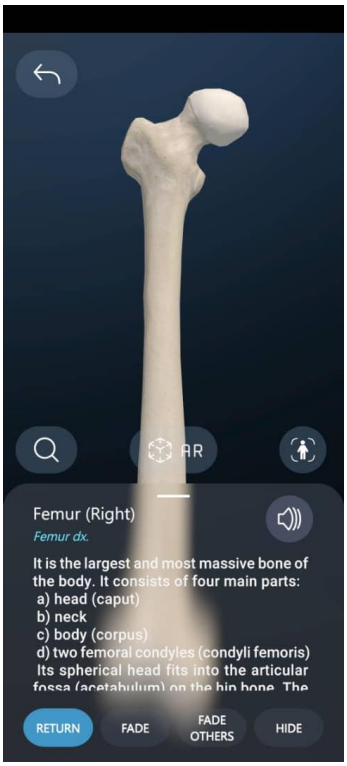


Figure 2-11 Isolating the specific selected part of the model

After entering the AR mode, the user will need to scan around their environment before the model can be displayed (Figure 2-12). In real environment modeling, users can move the model to different positions around their environment and interact with the model by moving around the devices to see different perspectives of the model and selecting the parts to see the detailed information (Figure 2-14). The model could be resized by toggling the button on the left side of the screen.

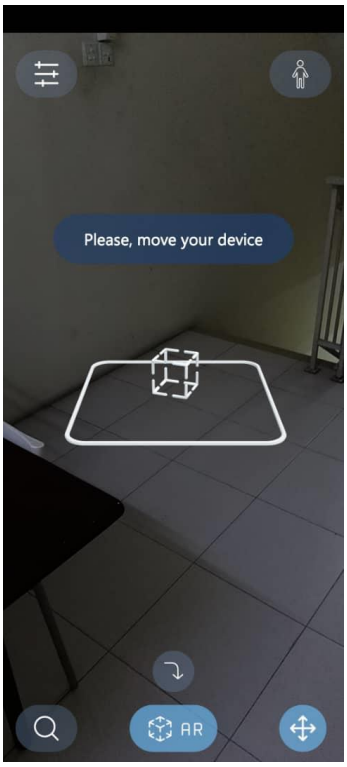


Figure 2-12 Environment Scanning

Figure 2-13 Positioning of 1:1 Model in Real Environment

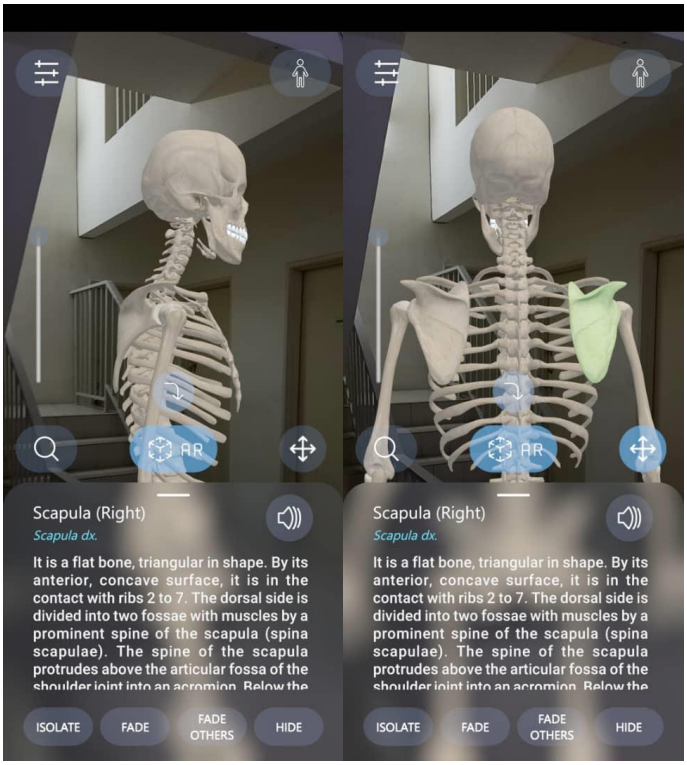


Figure 2-14 Interacting with the model

At the top right of the screen, users can change to other models according to different human systems (Figure 2-15), however, most of the models will need to be subscribed. While the settings button is at the top left corner of the screen and users will be able to find some basic settings and also the ways of control such as rotating, selecting and centering are indicated in that section (Figure 2-16). Meanwhile, users can search for a model quickly using the search function at the bottom left of the screen.

Figure 2-15 Selecting other models

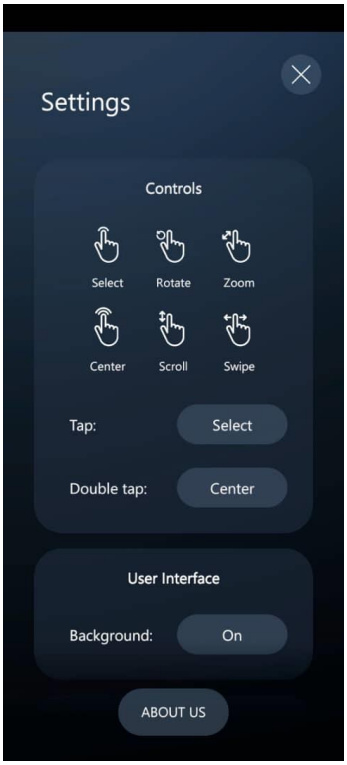


Figure 2-16 Settings of the app

Strengths of the Application:

First of all, this application provides abundant human organ models, and all parts of the model are provided with very detailed textual information and there is even an audio function for reading the human parts which is very useful for students if they are not familiar with the pronunciations of the certain organs or parts. Furthermore, this application provides the function to let users zoom and focus on observing and interacting with a particular selected part of the model, the unwanted parts of the model can be hidden so that it can give a clearer view for the users on their selected part. Moreover, the interactive functions such as moving around with devices to see the different parts of the model in AR mode and moving and rotating the model in the devices are very easy and smooth. Despite there are quite a lot of different categories of the human system, users still be able to locate their desired models by using the search function provided.

Weaknesses of the Application:

Despite there are quite a few enriched functions provided by this application, there are still some limitations noticed from the reviewing of the application. For example, there is no home screen for this application, the user will straightaway reach the model screen after the application is opened and this may result in a feeling of disoriented from the users as there is a lack of a central or starting point for navigation and subsequently decrease the user experiences. Besides, this application does not provide a help button or instructions for navigating the application which might increase the user learning curve and frustration with using the app, consequently decreasing user satisfaction. Other than that, this application provides limited free models for trial only, most models would need a subscription of around 55 Ringgit Malaysia every year, which is not so accessible for some students.

2.2.3 Complete Anatomy 2023

General Introduction of the Application:

Complete Anatomy 2023 [28] is a comprehensive AR-supported anatomy learning platform offered by 3D4Medical from Elsevier to Biology or Medical students. It is a flexible and personalized learning tool with incredibly detailed and large amounts of 3D models that aid in visualizing the human body for better understanding. This tool is powerful as users can customize the models based on their preferences and interact with the personalized models. Other than that, this app provides animation videos to visualize and animate concepts such as muscle movement or skeletal movement, meanwhile, it also offers abundant clinical-related courses to its users (Figure 2-17).

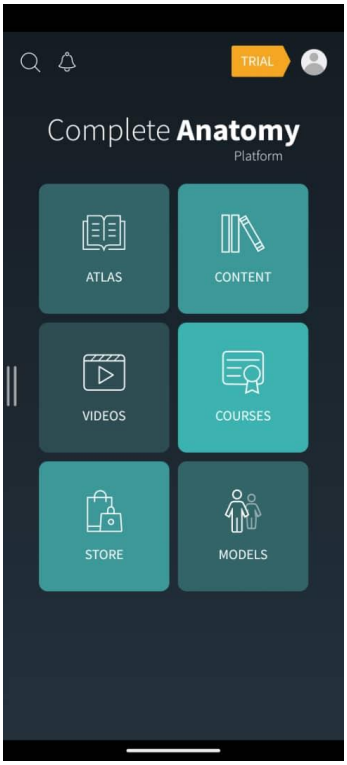


Figure 2-17 Home Screen of Complete Anatomy 2023

Features of the Application:

Before playing with the models, the application will require the user to customize their human model, by choosing their preferred facial features and also skin tone (Figure 2-18). After that, users can navigate to the menu “Atlas” and start to choose the anatomy models for different human systems. As there are 750 models available in the library, to help users quickly locate the item they want, the app provides filtering, sorting and searching functions (Figure 2-19).

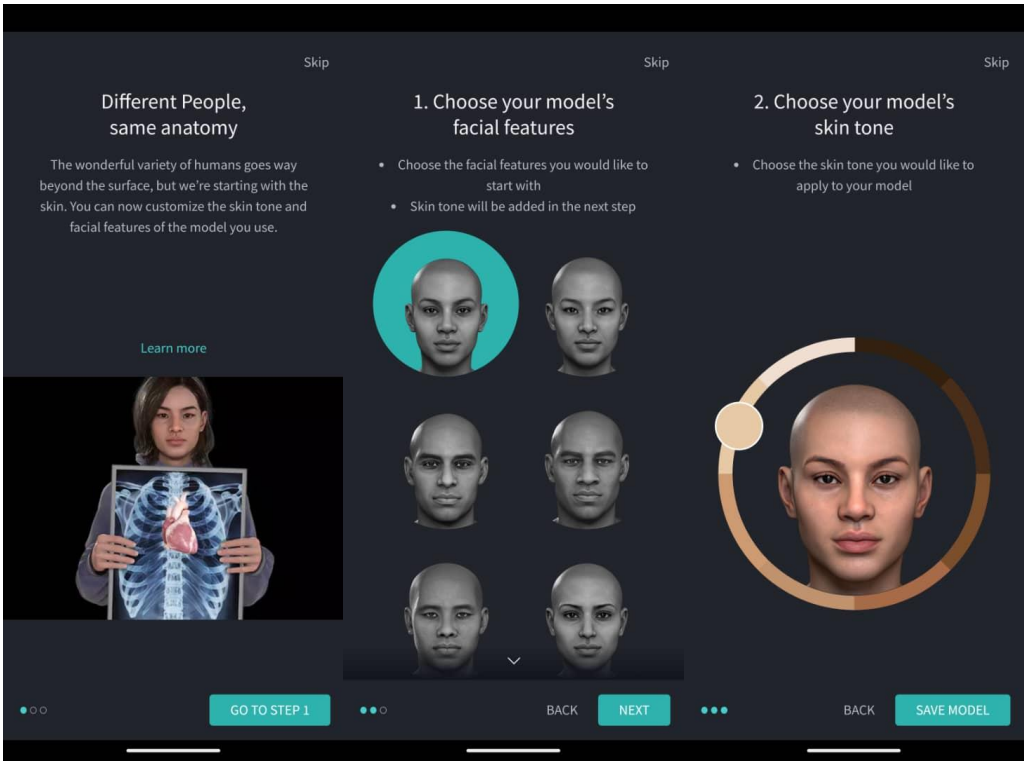


Figure 2-18 Customization of Model Appearance

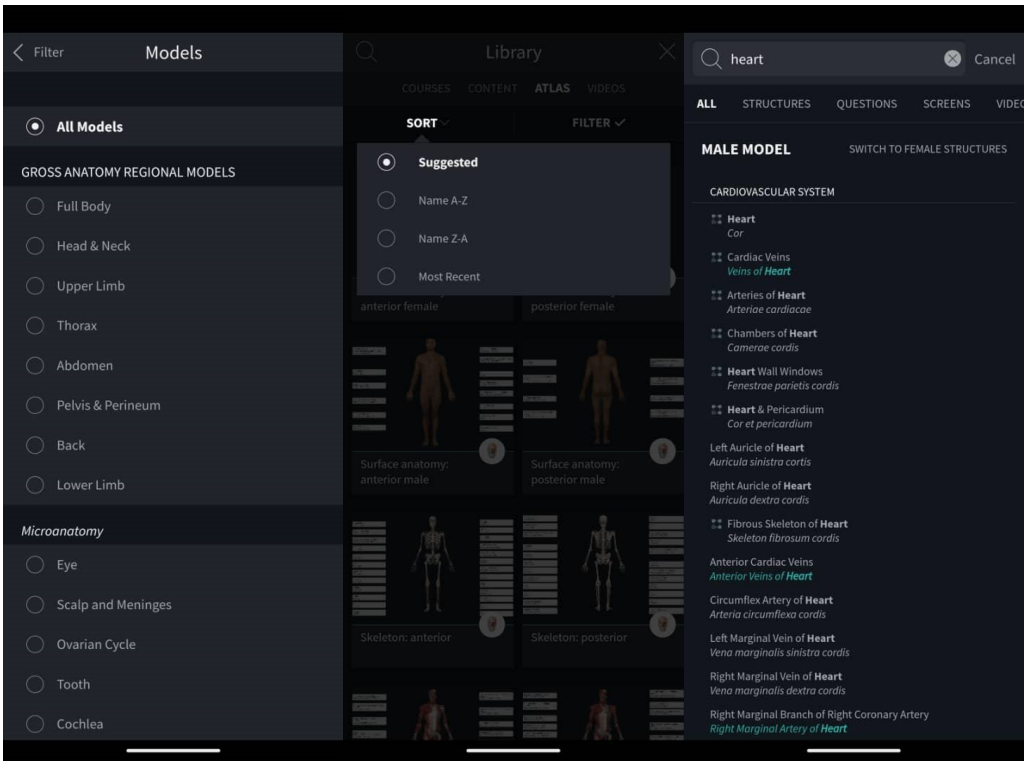


Figure 2-19 Filtering, Sorting and Searching functions

After selecting a model, users can view the model in either virtual or physical environments by selecting the AR mode button (Figure 2-20). Labels associated with the body part are displayed on the screen, and users can view the detailed information by either selecting a label or clicking on the particular part of the model (Figure 2-21) (Figure 2-22). For the interactive functions with the model, this application provides users the ability to move, rotate and zoom the models. In the AR mode, other than move, rotate and zoom, users can move around their devices to observe the models from different angles as well.

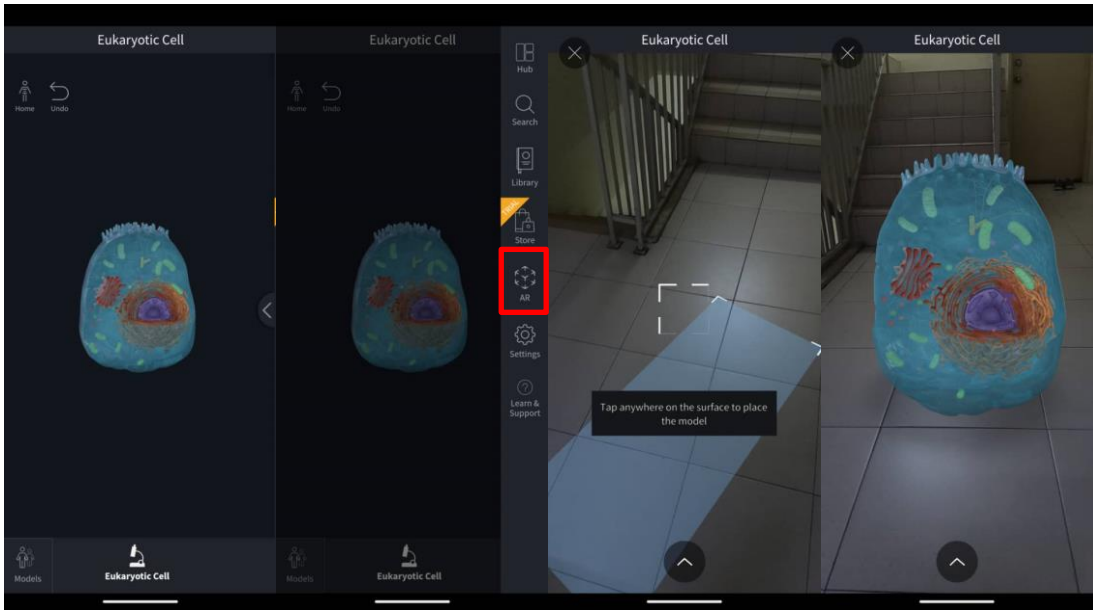


Figure 2-20 Virtual and Real Environment Model Display

Figure 2-21 Labels of the Model Parts

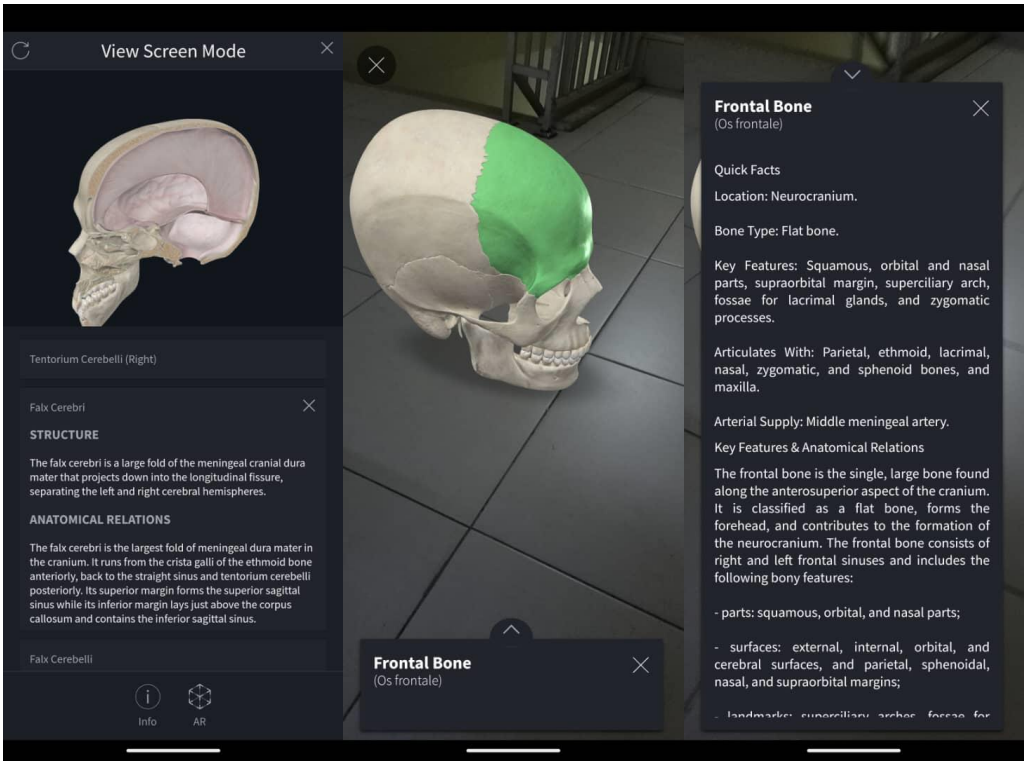


Figure 2-22 Displaying of Textual Information

Strengths of the Application:

One of the notable functions of this application is the user tutorial provided for users to shorten their learning curve on this app by educating the users on how to navigate between the app interfaces and also how to interact with the model (Figure 2-23). There is also a “Learn & Support” button at the right-side menu for users to obtain more information regarding how to use the app by either accessing video tutorials and blogs or contacting customer support. Other than that, this app also provides the audio function for the title of the human parts and the descriptions provided are very detailed and the content is accountable to the source of the references provided below (Figure 2-24). Furthermore, this application provides other modules such as animation videos and clinical courses that further enable the students to have a deeper understanding and insights into human anatomy topics (Figure 2-25).

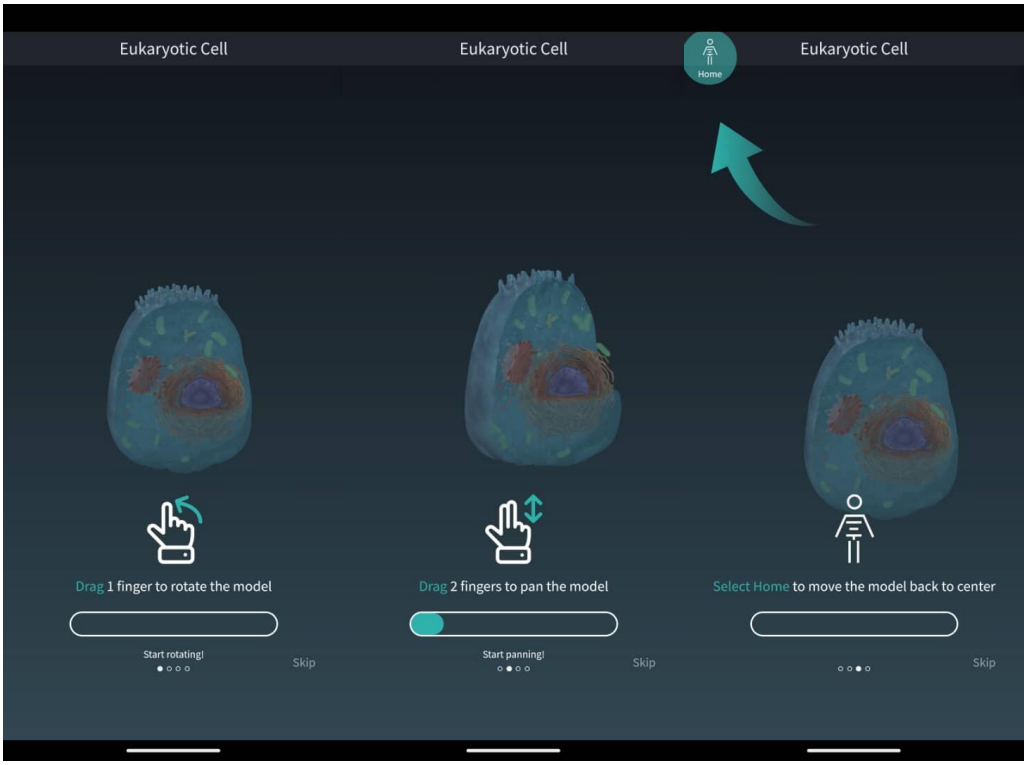


Figure 2-23 Tutorial on Model Interaction and Navigation

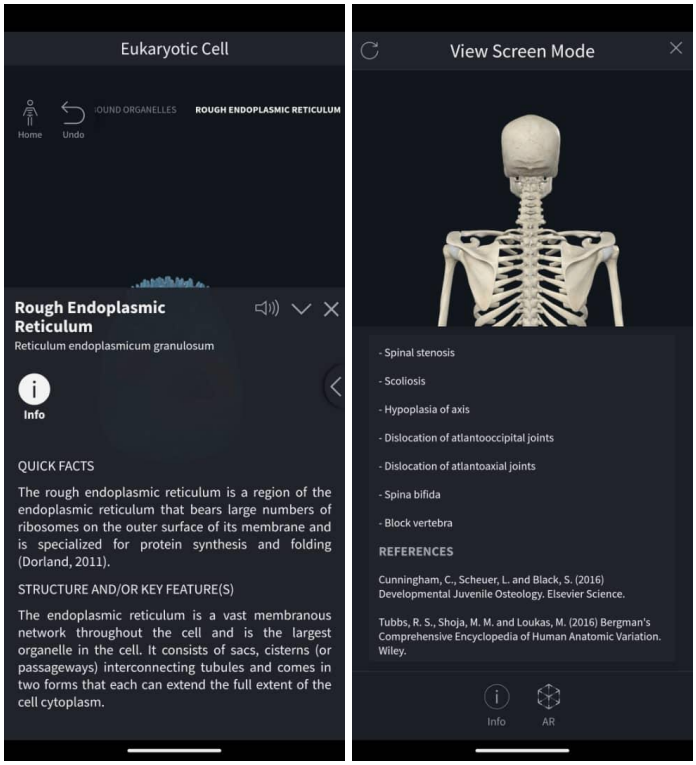


Figure 2-24 Audio function and Detailed Description

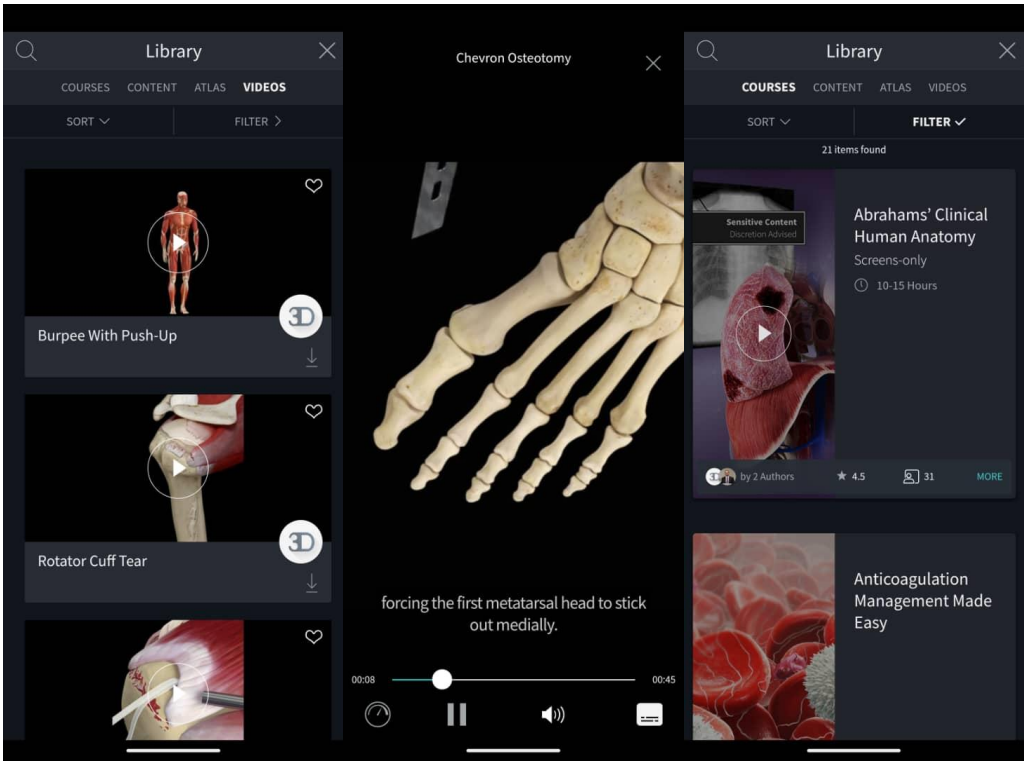


Figure 2-25 Videos and Courses

Weaknesses of the Application:

In terms of functionalities, there are no obvious limitations observed. However, to access most of the models and features, the students would need to subscribe to their Student Plan which costs around 150 Ringgit Malaysia per year. Therefore, the effectiveness of the app is hindered by limited free trial and free-access periods as not all students have the financial capacity to subscribe to the app. As a result, the accessibility and affordability of this application by students is largely limited.

2.3 Comparison of the Reviewed Applications with Proposed Application

Table 2-2 Comparison of the Reviewed Applications with Proposed Application

Criteria		**Science AR**	**High School Anatomy 21**	**Complete Anatomy 2023**	**Proposed Application**
User Interface	Home Page	Available	Not available	Available	Available
	Settings Page	Not available	Available	Available	Available
	Help Page/ Tips	Available	Available	Available	Available
Navigation	Instruction and Tutorial	Not available	Not available	Available	Available
	Ease of navigation	Easy	Moderate	Easy	Easy
Model Interaction	Zoom	Available	Available	Available	Available
	Move	Available	Available	Available	Available
	Rotate	Available	Available	Available	Available
	Back to Original button	Not available	Not available	Available	Available
	Model parts selection	Not available	Available	Available	Available
Other Features	Model Filtering	Not available	Not available	Available	Available
	Model Sorting	Not available	Not available	Available	Available
	Model Searching	Available	Available	Available	Available
	Labelling and Detailed Information	Not available	Available	Available	Available

	Image Taking	Available	Not available	Available	Available
	Quiz Module	Not available	Not available	Not available	Available
	Gamification	Not available	Not available	Not available	Available
Affordability	Pricing	Free	Moderate	High	Free

In summary, the reviewed applications have their limitations in terms of their functionalities or design. In the comparison of the functionalities, Complete Anatomy is the most comprehensive application designed and developed that carefully considers criteria such as user-friendliness, user engagement and accessibility. However, it has the highest pricing in comparison with the other two reviewed applications. While for other applications, it is commonly found that several limitations such as lack of necessary user interfaces such as home and settings pages, lack of instructions and tutorials that aid users in using the app and lack of buttons in model interaction that help users to regain the model in original view and position. Other than that, there is also a gap for improvement for the features such as filtering and sorting the list of models as well as features during model interaction such as model parts labeling, textual information along with the image taking function during AR mode. The proposed application will build upon the strengths of the reviewed applications and refine based on their deficiencies meanwhile implementing the quiz module and gamification approach that are absent in the reviewed applications.

2.4 User Requirements Gathering

After reviewing technology used and previous work on AR biology apps, it is evident that while AR technology enhances engagement and interactivity in learning, many apps face challenges related to usability, content alignment with educational goals, and technological limitations. To address these, a user requirements gathering survey has been developed to further explore user preferences regarding the app's functionalities, such as AR model interactions, quiz features, and technology preferences. The survey

aims to refine the app's design by aligning it with user expectations and overcoming the identified weaknesses from past research. There are 20 respondents in this Google Form survey and all of them are secondary Form 4 students who are currently taking Biology subject in their school. This survey comprises 3 sections that assess the respondents' general experience, functional requirements and technology preferences.

2.4.1 General Experience

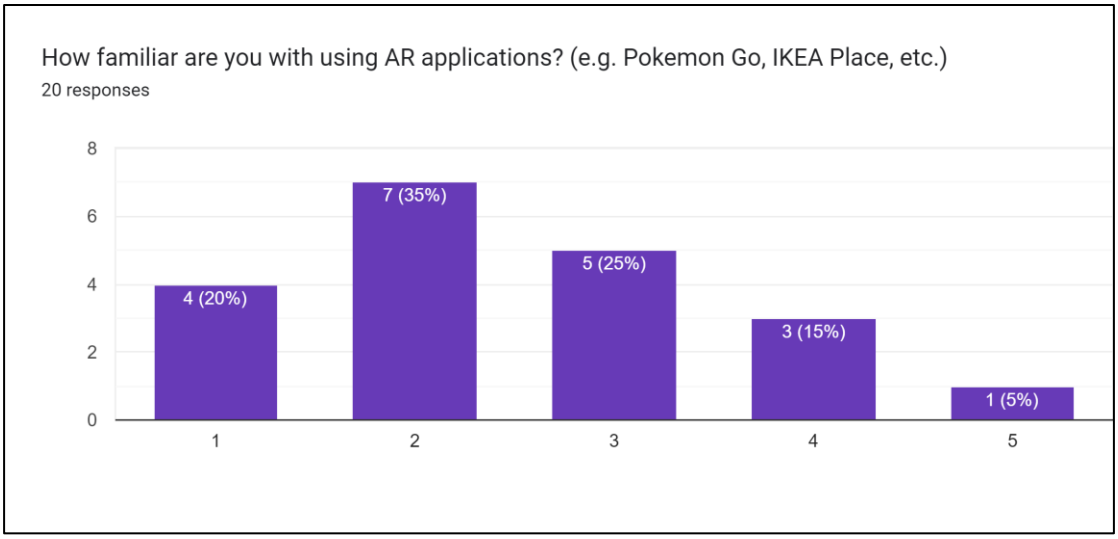


Figure 2-26 Familiarity using AR App Questionnaire

The survey results on familiarity with AR applications indicate that the majority of respondents (35%) have moderate familiarity, rating their experience as 2 on a scale where 1 is very familiar and 5 is not familiar at all. About 20% of participants reported being very familiar with AR, while 25% rated themselves at a middle level of familiarity. A smaller portion of the respondents (15%) indicated lower familiarity, and only 5% said they are not familiar with AR applications at all. This suggests that while most users have some exposure to AR technology, there is a varying range of expertise among the participants.

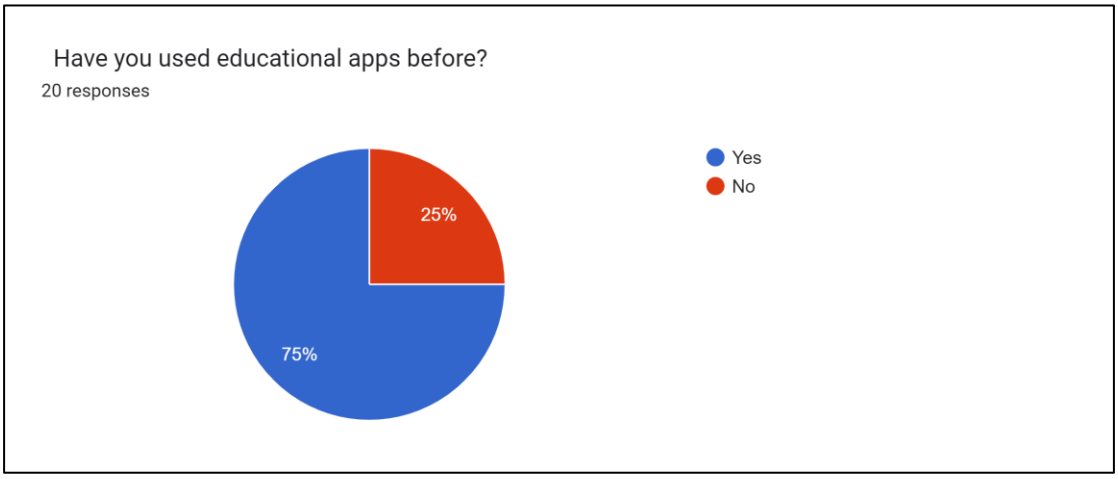


Figure 2-27 Experience with Educational App Questionnaire

The survey results indicate that the majority of respondents (75%) have previously used educational apps, while 25% have not. This suggests that most participants are familiar with using technology for learning, which could influence their experience and expectations when using an AR-based educational app. However, a quarter of the participants may represent users who are less accustomed to integrating apps into their learning routine, highlighting the need for an intuitive design.

2.4.2 Functional Requirements

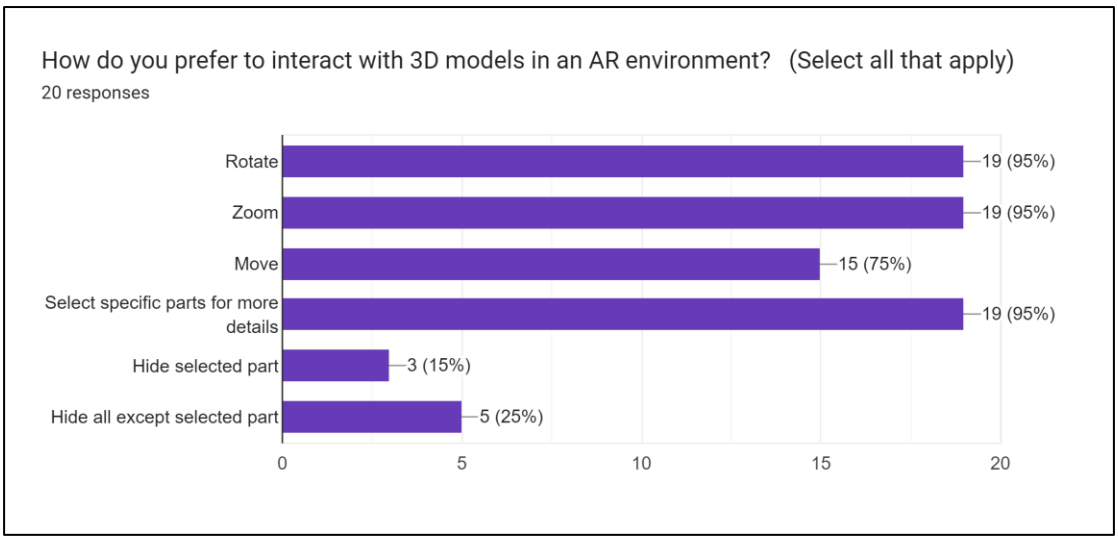


Figure 2-28 Interaction Methods Questionnaire

The survey results show that the majority of respondents (95%) prefer to interact with 3D models in an AR environment by **rotating**, **zooming**, and **selecting specific**

parts for more details. A significant portion (75%) also expressed a preference for being able to **move** the model. Fewer respondents indicated a desire for additional functionality, with 25% wanting the option to **hide all except the selected part** and 15% opting for the ability to **hide only the selected part**. This indicates that users prioritize basic model manipulation and detailed exploration, while more advanced features such as hiding parts are of interest to a smaller group.

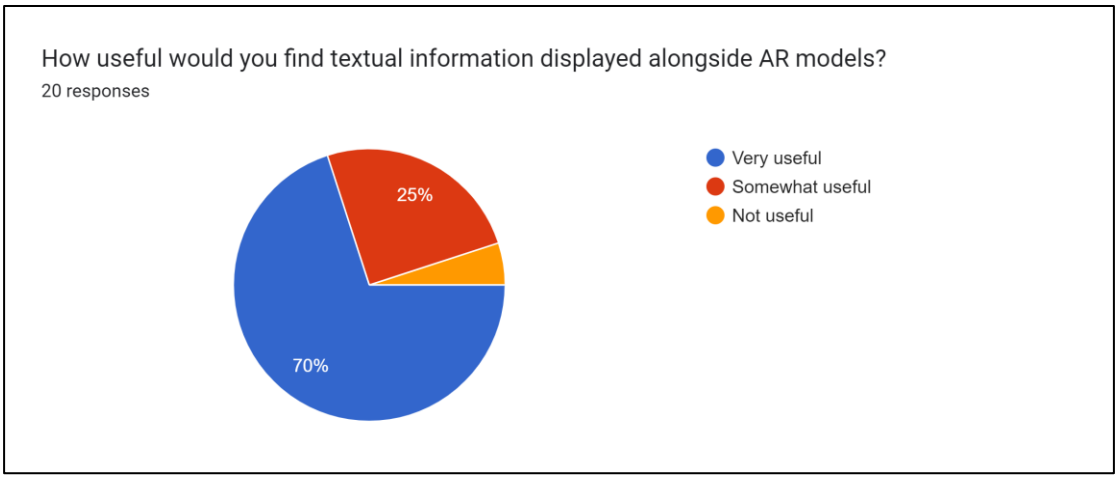


Figure 2-29 Usefulness of Textual Information Questionnaire

The survey results reveal that the majority of respondents (70%) find textual information displayed alongside AR models to be **very useful**, while 25% find it **somewhat useful**. Only a small fraction (5%) indicated that they consider textual information to be **not useful**. This suggests that most users view the combination of visual and textual information as an important feature for enhancing their understanding of AR models, emphasizing the need for clear and detailed annotations in the app.

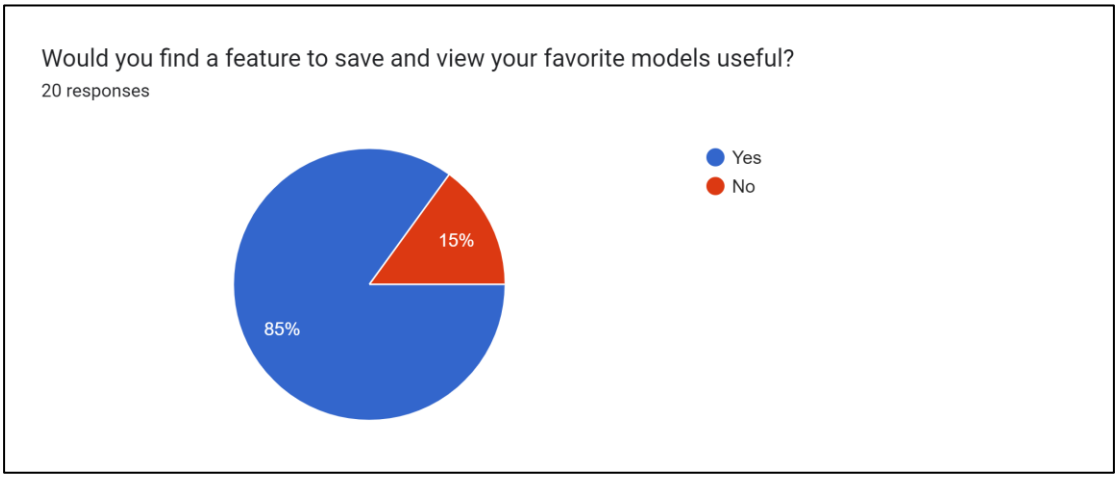


Figure 2-30 Add to Favourite Feature Questionnaire

The survey results indicate that a significant majority of respondents (85%) would find a feature to save and view their favorite models useful, while only 15% do not see this feature as necessary. This suggests that most users value the ability to easily access specific models they are interested in, making "favorites" feature a highly desirable addition to the app for enhancing user convenience and engagement.

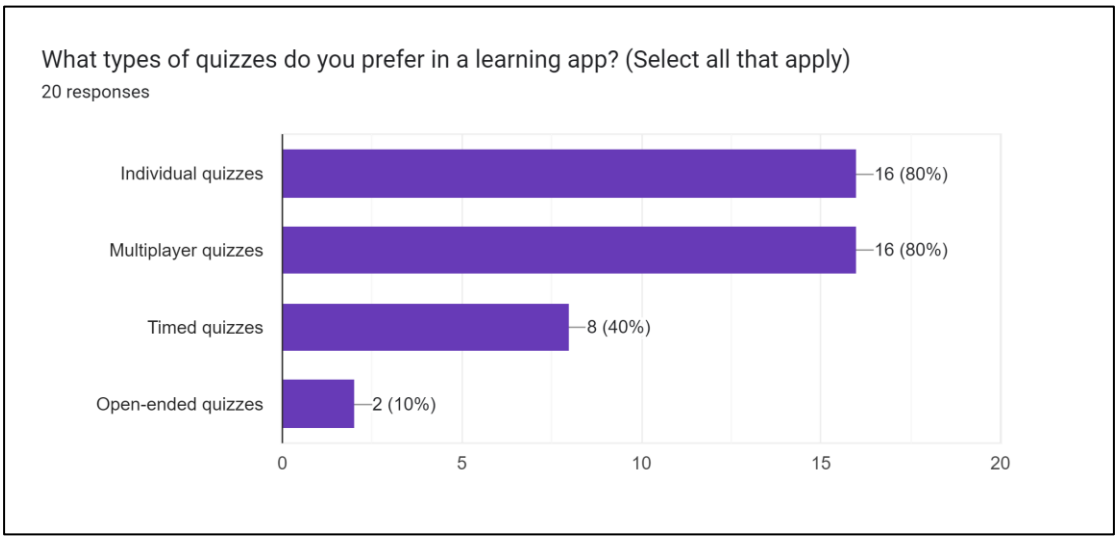


Figure 2-31 Types of Quizzes Questionnaire

The survey results show that **individual quizzes** and **multiplayer quizzes** are equally popular, with 80% of respondents preferring both types. Additionally, 40% of respondents indicated a preference for **timed quizzes**, while a smaller portion (10%) preferred **open-ended quizzes**. This suggests that most users favor a mix of competitive

and individual quiz modes, with a significant interest in timed quizzes, while open-ended quizzes appeal to a smaller group.

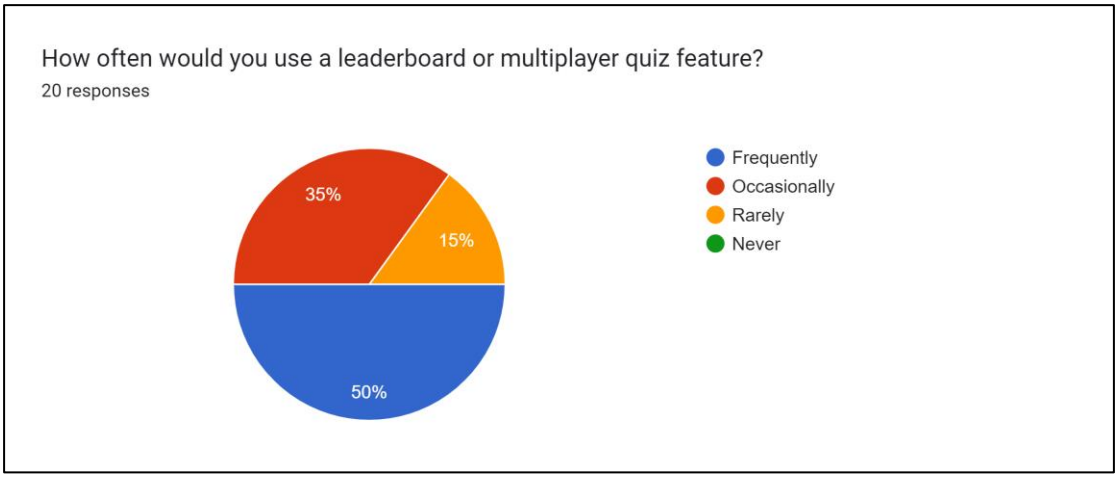


Figure 2-32 Leaderboard Questionnaire

The survey results indicate that half of the respondents (50%) would use a leaderboard or multiplayer quiz feature **frequently**, while 35% would use it **occasionally**. A smaller portion (15%) indicated that they would use the feature **rarely**, and none of the respondents selected **never**. This suggests that a leaderboard or multiplayer quiz feature is likely to be well-utilized, with many users showing strong interest in competitive or social learning experiences.

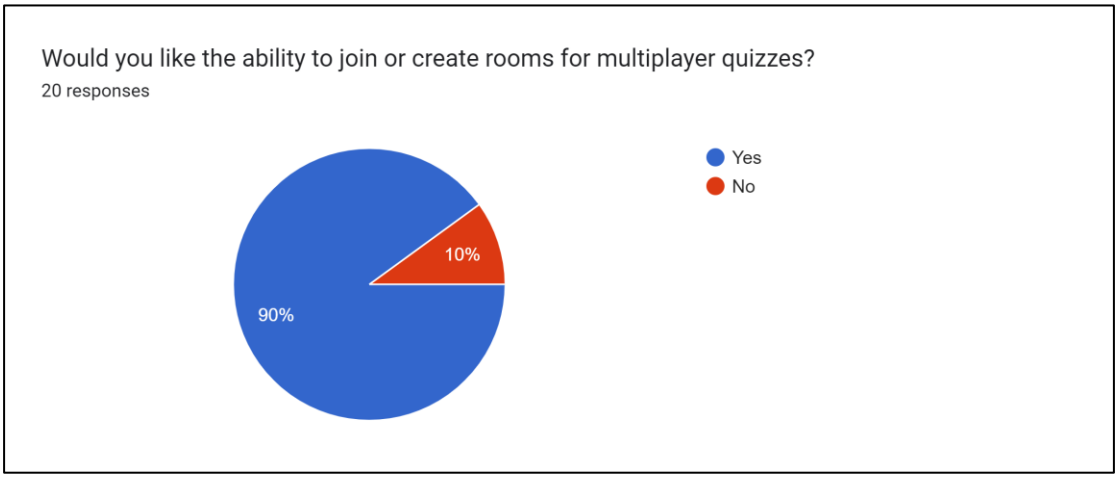


Figure 2-33 Join Room Feature Questionnaire

The survey results show that majority (90%) of respondents would like the ability to join or create rooms for multiplayer quizzes, while only 10% indicated that they

would not find this feature useful. This result further emphasizes that users value the social and collaborative aspects of learning through the app.

2.4.3 Technology Preferences

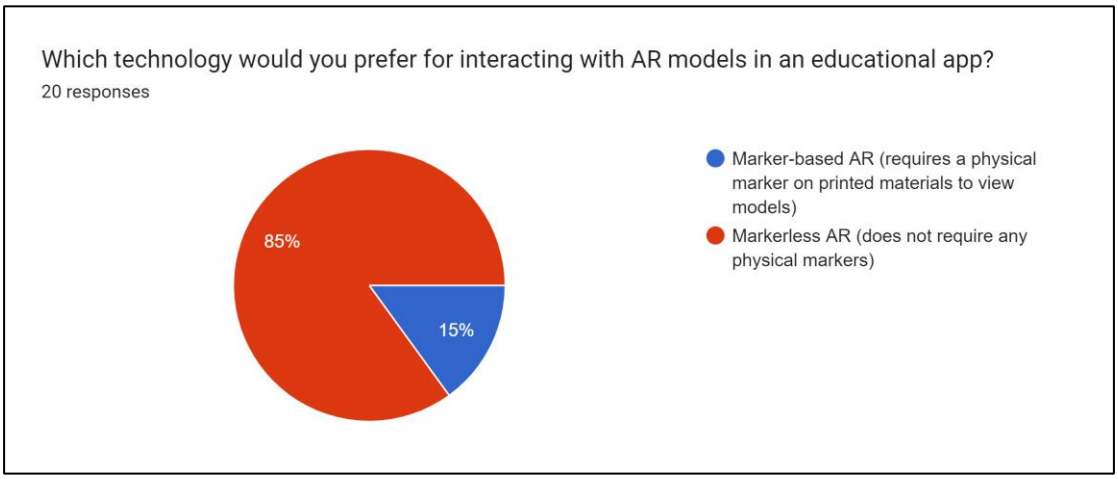


Figure 2-34 Technology Preferred Questionnaire

The survey results indicate that a large majority of respondents (85%) prefer **markerless AR**, which does not require physical markers to interact with AR models in an educational app. Only 15% of respondents indicated a preference for **marker-based AR**, which requires printed materials. This suggests a clear user preference for more flexible and accessible technology that allows for seamless interaction without the need for physical markers.

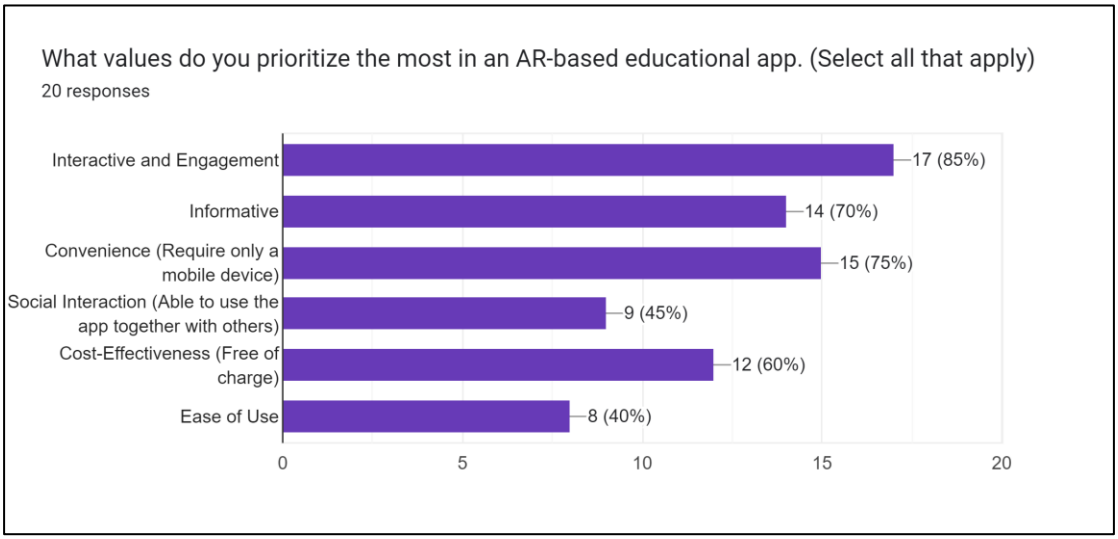


Figure 2-35 Values Prioritized Questionnaire

The survey results indicate that the most important value for users in an AR-based educational app is **interactive and engagement**, with 85% of respondents prioritizing it. **Convenience** (requiring only a mobile device) is the second most valued feature, selected by 75% of participants. **Informative** content follows closely, with 70% of users valuing this aspect. Additionally, 60% of respondents value **cost-effectiveness**, while **social interaction** (45%) and **ease of use** (40%) are also significant but less prioritized. Overall, these responses highlight that users prioritize engaging, informative, and convenient experiences when using AR-based educational apps, with a secondary emphasis on cost and social features.

2.5 Proposed Solutions

The proposed application in this project is designed to address the limitations identified in previous applications and integrate findings from the user requirements survey to create an engaging and comprehensive educational tool that seamlessly incorporates AR technology into the secondary biology curriculum. Utilizing **markerless AR** technology, which was overwhelmingly preferred by users (85%) in the survey, the app will allow students to interact with 3D models in their real-world environment without the need for physical markers. This enhances accessibility and

ease of use, enabling students to have hands-on, visually immersive learning experiences that facilitate a deeper understanding of complex biological concepts.

Moreover, the proposed application will be able to be accessed by all students, allowing them to benefit from the app's functionalities without a financial barrier, eliminating one of the common limitations found in other systems. Other than improving the common limitations from other reviewed systems, the app will additionally incorporate a quiz module to enable students to have a test on the topics learned during their concepts visualization, further reinforcing their knowledge in a dynamic manner and enhancing their learning engagement and effectiveness. In response to user feedback from the survey, this module will go beyond traditional quiz formats by introducing gamification, promoting friendly competition and enhancing motivation. This approach aims to improve user retention and create a more enjoyable and effective learning experience. The combination of immersive AR technology and gamified learning tools ensures that the app addresses both educational needs and user preferences.

Chapter 3

System Methodology/Approach

This chapter will discuss the design specifications such as the methodology and the process of each development phase before the justification of the hardware and software requirements. Then, the timeline for developing this project will be delineated.

3.1 Methodologies and General Work Procedures

3.1.1 Overview of ADDIE Model

This project will adopt ADDIE model as the development approach as ADDIE is one of the most used instructional system design (ISD) models that could effectively and systematically develop an instructional and educational-based system or application. “ADDIE” which is the acronym for Analyze, Design, Develop, Implementation, and Evaluation represents a sequential process in developing a predictable educational product.

This model provides a significant degree of flexibility in comparison with other traditional methodologies as each of its phases or steps does not necessarily progress linearly. The process could be iterative as each phase will be subjected to formative evaluation for improvements and modifications and the results could lead to reenter and refinement of previous stages [29]. Figure 3-1 below by Steven J. McGriff shows the detailed process in ADDIE model.

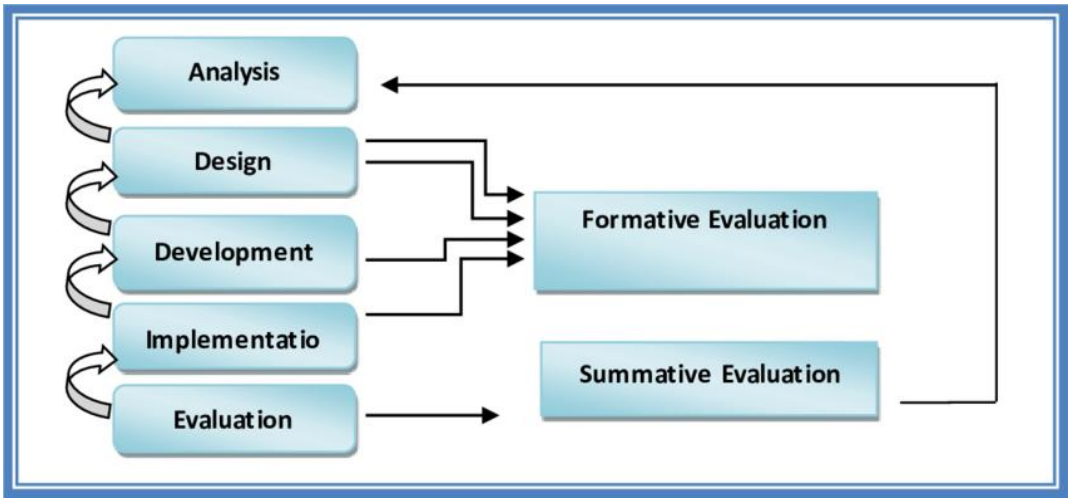


Figure 3-1 ADDIE Model

The detailed steps for the development process of this project in each phase by practicing the ADDIE approach are described below:

- **Analysis Phase**

  In the analysis phase, the underlying problems related to the project topic will be thoroughly analyzed through the literature review to identify the requirements of this project, and then the corresponding solutions will be proposed. The existing similar applications are investigated for the purpose to learn the strengths and improve the proposed solutions based on the weaknesses. The user requirements and preferences are also collected at this point. The project goals are defined at this phase as well to serve as the inputs for the next phase.

- **Design Phase**

  In the design phase, the information collected from the previous phase will be used to plan the developing strategies, outline the scope and draft the design of the application. Several diagrams such as system block diagram and use-case diagrams will be drawn to illustrate the functionality and design of the entire application. Based on the project scope, the content in the application is planned in detail before the user interface could be drafted out via the mockups before the development phase.

- **Development Phase**

  In the development phase, the programming process starts taking place to develop the application based on the plans drafted in previous phases. The required resources such as the 3D models are acquired and created during this phase and integrated into the application. The interfaces and functionalities are then coded to meet the objectives of the project. The project prototype will be tested out from time to time based on the earlier drafted verification inputs for improvements and modifications.

- **Implementation Phase**

  The implementation phase will include the distribution of the developed application to a small group of students, that is, the targeted users, to perform app effectiveness testing and pilot testing for the purpose of capturing feedback. A survey form will be distributed along with the application for opinion and result collection.

- **Evaluation Phase**

  The evaluation phase includes two types of evaluation, which are formative evaluation and summative evaluation. The formative evaluation will be carried out in every phase especially in the development and implementation phases to assess user engagement and the effectiveness of the developed application. While for summative evaluation, the overall outcomes are measured and compared, the limitations will be summarized, and the project conclusion will be drawn.

3.2 System Requirements

3.2.1 Hardware

The primary hardware involved in developing this mobile application includes a laptop and a smartphone. The laptop will serve as the development workstation to run AR development tools and integrated development environments (IDEs) such as Unity and Visual Studio Code. The laptop will be a crucial infrastructure to ensure the processes such as coding, debugging and testing executed smoothly and seamlessly. On

the other hand, the smartphone will serve the role as the target device to deploy and test the application developed. The smartphone used must be AR-capable, with powerful processor and high-resolution display to ensure seamless rendering and visual overlays. The specifications of the hardware that will be used are described as below:

Table 3-2 Specifications of Laptop

Description	Specifications
Model	HP Pavilion Plus Laptop 14
Processor	13th Gen Intel(R) Core(TM) i5-1335U
Operating System	Windows 11 Home Single Language
Graphic	Intel(R) Iris(R) Xe Graphics
Memory	16GB RAM
Storage	476GB SSD

Table 3-3 Specifications of Smartphone

Description	Specifications
Model	Vivo V27e
Processor	2.2 GHz Helio G99 Octa-core
Operating System	Funtouch OS 13 Global
Graphic	ARM Mali-G57 MC2
Memory	8GB+8GB Extended
Storage	256GB
Rear Camera	Triple: 64P, f/1.8, (wide), PDAF, OIS 2MP, f/2.4, (macro) 2MP, f/2.4, (depth)

3.2.2 Software

A set of software tools and frameworks is essential to realize the creation of a comprehensive AR-based mobile application. The primary software tools and framework involved such as Unity, Vuforia and Flutter are described as follows:

Table 3-4 Software Required Throughout the Project

Software	Description
Unity	Unity will serve as the main development environment for designing, developing and deploying the AR application. It is a powerful and popular game engine that is integrated with tools purpose-built for AR creators. It could assist in building a visually engaging and interactive application by providing seamless integration of 3D models and animation into the application.
EasyAR	EasyAR is an essential software development kit that can be integrated with Unity for the creation of AR application. It provides important functions such as recognizing and tracking images and surfaces, allowing the overlaying of and interaction between virtual objects with the real environment.
Visual Studio	Visual Studio will be the coding environment for developing the scripts that provide functionalities to the 3D models, scenes and other UI elements in Unity.
Firebase	Firebase will serve as a dynamic database solution for the application due to its real-time database that enables seamless synchronization of data between the app and the cloud, allowing instant updates of the learning material, progress tracking and collaborative features among users. Moreover, its user authentication feature provides a secure registration and login process, and its cloud storage feature allows secure and effective storage of the app contents.
Photon Fusion	Photon Fusion is a high-performance networking engine designed for real-time multiplayer applications, and it provides software development kit that can be imported into Unity, making it an ideal solution for integrating multiplayer functionality in the quiz module.

Figma	Figma is a powerful design tool that can be used to create user interface mock-ups, wireframes, and prototype and it can also be an effective diagram-drawing tool. It is easy to use and with its rich plugin ecosystem that offers a wide range of extensions and third-party services, the design process is flexible yet efficient.

3.3 Timeline

3.4.1 Timeline for FYP1

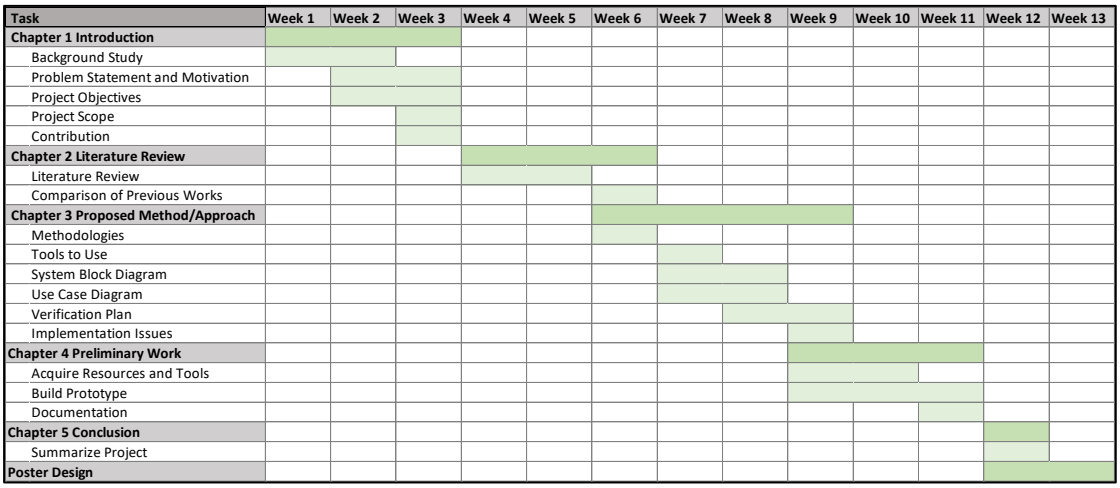


Figure 3-2 Timeline for FYP1

3.4.2 Timeline for FYP2

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Design													
Refine Previous Diagram													
Activity Diagram													
Interface Mockups													
Development													
General Module													
AR Learning Module													
Quiz Module													
Black Box Testing													
Implementation													
Distribution													
User Acceptance Testing													
Collect Feedback													
Evaluation													
Analyze Result													
Refinement and Modification													
Report Documentation													
Poster Design													

Figure 3-3 Timeline for FYP2

Chapter 4

System Design

This chapter provides a comprehensive overview of the system's design, beginning with the system architecture diagram that outlines the key components, their interactions, and the overall structure of the application. It is followed by the system block diagram, which further breaks down the individual modules and their connections. The use case diagram illustrates the primary functionalities from a user perspective and detailed activity diagrams are included to map out the step-by-step workflows for critical processes such as login, viewing 3D models, and taking quizzes. Finally, the chapter concludes with UI mockups that visually represent the user interface design, showcasing how the system's features will be presented and interacted with by the user.

4.1 System Architecture Diagram

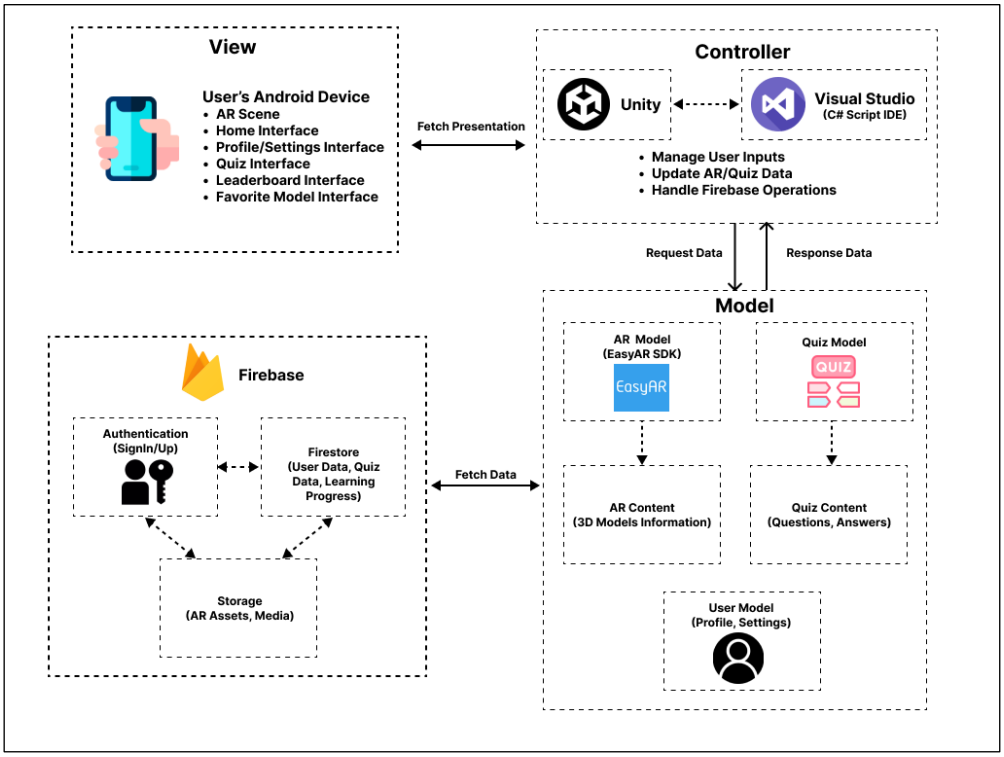


Figure 4-1 System Architecture Diagram

The architecture diagram for the AR-based biology learning application is structured using the Model-View-Controller (MVC) pattern. The **View** layer, hosted on the user's Android device, displays AR scenes, quizzes, and other interfaces, allowing users to interact with the app through the user interfaces. The **Controller**, managed via C# scripts attached in Unity, processes user inputs, updates AR/quiz data, and handles Firebase operations, ensuring seamless interaction between the view and the model by updating the Model as necessary and making requests to Firebase for data or authentication. The **Model** layer encapsulates the data, including AR models' content, quiz questions, and user profiles, with Firebase providing backend support for authentication, data storage, and asset management. This architecture ensures modularity, scalability, and robust data management for this proposed educational app.

4.2 System Block Diagram

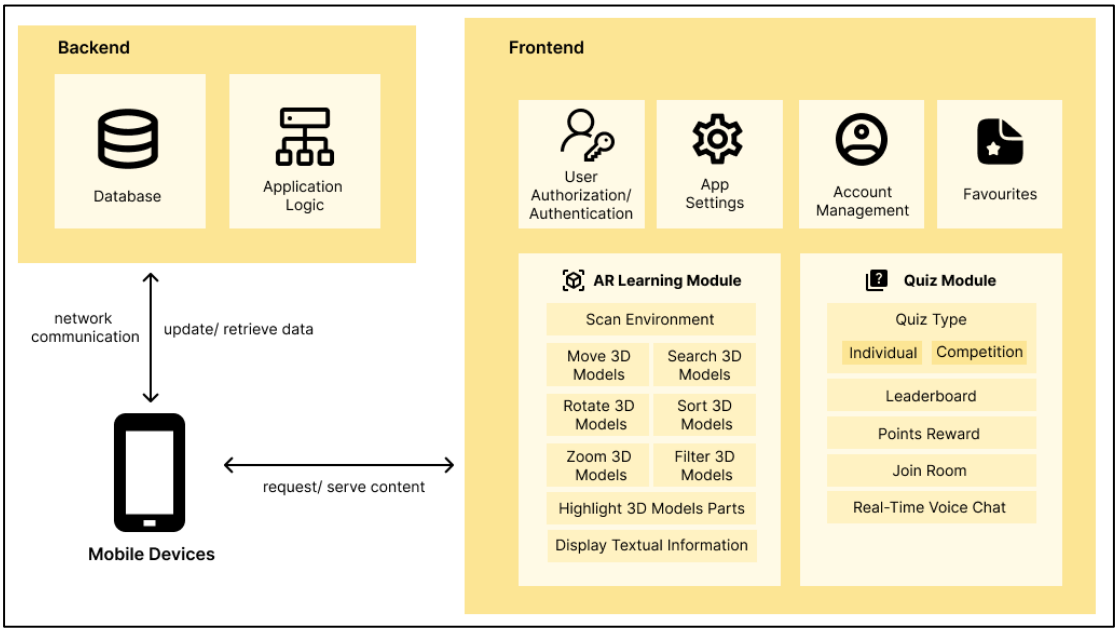


Figure 4-2 System Block Diagram

When users engage with the mobile application, the frontend and backend work together seamlessly to ensure a smooth experience. On the frontend, users interact with the app's interface, and the client-side code processes these interactions, handling UI

updates and triggering network requests. The backend receives these requests, processes the application logic, communicates with the database, and generates a response. This response is then returned to the frontend, where the client-side code processes the data, updates the interface, and provides real-time feedback to the user. Throughout this process, users can easily navigate and access all the app's features, including exploring AR models and completing quizzes, ensuring a fluid user experience.

4.3 Use Case Diagram

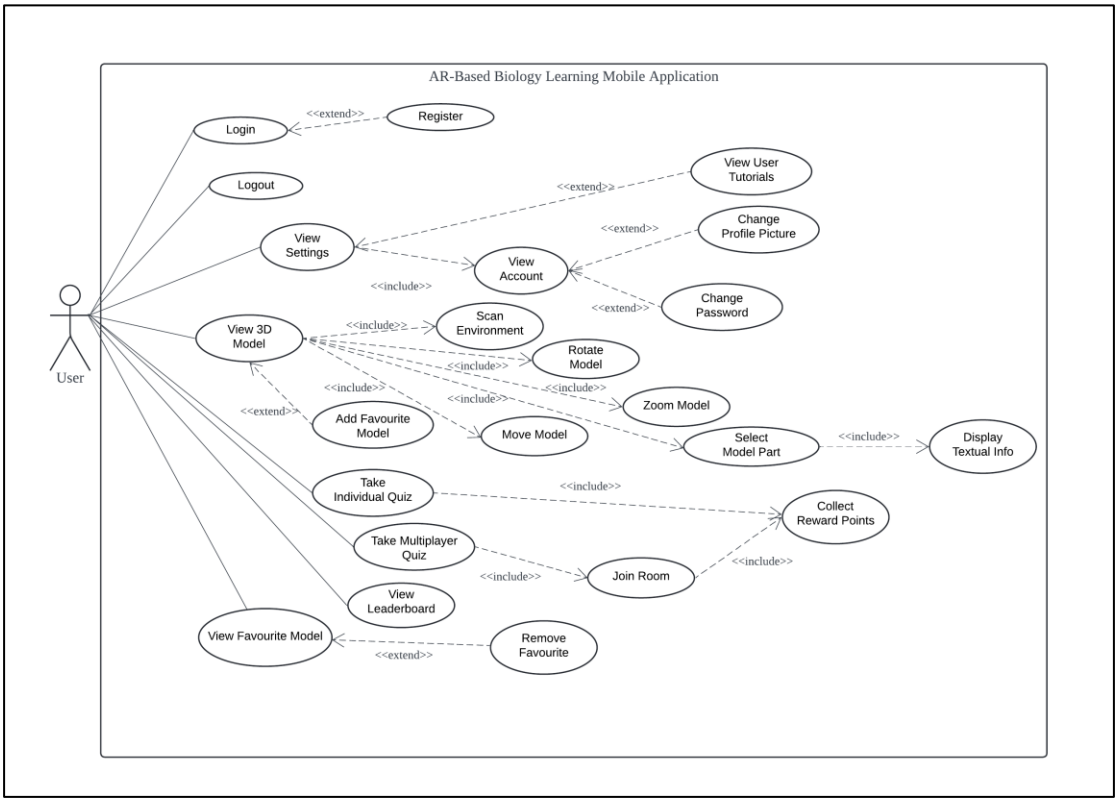


Figure 4-3 Use Case Diagram

For this AR-Based Biology Learning Mobile Application, the actor will be the user, that is, a secondary school student. There are a total of 7 main use cases with each followed by multiple included or extended use cases. First of all, the users will have to login to the application before accessing the application contents. If they did not have an account yet, they will need to register. While a logged in user can opt to logout. The users can choose to view their app settings or edit their account information.

Significantly, the users can enter the AR Learning module and choose the model that they want to study. Then, before the model can be displayed, they would have to scan their environment on a flat surface. After that, they can interact with the model and view the textual information displayed. A user can add models to their favorite page for easy access next time. While for the Quiz module, the users will have 2 options, either take an individual quiz or have a multiplayer quiz that they can join a room with their friends to take the quiz together. The users can view the leaderboard to see their ranks based on the total points that they have been awarded through the game.

4.4 Activity Diagram

4.4.1 Login/Register Activity

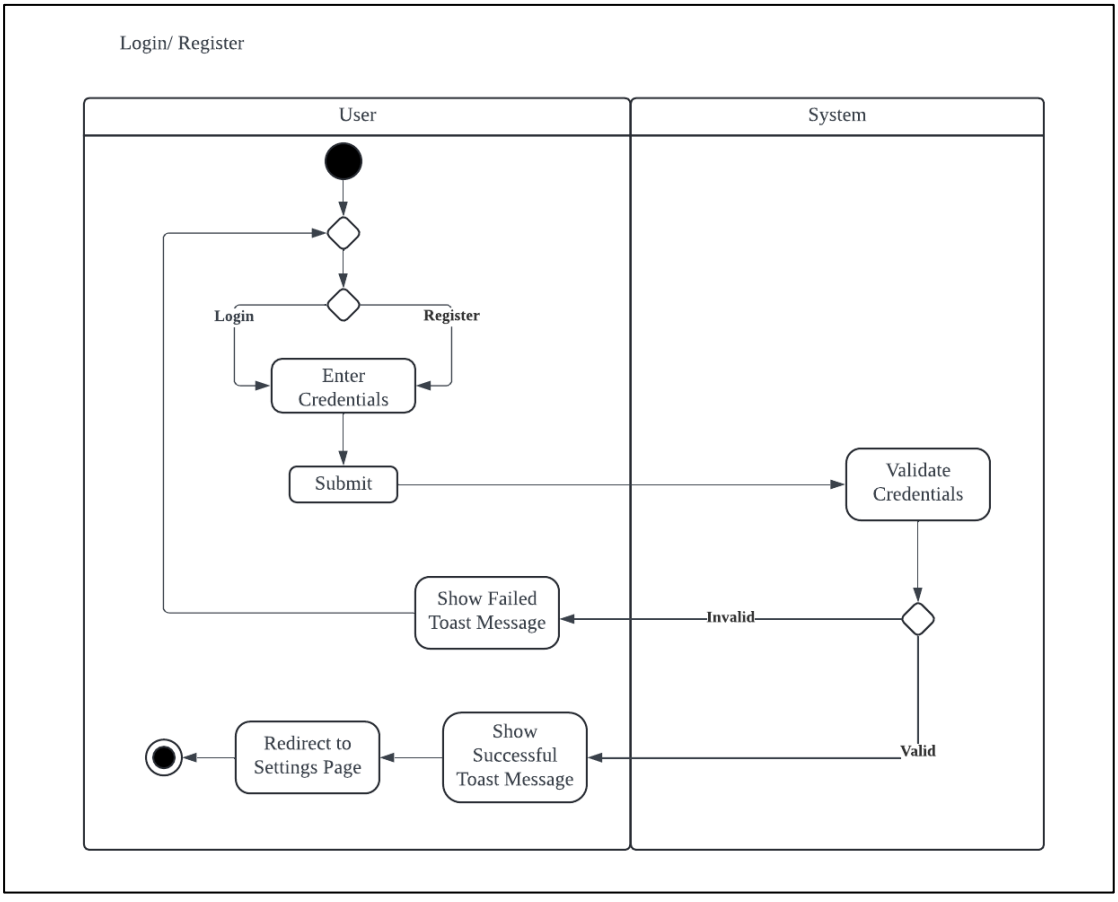


Figure 4-4 Login/Register Activity Diagram

The login or register process begins with the user choosing to either log in or register. The user then enters their credentials and submits them. The system validates

these credentials. If the credentials are invalid, the system shows a failed toast message, prompting the user to retry. If the credentials are valid, the system displays a successful toast message, after that the user is redirected to the settings page.

4.4.2 View 3D Model Activity

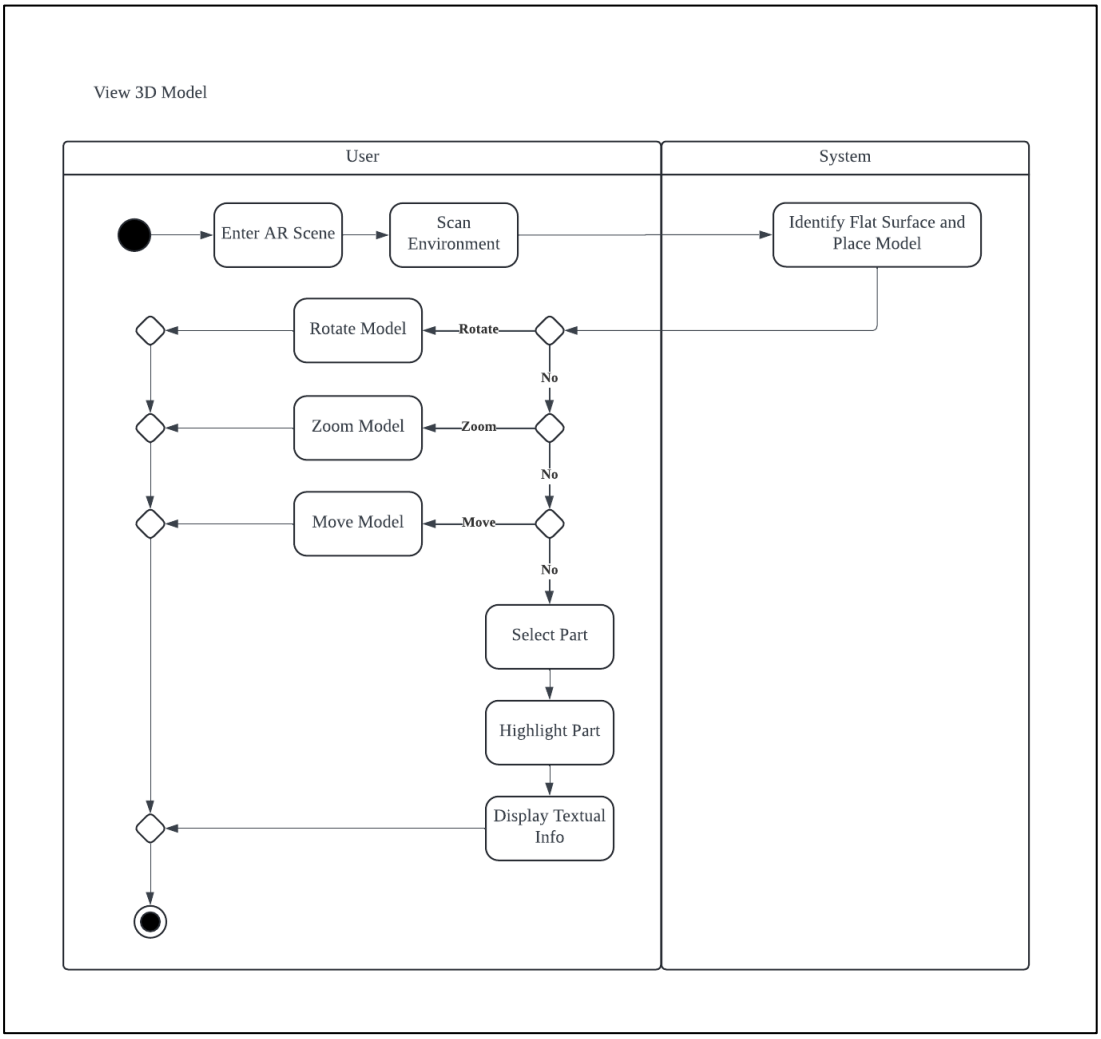


Figure 4-5 View 3D Model Activity Diagram

In the process of viewing and interacting with a 3D model in an AR environment, the user begins by entering the AR scene, where the system scans the environment to identify a flat surface and place the model. Once the model is placed, the user can interact with it in various ways, such as rotating, zooming, or moving the model. Each of these actions leads to a decision point, allowing the user to perform multiple interactions. If the user decides not to rotate, zoom, or move the model, they can select

a specific part of the model. The system then highlights the selected part and displays textual information about it. The activity ends after the user has finished interacting with the model.

4.4.3 View Favorite Activity

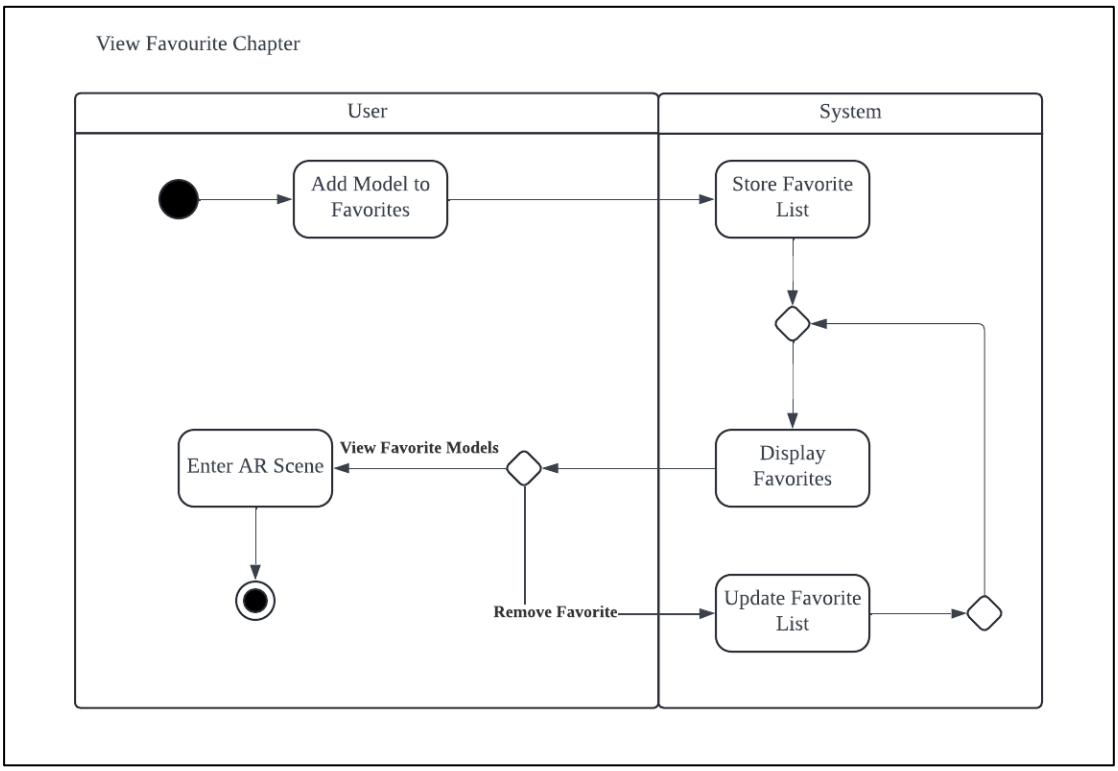


Figure 4-6 View Favourite Activity Diagram

This activity diagram illustrates the process of viewing and managing a user's favorite AR model. The process begins with the user adding a model to their favorites, which prompts the system to store the updated favorites list. When the user decides to view their favorite models, the system displays the stored favorites. If the user chooses to remove a model from the favorites, the system updates the favorites list accordingly and then displays the updated list. Finally, the user can enter an AR scene from the list of favorites.

4.4.4 Take Quiz Activity

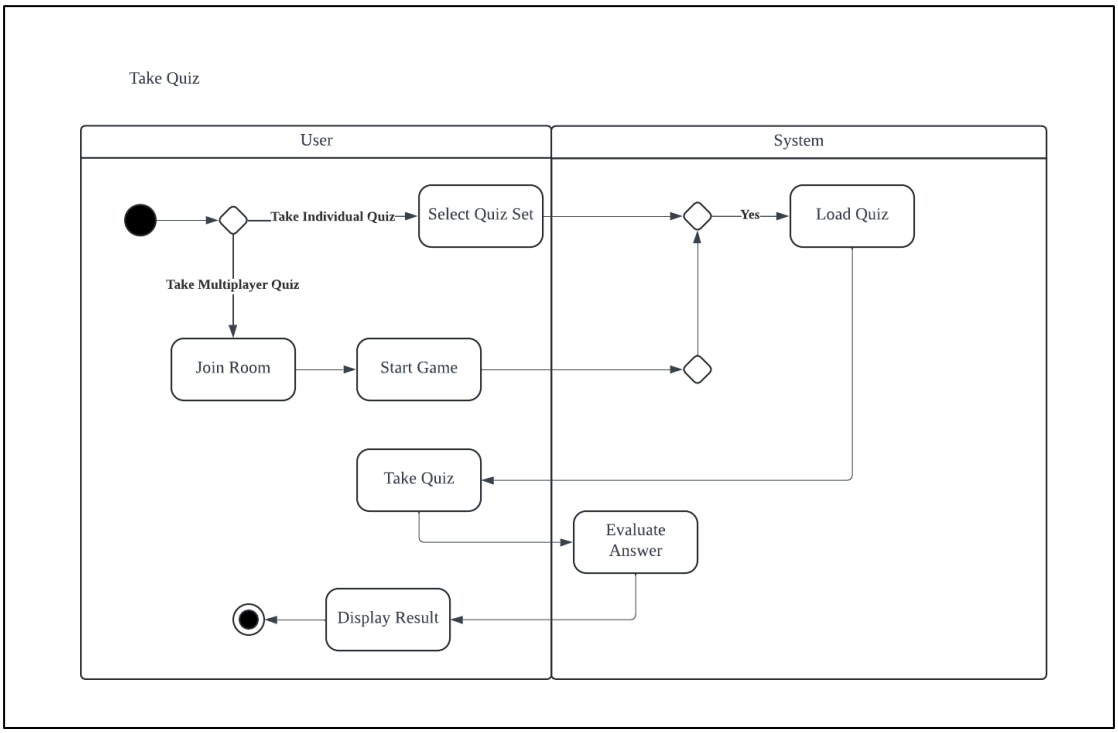


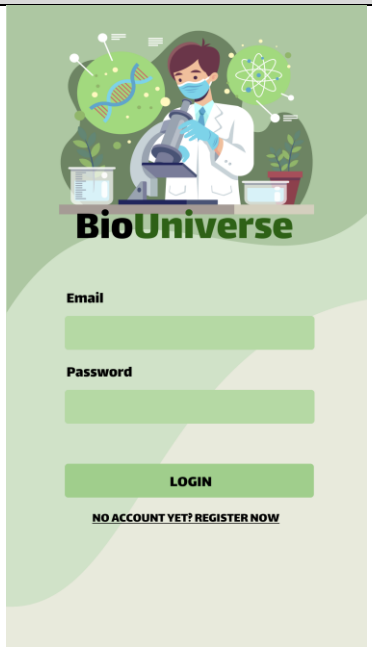
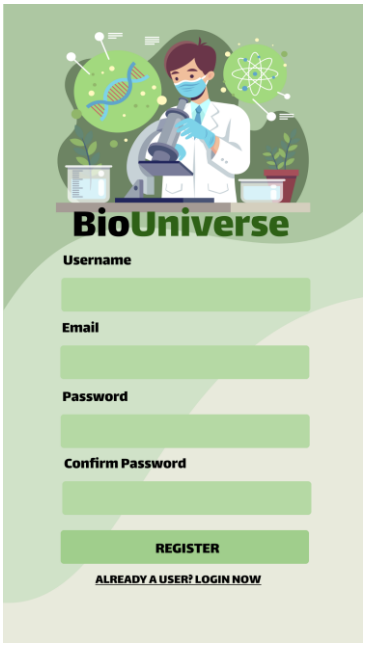
Figure 4-7 Take Quiz Activity Diagram

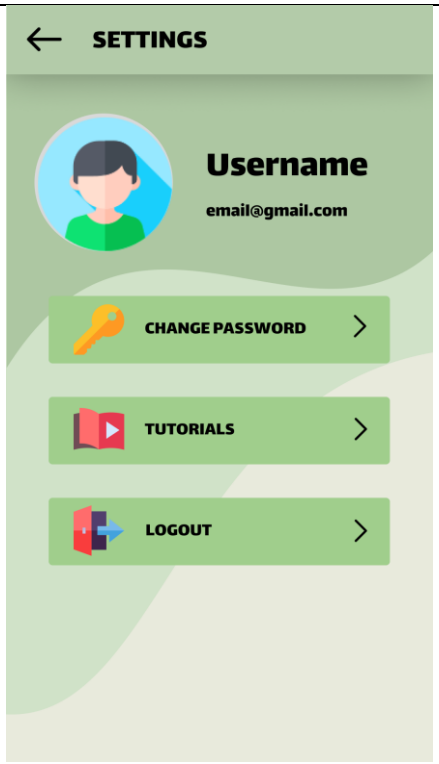
This activity diagram outlines the process of taking a quiz, including both individual and multiplayer modes. The process begins with the user deciding between taking an individual quiz or a multiplayer quiz. For the individual quiz, the user selects a quiz set, and the system loads the quiz questions. The user then takes the quiz, and upon submission, the system evaluates the answers and displays the result.

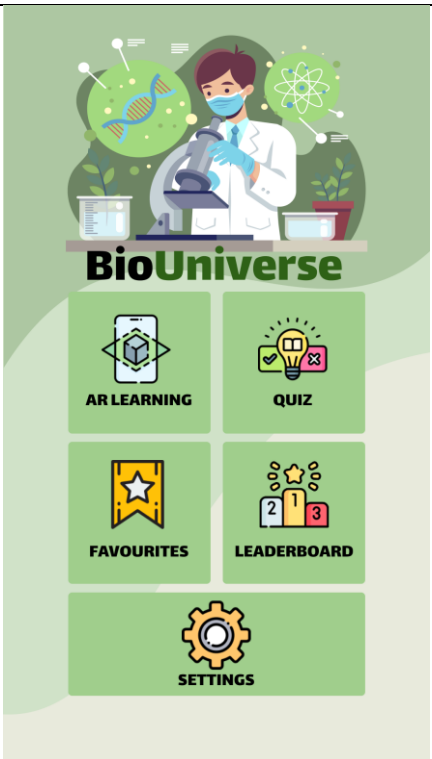
For the multiplayer quiz, the user first joins a room, and once all participants are ready, the game starts. The quiz is then conducted, similar to the individual mode, with the system evaluating the answers and displaying the results at the end.

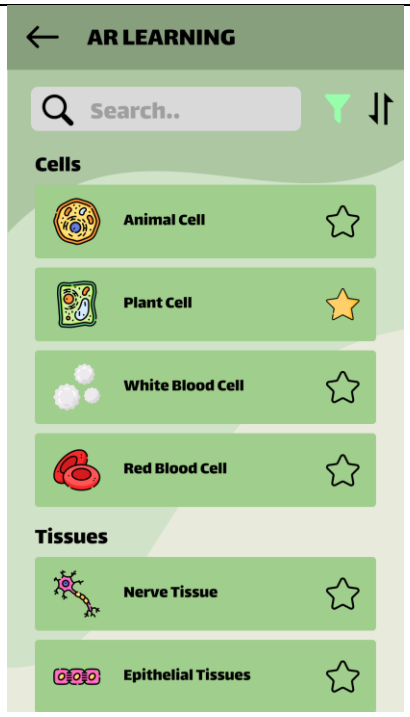
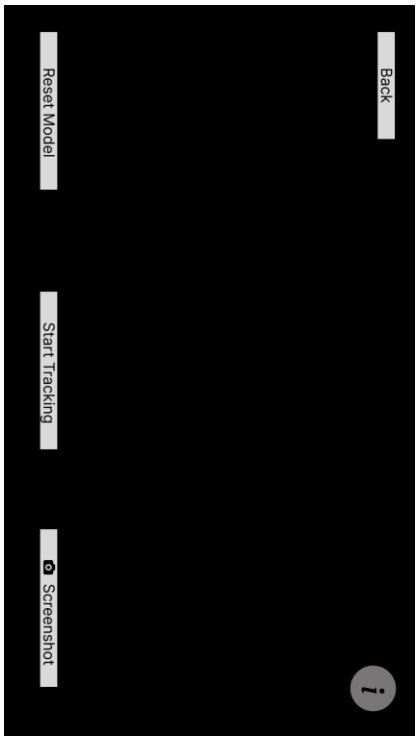
4.5 UI Mock-Ups

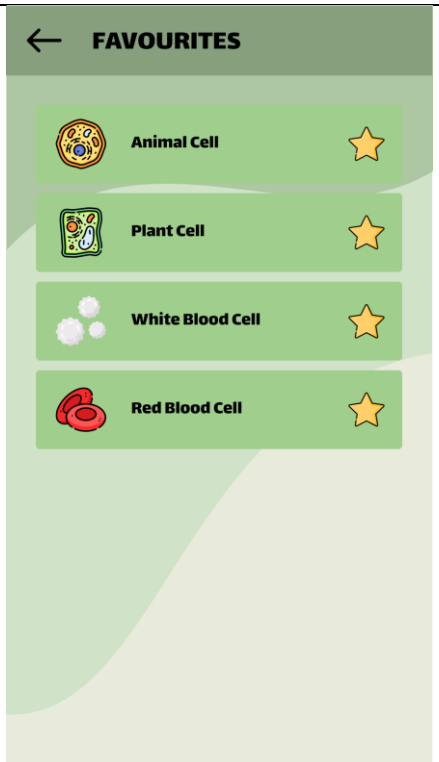
Table 4-1 UI Mockups

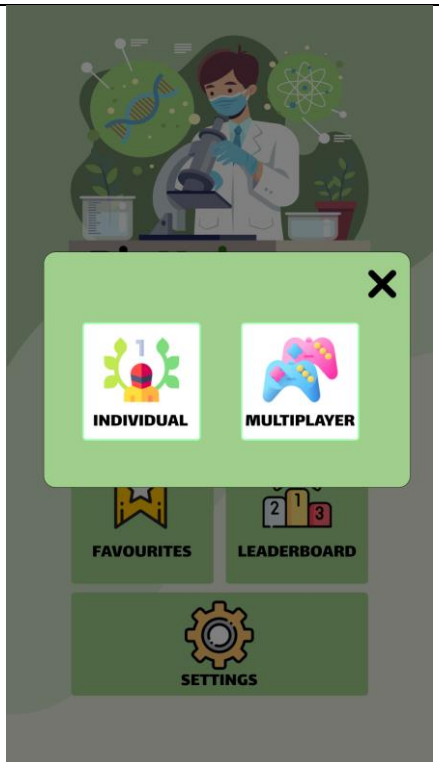
Screen	Mock-Up	Description
Login and Register	 Figure 4-8 Login Screen Mockup  Figure 4-9 Registration Screen Mockup	**1. Login Screen** The login screen features fields for the user to enter their email and password, with a prominent "Login" button for access. Below the login button, there is an option for users who do not have an account to register by clicking the "No account yet? Register now" link. 2. **Registration Screen** The registration screen allows new users to create an account by entering a username, email, password, and confirming their password. The "Register" button is prominently placed below these fields. For users who already have an account, a link is provided at the bottom to return to the login screen, labeled "Already a user? Login now."

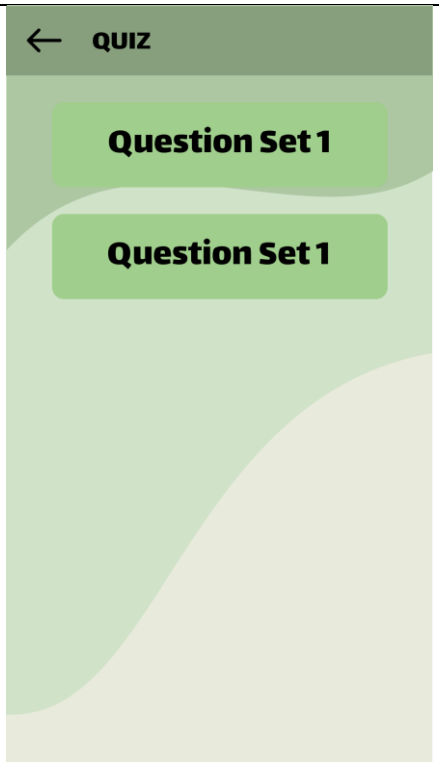
Settings/Profile	 Figure 4-10 Settings Screen Mockup	This screen provides users with access to manage their account and app preferences. • **Profile Section**: At the top, the screen displays the user's profile information, including a profile picture, username, and email address. Users can update their profile picture by clicking on it. • **Change Password**: The first button allows users to change their password, • **Tutorials**: The second button links to tutorials, providing users with helpful guides on how to use the app or learn more about the features. • **Logout**: The third button is for logging out of the app.

Home	 Figure 4-11 Home Screen Mockup	The home screen serves as a central hub where users can access the app's main features with the 5 buttons. • **AR Learning**: This button leads to the AR models menu of the app, where users can choose a model and interact with the 3D model. • **Quiz**: The quiz section can be accessed through this button • **Favourites**: Users can access their list of favourite AR models or content by tapping this button. • **Leaderboard**: This button takes users to a leaderboard where they can see how they rank compared to others in quizzes. • **Settings**: The settings button allows users to manage their account.

AR Module	 Figure 4-12 AR Model Menu Screen Mockup  Figure 4-13 AR Scene Screen Mockup	**1. AR Model Menu Screen** • **Search, Filter & Sort**: At the top of the screen, there is a search bar that allows users to quickly find specific content. The filter icon and sort icon next to the search bar indicates that users can sort or filter the content based on certain criteria. • **Model Listing**: The screen shows listings of buttons for the models and each model button has a star button on the right, allowing users to mark their favourite models. **2. AR Scene Screen (Horizontal Layout)** User's Camera with overlays of 3D Models and buttons. • **Reset Model**: This button allows users to reset the AR model to its original position and size. • **Start Tracking**: This button initiates the AR model's tracking in the physical space. • **Screenshot**:

		This button lets users take a screenshot of the current AR scene, saving the image to their device. • **Back**: Positioned at the top left, this button allows users to return to the previous screen or exit the AR model view. • **Info**: Positioned at the top right, this button allows users to view tips for interacting with the 3D models.
Favourite	 Figure 4-14 Favourite Screen Mockup	This screen shows the list of favourite models that user saved from the AR Model Menu Screen.

Quiz Module	 Figure 4-15 Quiz Mode Selection Panel Mockup	This **Quiz Mode Selection** screen prompts when the Quiz button in home screen is tapped to allow user to choose between two quiz modes: Individual Quiz or Multiplayer Quiz.

Individual Quiz	 Figure 4-16 Question Set Menu Screen Mockup	**1. Question Set Menu Screen** If user selects individual mode, a list of question sets available will be displayed to let them choose on the question set they want to attempt. **2. Individual Quiz Screen** The screen will display the timer, current and total question count, the question and its options. **3. Result Panel** After the quiz questions finished, a result panel will be displayed to summarize the user's score, time taken to complete, and points collected from the session. User can then choose to try again or back to the quiz set menu from the buttons below.

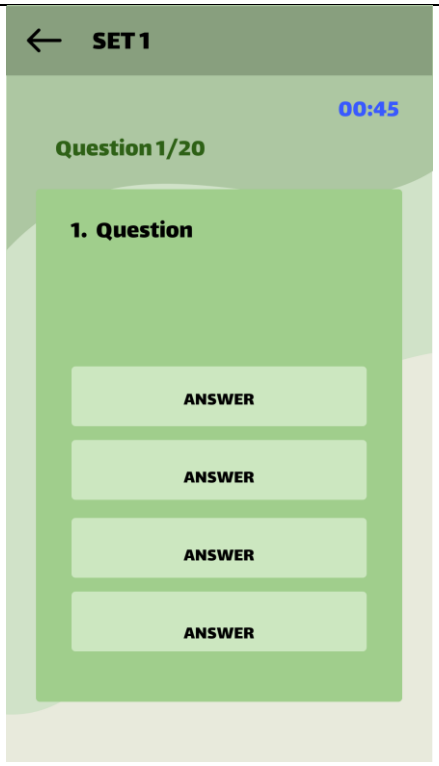


Figure 4-17 Individual Quiz Screen Mockup

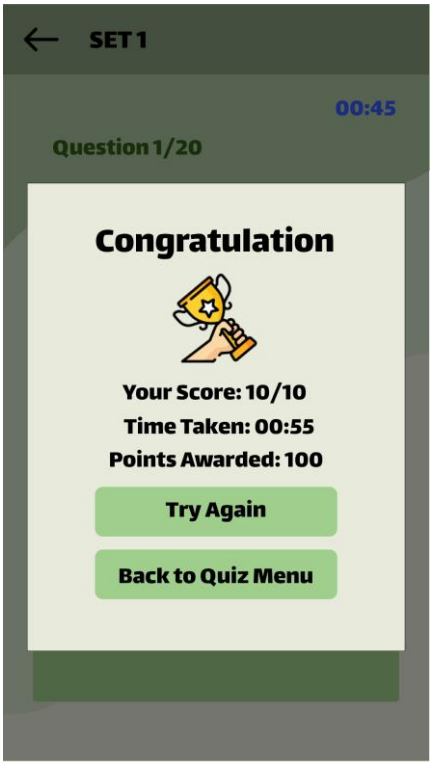
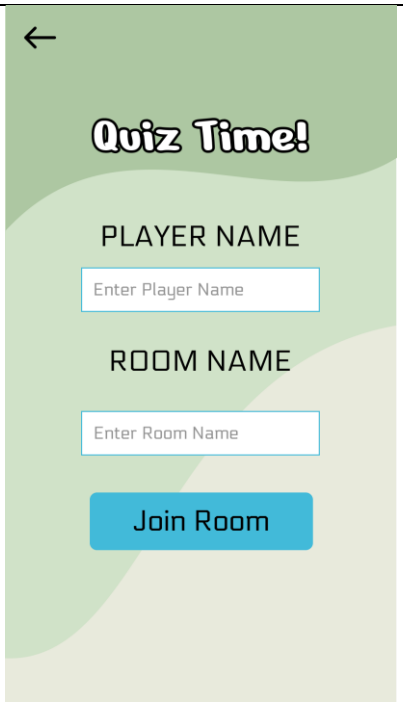
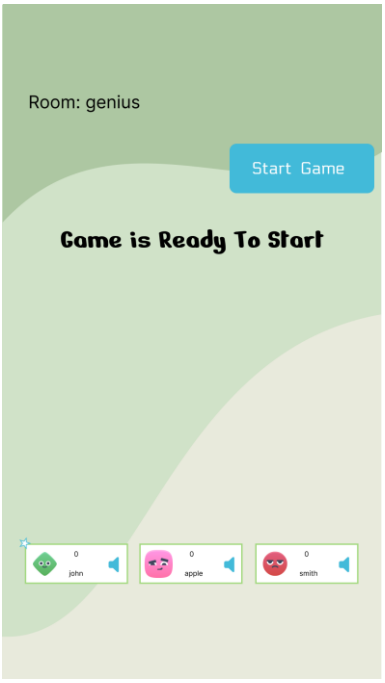


Figure 4-18 Result Panel Mockup

Multiplayer Quiz	 Figure 4-19 Multiplayer Quiz Game Lobby Screen Mockup  Figure 4-20 Multiplayer Quiz Game Room Screen Mockup	**1. Multiplayer Quiz Game Lobby Screen** To start a multiplayer quiz session, one needs to enter a player name and a room name before clicking the 'Join Room' button. **2. Multiplayer Quiz Game Room Screen** The first player who entered the room will be the host, with power to start the game. While other players will wait for the start of game by the host in this screen. Each player is represented by the rectangle box below the screen which contains avatar, name, score and a speaker button, and each player is free to choose an avatar at the left side of the rectangle. They can communicate with each other throughout the game or choose to mute their mic by clicking the speaker button. **3. Multiplayer Quiz Game Question Screen** This screen shows the question and its options after the game is started. The blue

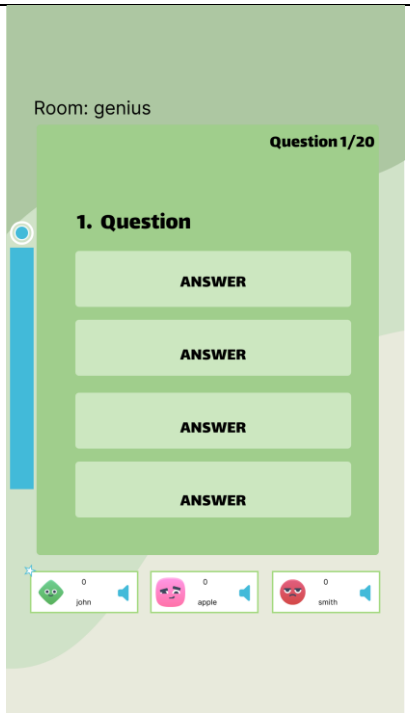


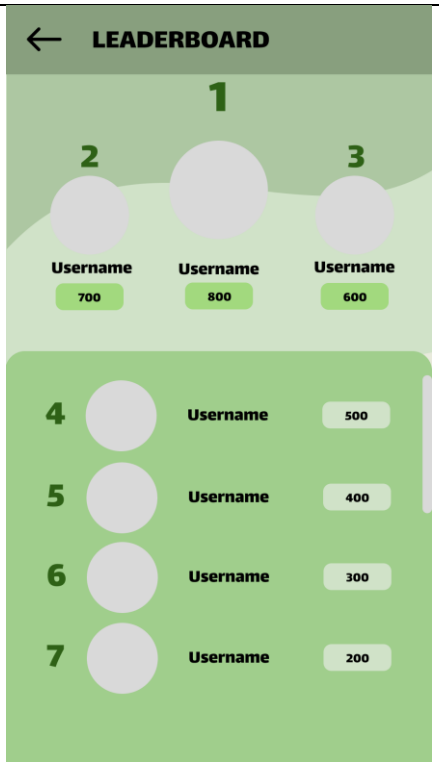
Figure 4-21 Multiplayer Quiz Game Question Screen Mockup

Figure 4-22 Multiplayer Quiz Game Result Screen Mockup

rectangle at the left side of the screen is the timer indicator and the question count is displayed at the top right of the question.

4. Multiplayer Quiz Game Result Screen

After the questions finished or the time is up, the top 3 winners will be displayed. The host can choose to start new game or leave session through the two blue buttons, while others will only be able to choose to leave session from their side.

Leaderboard	 Figure 4-23 Leaderboard Screen Mockup	This screen shows the top 15 users with their respective points earned from their participation of the quiz.

Chapter 5

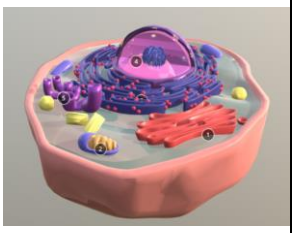
System Implementation

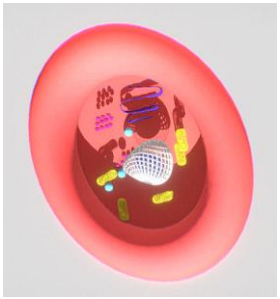
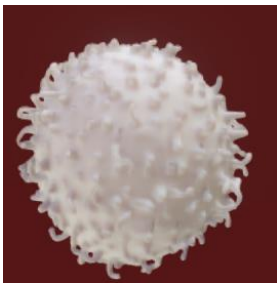
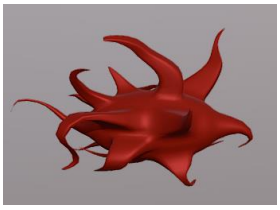
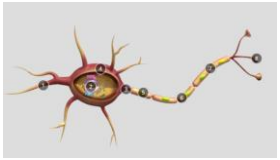
This chapter outlines the key steps taken to implement the proposed AR-based biology learning application. It begins by detailing the model collection process and provides an overview of the software setup and the integration of essential SDKs. The chapter also covers the system development, including key modules like login/registration, the AR learning module, quiz module, and leaderboard. Additionally, the system operation is documented, followed by an overview of the implementation challenges encountered during development.

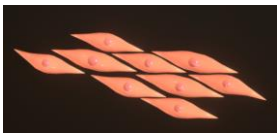
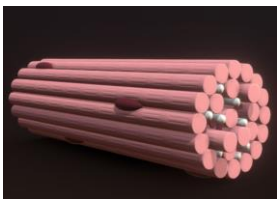
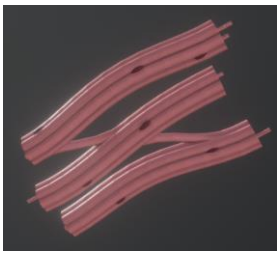
5.1 Model Collection

Several biological 3D models are downloaded from the Sketchfab, a website that allows upload, view, share and download of 3D models. Most 3D assets on Sketchfab are not free, however, the models downloaded and used in this project are all freely available and are listed in the table below.

Table 5-1 Model Collected

Model	Source	Credit
Animal Cell 	https://sketchfab.com/3d-models/animal-cell-20-annotated-in-english-0d9f7f4257224975b2ef83a283709b2f	"Animal Cell 2.0 (Annotated in English)" by generalvivi is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).
Plant Cell 	https://sketchfab.com/3d-models/plant-cell-cell-structure-1c5ce80d03d149208d30cc5aeb6e42fb	"Plant Cell - Cell Structure" by Vida Systems is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).

Red Blood Cell 	https://sketchfab.com/3d-models/red-blood-cell-43699fbe9bf4452facbfbab37867eb0d	""Plant Cell - Cell Structure" by James Bogucheski is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/)." by Vida Systems is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).
White Blood Cell 	https://sketchfab.com/3d-models/leukocytes-60234a65e0334b6ebc3507a68d5a69da	"Leukocytes" by gelmi.com.br is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).
Platelet 	https://sketchfab.com/3d-models/blood-platelet-thrombocyte-08fed7ab59514804b07804e40a57ef33	"blood platelet / thrombocyte" by i.isabelgordon is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).
Nerve Tissue 	https://sketchfab.com/3d-models/bagian-jaringan-saraf-85fcf899d96f43d8bd074078034736b7	"Bagian Jaringan Saraf" by Gusti Aldo Wijaya is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).

Smooth Muscle 	https://sketchfab.com/3d-models/smooth-muscle-cell-1525fe1477e34d578836236c6a14f5cf	"Smooth Muscle Cell" by _Bonehead14 is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).
Skeletal Muscle 	https://sketchfab.com/3d-models/skeletal-muscle-cell-anatomy-a491668e5891445e8e29d6ac4abf41bd	"Skeletal Muscle Cell Anatomy" by _Bonehead14 is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).
Cardiac Muscle 	https://sketchfab.com/3d-models/cardiac-muscle-cell-anatomy-16e33d3b0be74b4c800cb7601fb51dd2	"Cardiac Muscle Cell Anatomy" by _Bonehead14 is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).
Digestive System 	https://sketchfab.com/3d-models/digestive-system-ebbfed1dfc6047bda5f5f287c34a1332	"Digestive System" by gjoaobatista992 is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).

Female Reproductive System 	https://sketchfab.com/3d-models/female-reproductive-organs-x-section-6c89dc45574c40b3981e8de6310d28d4	"Female Reproductive Organs-X Section" by CVallance is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).
Male Reproductive System 	https://sketchfab.com/3d-models/male-reproductive-system-17bdcd1c2e9046d1abde72eff5c2cd0d	"MALE REPRODUCTIVE SYSTEM" by prabhatsharma8030 is licensed under Creative Commons Attribution (https://creativecommons.org/licenses/by/4.0/).

5.2 Software Setup

5.2.1 Unity Setup

Unity Hub is downloaded in the version of 3.8.0 with the Editor in version of 2022.3.23f1. After installing the Unity Editor, a free Unity Personal license is activated before creating a new Unity project. Since the project will be developed for Android platform, the necessary Android external tools such as JDK, SDK and NDK are set up. The external script editor for Unity is set to Visual Studio 2022 in the version 2.0.22.

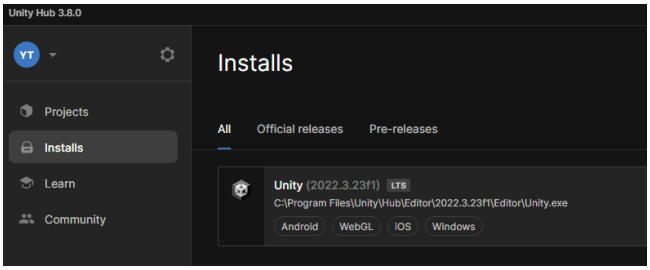


Figure 5-1 Unity Hub and Editor Version

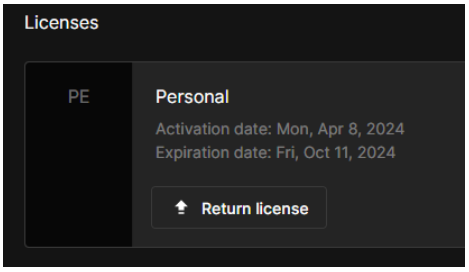


Figure 5-2 Unity Personal License

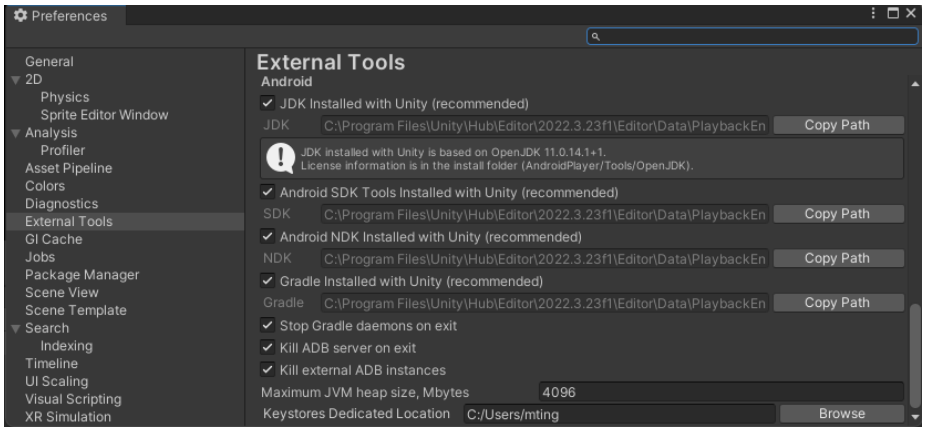


Figure 5-3 Android External Tool Setup

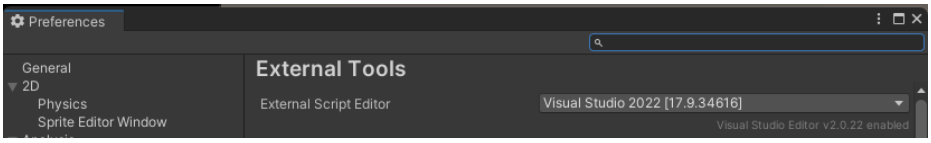


Figure 5-4 External Script Editor Setup

5.3 Setting and Configuration

5.3.1 EasyAR Sense SDK

EasyAR, which provides the AR functionalities, equipped with standalone SDK to be imported into Unity project. Before the functionalities can be integrated, a Sense License Key needs to be generated from EasyAR Develop Center and entered into Unity Project Settings under EasyAR field.

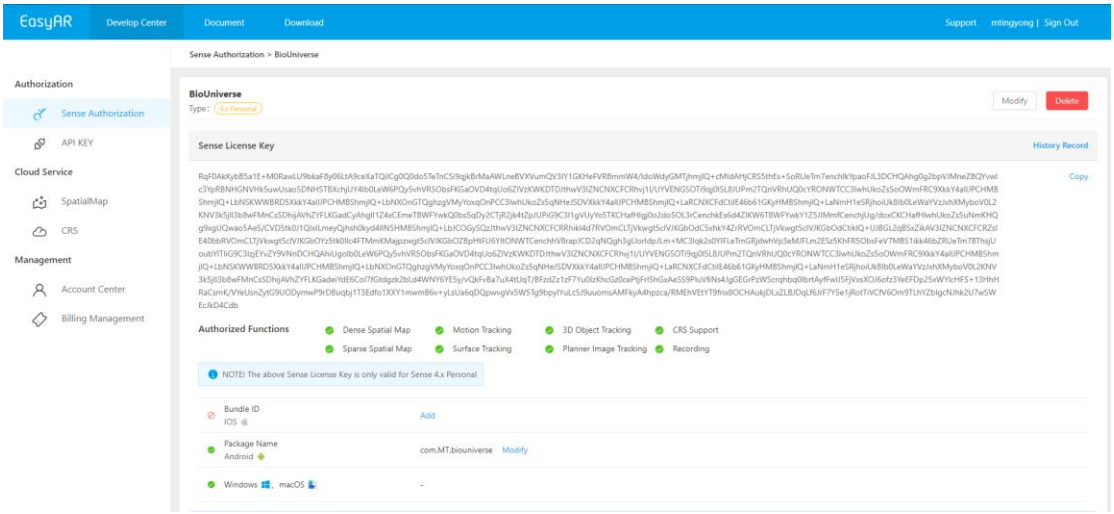


Figure 5-5 Generation of License Key from EasyAR Develop Center

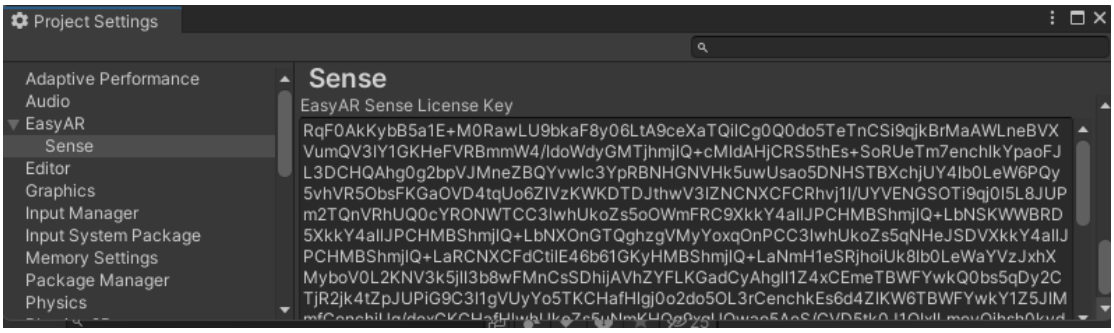


Figure 5-6 Importing Generated License Key into Unity Settings

5.3.2 Firebase SDK

Firebase SDK with services such as Authentication, Realtime Database and Storage along with its Google Play configuration files are imported into Unity after the Unity app is registered with Firebase. In the Firebase Console, the authentication is set up with “Email/Password” as the Sign-in provider. The required set up in Firebase Console is done at this stage.

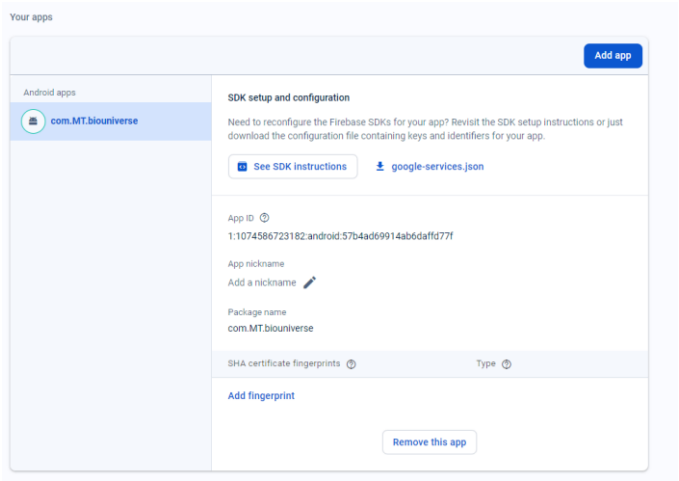


Figure 5-7 Register Unity App with Firebase

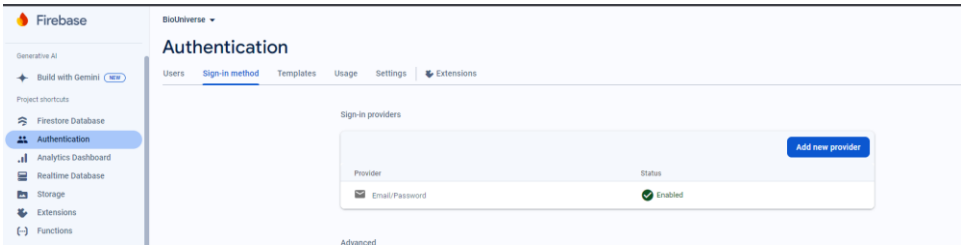


Figure 5-8 Setting Sign-in Provider

5.3.3 Photon Fusion SDK

The multiplayer quiz is supported by Fusion Quiz Network and to use this service, Photon SDK is required to be imported into Unity. The necessary configuration includes entering the Fusion App Id generated from Photon Engine Dashboard into the Photon Fusion Hub inside Unity.

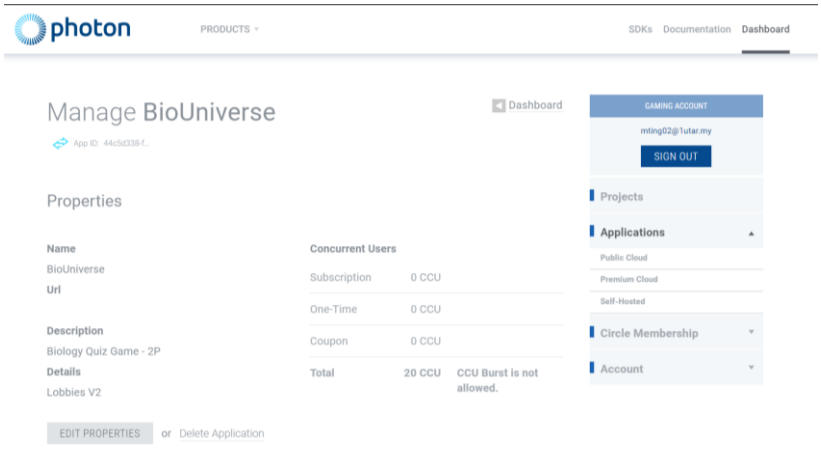


Figure 5-9 Generation of App ID from Photon Engine Dashboard

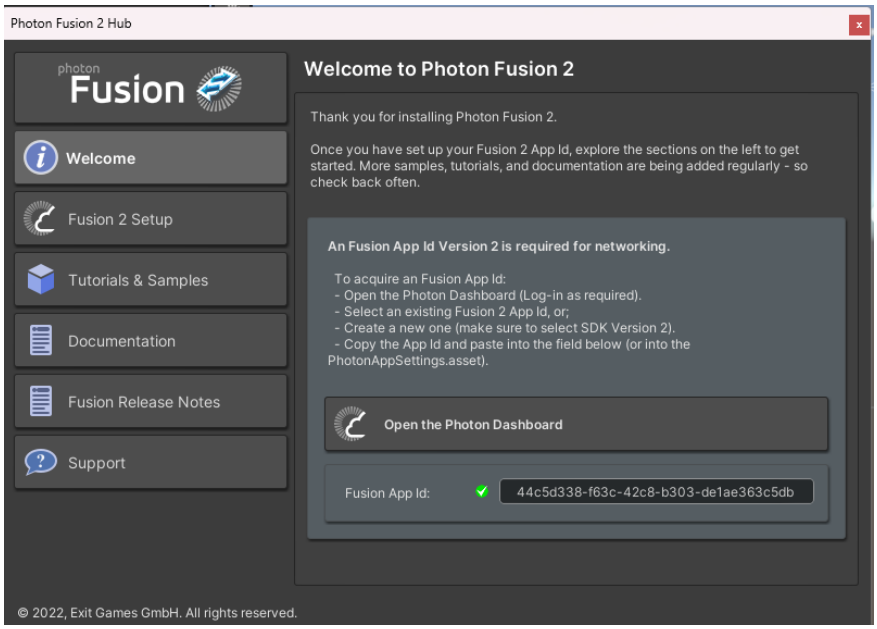


Figure 5-10 Entering App ID into Photon Fusion Hub

5.4 System Development

The major components of the system are described in the following sub-sections.

5.4.1 Login/Registration

The user interfaces were built with Unity Editor with the script that coding on the login and register functions attached. The user authentication part is controlled by Firebase. The important segments of the script that handles login and register functions are as below.

```
private IEnumerator LoginAsync(string email, string password)
{
    var loginTask = auth.SignInWithEmailAndPasswordAsync(email, password);

    yield return new WaitUntil(() => loginTask.IsCompleted);

    if (loginTask.Exception != null)
    {
        Debug.LogError(loginTask.Exception);

        FirebaseException firebaseException = loginTask.Exception.GetBaseException() as FirebaseException;
        AuthError authError = (AuthError)firebaseException.ErrorCode;


        string failedMessage = "Login Failed! Because ";

        switch (authError)
        {
            case AuthError.InvalidEmail:
                failedMessage += "Email is invalid";
                break;
            case AuthError.WrongPassword:
                failedMessage += "Wrong Password";
                break;
            case AuthError.MissingEmail:
                failedMessage += "Email is missing";
                break;
            case AuthError.MissingPassword:
                failedMessage += "Password is missing";
                break;
            case AuthError.UserNotFound:
                failedMessage = "Account does not exist";
                break;
            default:
```

Figure 5-11 Login C# Script Segment

```
private IEnumerator RegisterAsync(string name, string email, string password, string confirmPassword)
{
    if (name == "")
    {
        warningRegisterText.text = "Missing Username";
        yield return new WaitForSeconds(2f);
        warningRegisterText.text = "";
    }
    else if (email == "")
    {
        Debug.LogError("email field is empty");
    }
    else if (passwordRegisterField.text != confirmPasswordRegisterField.text)
    {
        warningRegisterText.text = "Password Does Not Match!";
        yield return new WaitForSeconds(2f);
        warningRegisterText.text = "";
    }
    else
    {
        var registerTask = auth.CreateUserWithEmailAndPasswordAsync(email, password);

        yield return new WaitUntil(() => registerTask.IsCompleted);

        if (registerTask.Exception != null)
        {
            Debug.LogError(registerTask.Exception);

            FirebaseException firebaseException = registerTask.Exception.GetBaseException() as FirebaseException;
            AuthError authError = (AuthError)firebaseException.ErrorCode;

            string failedMessage = "Registration Failed! Becuase ";
            switch (authError)
```

Figure 5-12 Register C# Script Segment

5.4.2 AR Scene

In an AR scene, the surface tracker function will detect flat surfaces and place the 3D model. While the interactions with the models such as rotating, moving and zooming are manipulated by the touch controller.

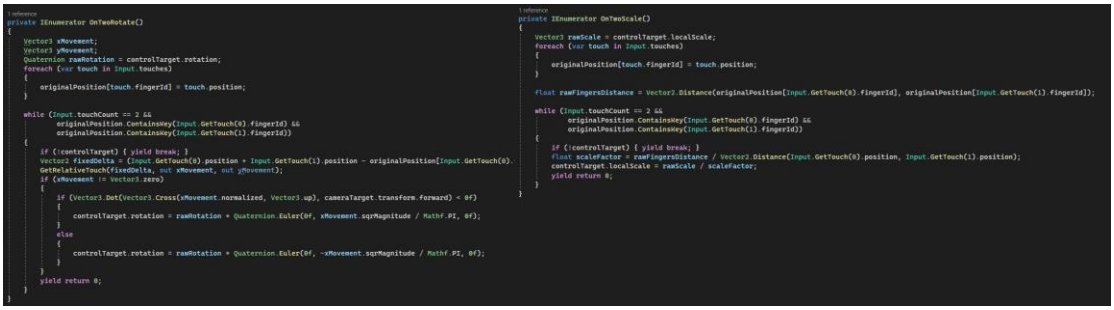


Figure 5-13 Touch Controller C# Script Segments

5.4.3 Quiz Module

For multiplayer quiz that is supported by Fusion Quiz Network, the network game session is started by the Network Runner which is core component of Fusion that is responsible for handling the networking. A new room is created if the connection is successful, or else, the system displays the error message.

```
public async void StartGame(bool joinRandomRoom)
{
    canvasGroup.interactable = false;
    loadingPanel.SetActive(true);

    StartGameArgs startGameArgs = new StartGameArgs()
    {
        GameMode = GameMode.Shared,
        SessionName = joinRandomRoom ? string.Empty : LocalRoomName,
        PlayerCount = 20,
    };

    NetworkRunner newRunner = Instantiate(_networkRunnerPrefab);

    StartGameResult result = await newRunner.StartGame(startGameArgs);

    if (result.Ok)
    {
        roomName.text = "Room:  " + newRunner.SessionInfo.Name;

        GoToGame();
    }
    else
    {
        roomName.text = string.Empty;

        GoToMainMenu();

        errorMessageObject.SetActive(true);
        TextMeshProUGUI gui = errorMessageObject.GetComponentInChildren<TextMeshProUGUI>();
        if (gui)
            gui.text = result.ErrorMessage;

        Debug.LogError(result.ErrorMessage);
    }
    loadingPanel.SetActive(false);
    canvasGroup.interactable = true;
}
```

Figure 5-14 Multiplayer Quiz Start Game Code Segment

5.5 System Operation

5.5.1 Open App and Login/Register

The developed application starts with a splash screen that displays the app background and app name. New users or logout users will be navigated to the login screen after the splash screen while existing or logged-in users will be navigated to their settings screen after opening the app. If the user does not have an account yet, they can navigate to the registration screen by tapping the “NO ACCOUNT YET? REGISTER NOW” link on the login screen. A user can also always navigate from the registration screen back to the login screen by tapping the “ALREADY A USER? LOGIN NOW” link in the registration screen. To either log in or register, a user needs to enter their credentials and click the “LOGIN” or “REGISTER” buttons respectively. Firebase Authentication will check for the validity of the inputs submitted and display toast messages to feedback users.

Figure 5-15 Splash Screen

Figure 5-16 Login Screen

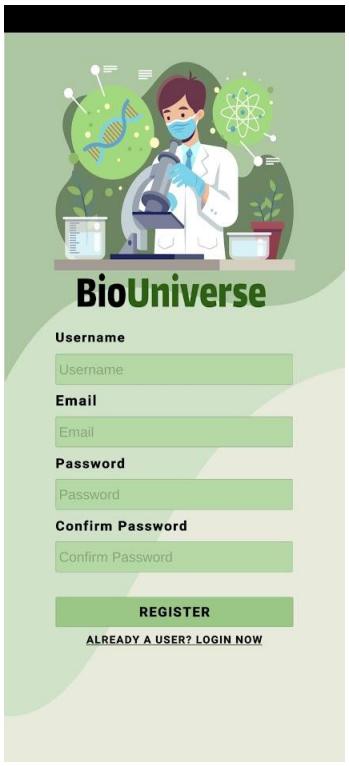


Figure 5-17 Registration Screen

5.5.2 Account Settings and View Tutorials

In the account settings screen, a user will see their profile info at the top part of the screen and three options buttons below it that allow the user to change their existing password to a new password, watch tutorials and log out from their account. The users can change their profile pictures by tapping on it, and they will be able to select a picture from their devices' gallery and upload to the system. To change a new password, the users must enter their old password before entering the new password and reconfirming the password. If the old password is correct, the new password fulfils minimum requirements as well as matches with confirmed new password, the app will prompt a successful toast message. Else, it prompts error messages.

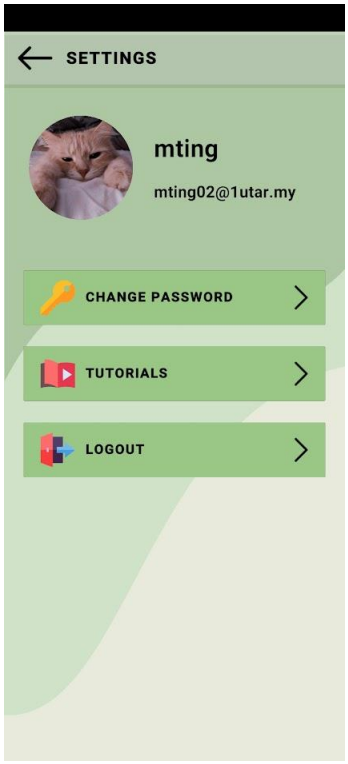


Figure 5-18 Settings Screen

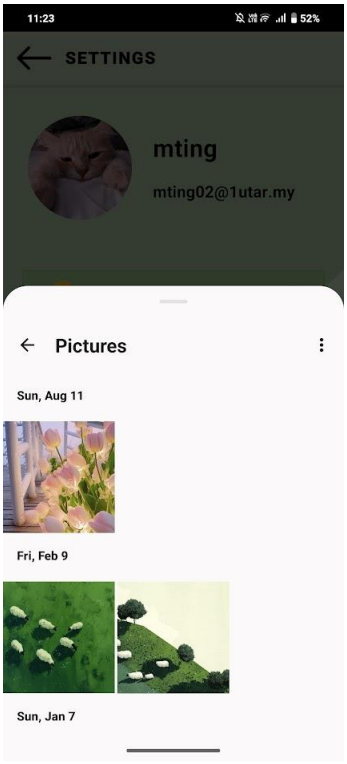


Figure 5-19 Change Profile Picture

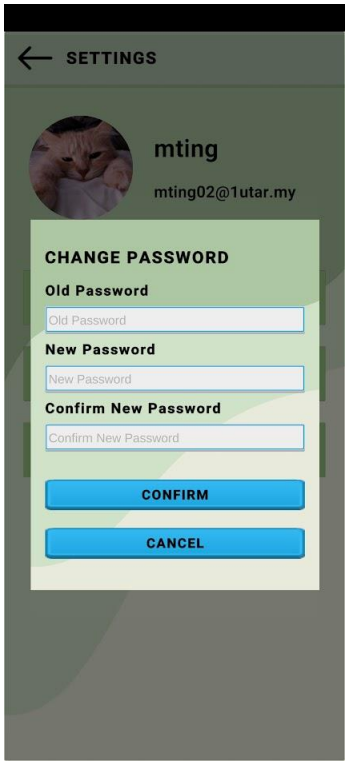


Figure 5-20 Change Password

The tutorial menu panel prompts if users click on the “TUTORIALS” button. Users can select which tutorials they are interested in and see the detailed guidelines on how to use certain functions in the app.

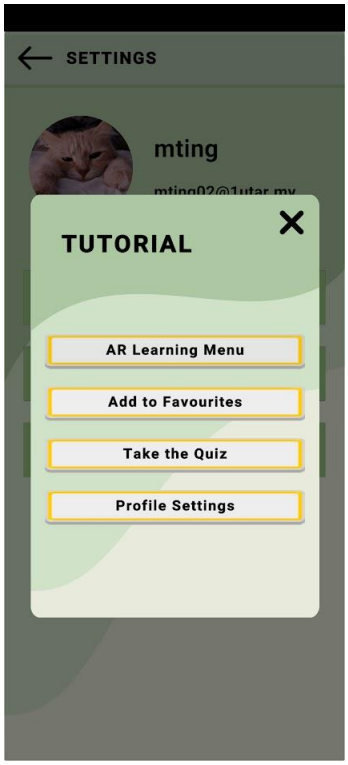


Figure 5-21 Tutorial Menu Panel

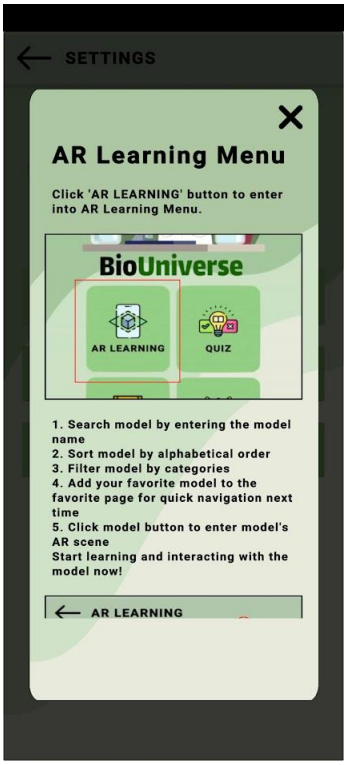


Figure 5-22 AR Module Tutorial

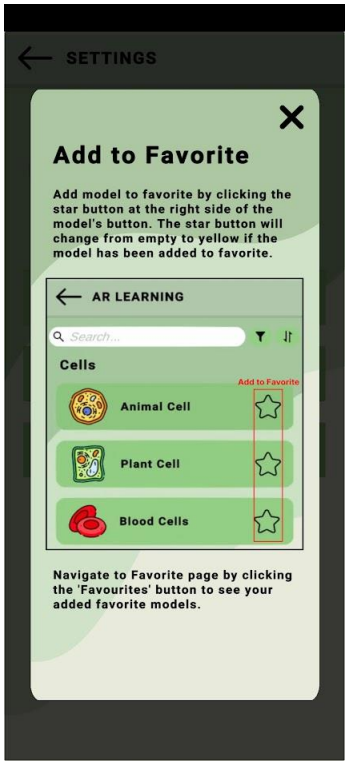


Figure 5-23 Add to Favorite Tutorial

5.5.3 Home Screen

The home screen of the app consists of 5 buttons that represent the main components of the app.

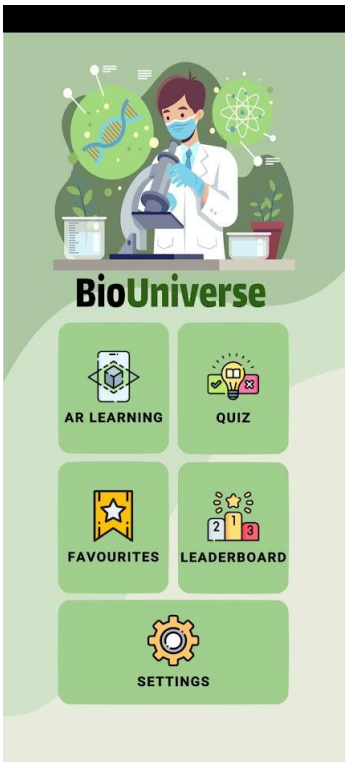


Figure 5-24 Home Screen

5.5.4 AR Models Menu

This screen prompts if users click the “AR LEARNING” button in the home screen. The scrollable list of available biological models is displayed in categories. Clicking any of the models will navigate users to the corresponding model’s AR scene. Users can search for a specific model by entering the model’s name into the search bar at the top of the screen, matching model will be displayed.

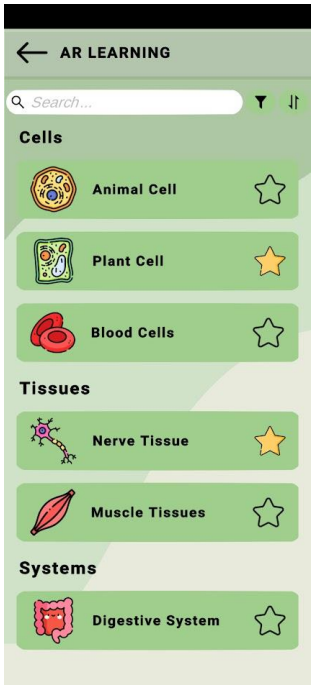


Figure 5-25 AR Models Menu Screen

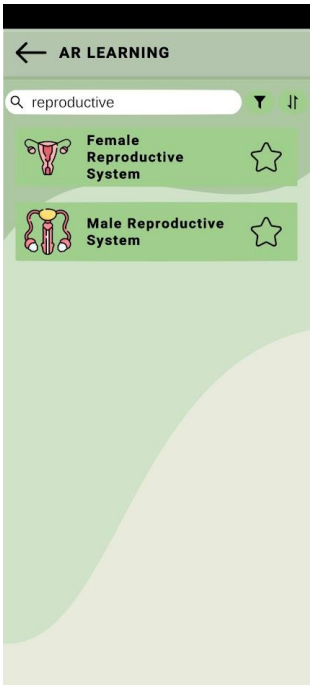


Figure 5-26 Search Function

Users can filter models by clicking the filter button next to the search bar, they can choose to view all categories or specific category as shown in the figure below.

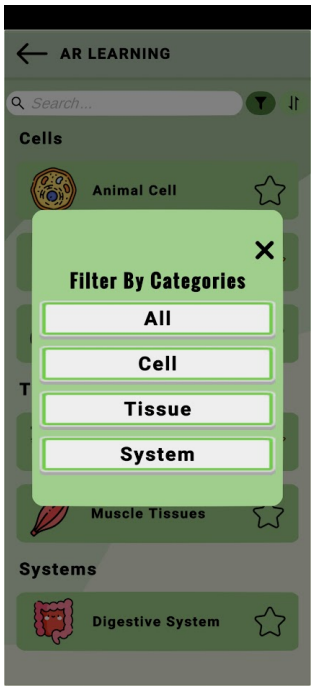


Figure 5-27 Filter Function

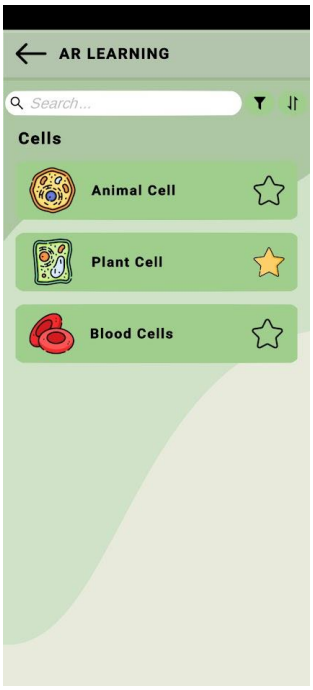


Figure 5-28 Filter Result

Other than filter, users can sort the model list by alphabetical order as shown in figures below.

Figure 5-29 Sort Function

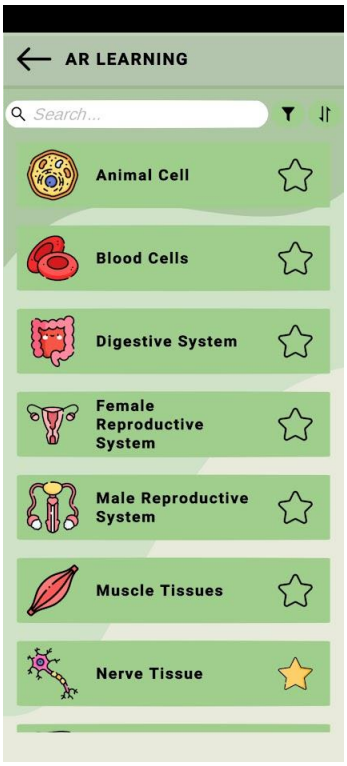


Figure 5-30 Sort Result

5.5.5 AR Camera Scene

When entering the AR Camera Scene for any model, the model will be displayed as soon as a surface is tracked. The screen layout is simple to prevent any confusion or distraction to users during their model interaction and learning process. There is an info button at the top right of the screen that users can always tap on to check on how to interact with the 3D models. Tapping the model parts will highlight the selected part along with the overlay of corresponding information. Users can conveniently tap the screenshot button at the bottom right of the screen to capture the screen with certain pieces of information displayed along with the model at the desired angle and position. The captured image is directly saved to the user's device's album as shown in the figure

below. Moreover, if users click the “Stop Tracking” button, the model will disappear from the screen, and click the button again, the model will be redisplayed. No matter what angle or position that users have made to the model, they can always restore the model to its original view by clicking the “Reset Model” button.

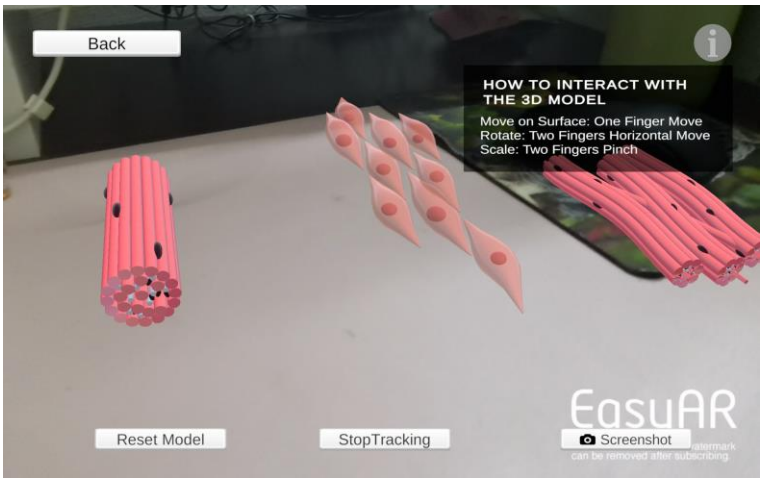


Figure 5-31 Info Button to show Interaction Tips

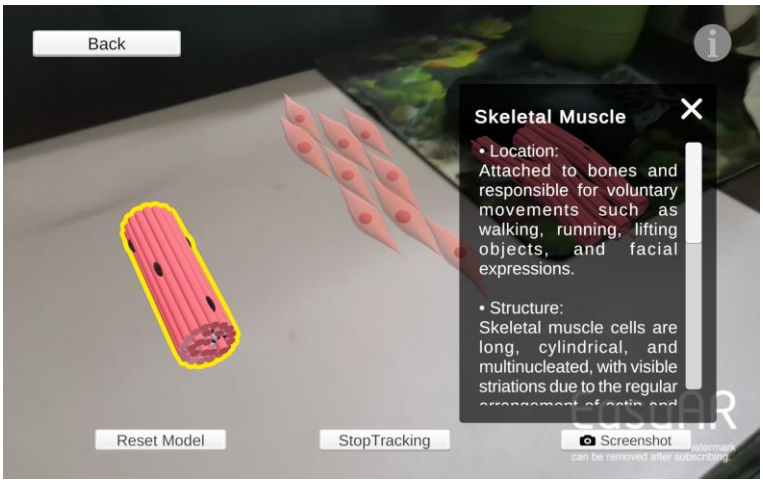


Figure 5-32 Textual Information on Selected Part

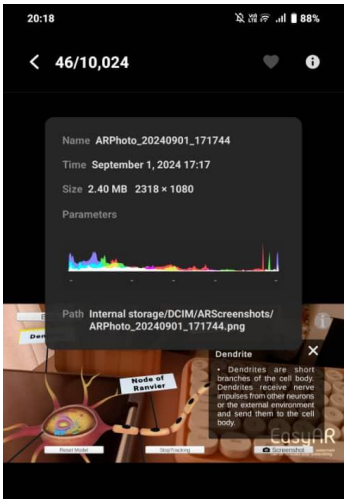


Figure 5-33 Captured Screenshot Saved in Album

5.5.6 Favourite Models

Users can toggle the star button at the right of the model button in the AR Models Menu Screen if they wish to add the model to their favourite models. The added models will be updated in the favourites screen, and users will be able to enter their favourite model's AR scene in just a few clicks in their next use.

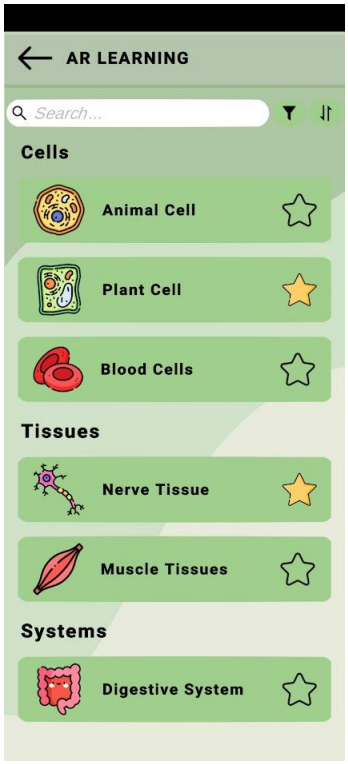


Figure 5-34 AR Models Menu Screen

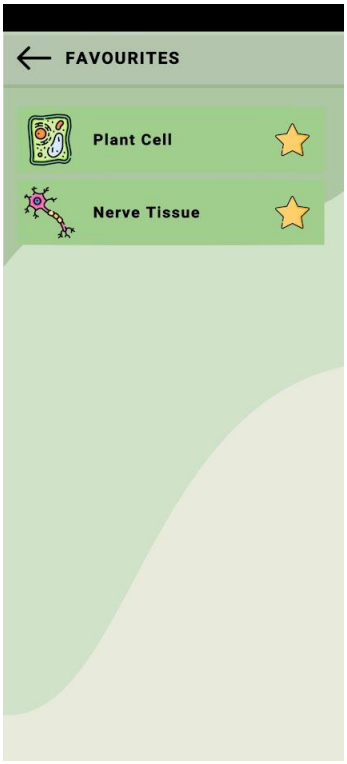


Figure 5-35 Favourite Models Screen

5.5.7 Quiz Taking

Users can choose which quiz mode they want to attempt in the quiz mode selection panel as shown in the figure below. This panel prompts when users click on the “QUIZ” button on the home screen.

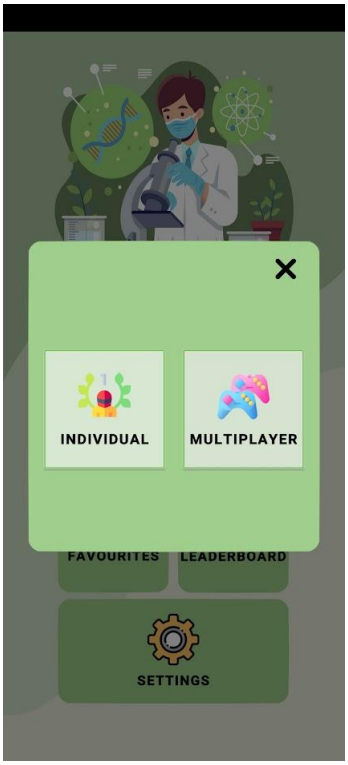


Figure 5-36 Quiz Mode Selection Panel

If users select individual quiz mode, they will be navigated to the question sets screen. After selecting the quiz set that they want to attempt, they will be navigated to the corresponding quiz session. The result panel prompts after they finish answering the questions, showing their correct answers count, time taken to complete, and points collected from that particular quiz session. They can opt to try that question set again or back to the quiz menu from the two buttons at the bottom of the result panel.

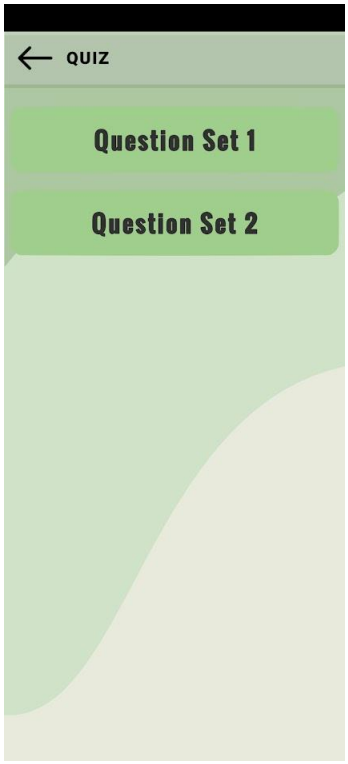


Figure 5-37 Individual Quiz Question Sets

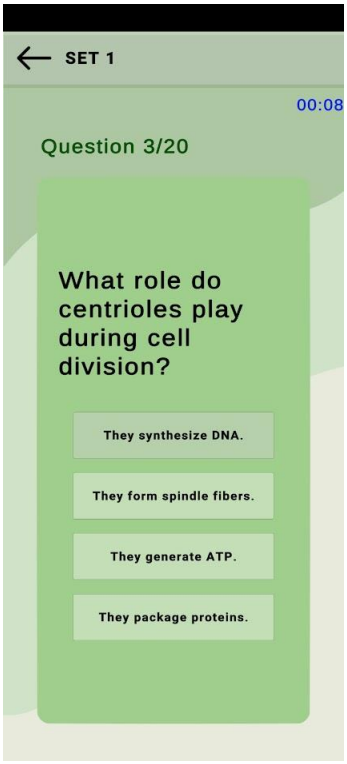


Figure 5-38 Individual Quiz Session

Figure 5-39 Individual Quiz Result Panel

In contrast, if users choose multiplayer quiz mode, they will be navigated to the game lobby, and they will have to enter their player name and the room name they wish to join. Users will join into same game session, as long as they enter the same room name they agreed upon themselves. The maximum number of players per session is up to 20. The first user that gets into the room will be the game host, with the authority to start the game. While others will have to wait in the room until the host starts the game. They are free to choose their avatar displayed on the screen, and they can communicate with each other freely throughout the entire game session unless they turn off their mic by clicking the speaker icon.

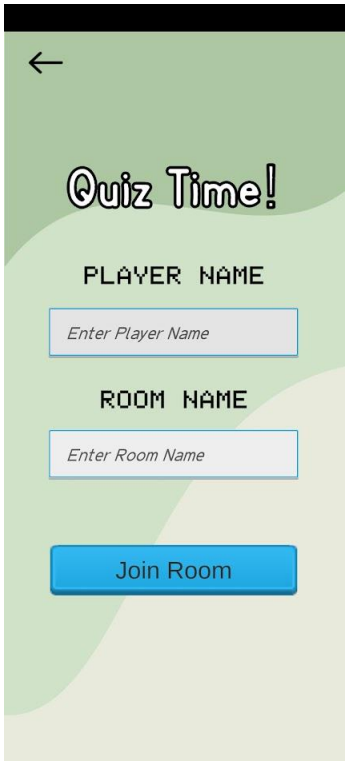


Figure 5-40 Game Lobby

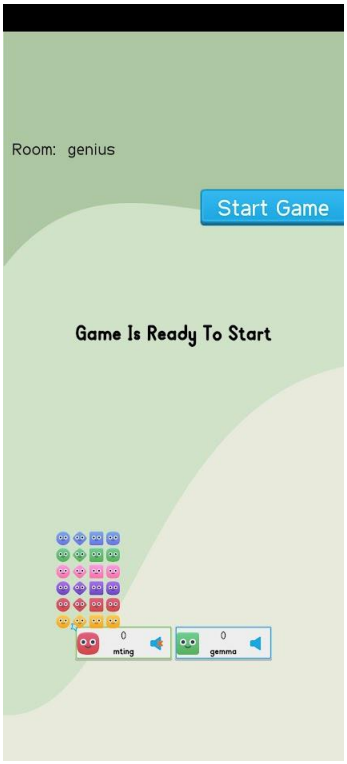


Figure 5-41 Game Room

After the game starts, for each question, there will have 30 seconds of countdown represented by the time indicator from the left side of the screen. The correct answer will not be revealed until all players choose their answer or the time is up. Only the top 3 winners based on the points scored will be displayed on the result screen. A user can choose to leave the session or wait for the host to start another session.

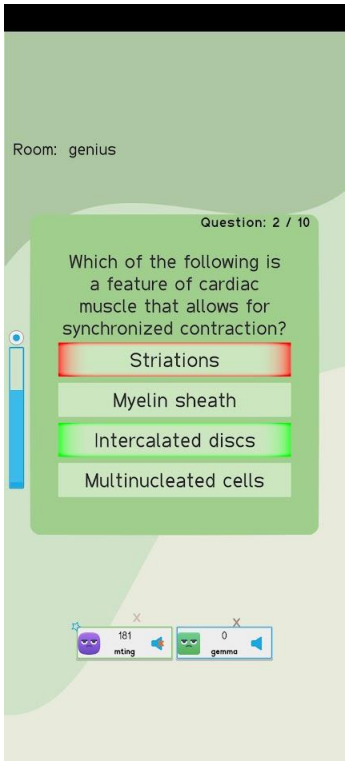


Figure 5-42 Multiplayer Quiz Session

Figure 5-43 Multiplayer Quiz Result

5.5.8 View Leaderboard

Users can view the top 15 points scorers in the leaderboard screen.

Figure 5-44 Leaderboard Screen

5.6 Implementation Issues and Challenges

A few difficulties were faced during the development and implementation. One of the significant challenges would be the acquisition of 3D biology models. The free available models are often too simple and might not be able to be a good study subject for the user to learn the details. Therefore, quite a long time was taken to search for the appropriate models. However, the models acquired came in different formats, while Unity only accepts and works fine with a few formats such as .fbx and .obj. Thus, trying different solutions to convert the unsupported formats into supported formats and import them into Unity took some additional time.

Another challenge would be the unfamiliarity with the development tools and languages. The app functions and interfaces were developed using C# and Unity but the limited proficiency in the language and the operation of the software hindered the efficiency and progress of the development process at the beginning stage, especially under stress and time constraints.

Besides, another difficulty that was frustrating was when integrating the Fusion Quiz Network into the multiplayer quiz module. Error kept prompting during the establishment of the network connection, but the error message was too vague and limited information about the error was able to be searched online. More time was then to be invested to try again and again which caused a little delay in the planned schedule.

Chapter 6

System Evaluation and Discussion

This chapter focuses on the system evaluation and discussion, providing insights into the app's functionality and performance. It begins with system testing which evaluates various functional test cases, followed by expert evaluation and user evaluation, which examine the results from the experiment and overall user feedback on the app's effectiveness. Lastly, the chapter ends with an evaluation of whether the objectives of the project were met.

6.1 System Testing and Performance Metrics

Functional testing was conducted to ensure that all features and functionalities of the app work intended as in planning, aligning with the designed requirements. This process involved verifying that key components, such as the AR learning module, quiz module, and user interface interactions, functioned correctly under various scenarios. The goal was to confirm that the app delivers a seamless user experience and meets its educational objectives.

6.1.1 User Authentication and Authorization Functional Test Case

Table 6-1 User Authentication and Authorization Functional Test Case

Action	Input	Expected Output	Actual Output	Pass/Fail
Registration	Provide valid and invalid registration information. • **Valid Email:** mting02@1utar.my • **Invalid Email:** mting1utar.my • **Valid Password:** Abc123 • **Invalid Password:**	Successful registration with valid inputs; Unsuccessful registration with appropriate error messages for invalid inputs or unmatched passwords.	Successful registration with valid inputs; Unsuccessful registration with appropriate error messages for invalid inputs or unmatched passwords.	Pass

	Any password lesser than 6 inputs • **Invalid inputs:** Leave blank to any fields			
Login	Enter valid and invalid login credentials. • **Valid Email:** Any registered email • **Invalid Email:** mting1utar.my or any unregistered email • **Valid Password:** The correct password • **Invalid Password:** Any wrong password • **Invalid inputs:** Leave blank to any fields	Successful login with valid credentials; denied access with error message for invalid credentials.	Successful login with valid credentials; denied access with error message for invalid credentials.	Pass
Logout	Click on the logout option in Settings screen.	Successfully logged out and cannot access app content without logging back in.	Successfully logged out and cannot access app content without logging back in.	Pass

6.1.2 Account Settings Functional Test Case

Table 6-2 Account Settings Functional Test Case

Action	Input	Expected Output	Actual Output	Pass/Fail
Change Profile Picture	Change profile picture to any	The device gallery prompt to let user	The device gallery prompt to let user	Pass

	picture by tapping the profile picture itself	choose a photo. Changed picture is reflected accurately in any screen.	choose a photo. Changed picture is reflected accurately in any screen.	
Change Password	Enter old password, new password and confirmed password. **Valid Inputs:** • Correct old password • New password with more than 6 inputs • Matching confirmed password with new password **Invalid Inputs:** • Incorrect old password • New password with less than 6 inputs • Unmatched confirmed password with new password	Successfully change password with valid inputs; prompt error message for invalid inputs until valid inputs are entered.	Successfully change password with valid inputs; prompt error message for invalid inputs until valid inputs are entered.	Pass
View User Tutorials	Click on the tutorial option in settings.	A tutorial menu panel prompts; all contents are scrollable and displays correctly.	A tutorial menu panel prompts; all contents are scrollable and displays correctly.	Pass

6.1.3 AR Learning Module Functional Test Case

Table 6-3 AR Learning Module Functional Test Case

Action	Input	Expected Output	Actual Output	Pass/Fail
Choose Model	Click on any model in the AR Menu Model screen.	The model's corresponding AR Camera scene loaded accurately. The model is placed once a surface is tracked.	The model's corresponding AR Camera scene loaded accurately. The model is placed once a surface is tracked.	Pass
Interact with Model	Rotate, move and zoom the AR models.	Smooth and accurate interaction with the models.	Smooth and accurate interaction with the models.	Pass
Select Model Part and Display Overlay Information	Click on parts that have information to be displayed.	The part selected is highlighted with correct information panel overlay on right side of the screen. The information is scrollable if it is longer than the panel.	The part selected is highlighted with correct information panel overlay on right side of the screen. The information is scrollable if it is longer than the panel.	Pass
View Model Interaction Tips	Click the info button on the top right of the AR scene.	The interaction tips panel is displayed. Click again will close the panel.	The interaction tips panel is displayed. Click again will close the panel.	Pass
Capture AR Camera Screen	Click the screenshot button on the bottom right of the AR scene.	The particular screen is captured, and the screenshot is saved to the device's gallery.	The particular screen is captured, and the screenshot is saved to the device's gallery.	Pass
Restore Model Original View	Click the reset model button on the bottom left of the AR scene.	The model is reset back to its original position and angle.	The model is reset back to its original position and angle.	Pass

Search Model	Enter a model name in the search bar in the AR Models Menu screen.	Model(s) that matches the entered input are displayed on the list.	Model(s) that matches the entered input are displayed on the list.	Pass
Filter Model	Click the filter model button and filter based on different categories.	Corresponding categories are filtered and displayed.	Corresponding categories are filtered and displayed.	Pass
Sort Model	Click the sort model button and sort the models.	The models are sorted based on sort options.	The models are sorted based on sort options.	Pass

6.1.4 Favourite Module Functional Test Case

Table 6-4 Favourite Module Functional Test Case

Action	Input	Expected Output	Actual Output	Pass/Fail
Add to Favourites	Click the star button next to the model's name in AR Models Menu screen.	Th empty star changes to filled star and vice versa, indicating adding or removing from favourites.	Th empty star changes to filled star and vice versa, indicating adding or removing from favourites.	Pass
View Favourites	Click the "FAVOURITES" button in home screen.	The list of favourite models displayed.	The list of favourite models displayed.	Pass
Remove Favourites	Click the filled star button in favourites screen.	The model is removed from favourites screen. The changes reflect in AR Models Menu screen as well.	The model is removed from favourites screen. The changes reflect in AR Models Menu screen as well.	Pass

6.1.5 Quiz Module Functional Test Case

Table 6-5 Quiz Module Functional Test Case

Action	Input	Expected Output	Actual Output	Pass/Fail
Choose Quiz Mode	Click "QUIZ" button in home screen.	A panel prompts with two buttons to let users choose individual or multiplayer quiz modes.	A panel prompts with two buttons to let users choose individual or multiplayer quiz modes.	Pass
Choose Quiz Set (Individual Mode)	Click "INDIVIDUAL" button in the Quiz Mode Selection panel. Choose any set of question.	The list of available question sets prompts; clicking any set navigates to the corresponding quiz session.	The list of available question sets prompts; clicking any set navigates to the corresponding quiz session.	Pass
Start Quiz (Individual Mode)	Click a question set, start answering the questions.	The question count displays correctly with timer running on the top right of the screen. "Correct" and "Incorrect" messages prompts for each correctly or incorrectly answered question respectively.	The question count displays correctly with timer running on the top right of the screen. "Correct" and "Incorrect" messages prompts for each correctly or incorrectly answered question respectively.	Pass
Display Result Panel (Individual Mode)	Finish answering all questions.	The result panel prompts with accurate correct answer count, time taken to complete, and points rewarded (10 points for each correct answer).	The result panel prompts with accurate correct answer count, time taken to complete, and points rewarded (10 points for each correct answer).	Pass

Quiz Lobby (Multiplayer Mode)	Click "MULTIPLAYER" button in the Quiz Mode Selection panel. Enter player name and room name and click join room.	All players are able to join into the same room if they enter same room name.	All players are able to join into the same room if they enter same room name	Pass
Display Error (Multiplayer Mode)	Turn off internet.	Connection error prompts and unable to join room.	Connection error prompts and unable to join room.	
Choose Avatar (Multiplayer Mode)	Click the avatar.	Options of avatar display; can change to any avatar freely throughout the game.	Options of avatar display; can change to any avatar freely throughout the game.	Pass
Real Time Voice Chat (Multiplayer Mode)	Click the speaker icon.	Able to mute or communicate in real time with all players inside the room throughout the game.	Able to mute or communicate in real time with all players inside the room throughout the game.	Pass
Start Quiz (Multiplayer Mode)	Game host click the "Start Game" button after all players joined.	Question displays consistently for every player with 30 seconds timer countdown. Correct answer are shown before changing to next question. Points are awarded to players who answer correctly.	Question displays consistently for every player with 30 seconds timer countdown. Correct answer are shown before changing to next question. Points are awarded to players who answer correctly.	Pass
Display Result (Multiplayer Mode)	Finish answering all questions.	The top three winners are displayed. "Start New Game" and "Leave Session"	The top three winners are displayed. "Start New Game" and "Leave Session"	Pass

		buttons appear in host's side while other players's side display only "Leave Session" button.	buttons appear in host's side while other players's side display only "Leave Session" button.	

6.1.6 Leaderboard Functional Test Case

Table 6-6 Leaderboard Functional Test Case

Action	Input	Expected Output	Actual Output	Pass/Fail
View Leaderboard	Click "LEADERBOARD" button in home screen.	The top 15 highest points scorers are displayed, with their profile picture, username, and point earned.	The top 15 highest points scorers are displayed, with their profile picture, username, and point earned.	Pass

6.2 Expert Evaluation

To gain professional insights into the educational value and usability of the app, an expert evaluation was carried out by sending the app, along with a questionnaire, to a secondary biology teacher with over 15 years of teaching experience. Although the teacher has extensive experience in teaching biology, she has never used augmented reality (AR) in her lessons before. The purpose of this evaluation was to gather feedback from an expert perspective, particularly on how effective and intuitive the developed app is as a tool for enhancing biology education. The teacher was asked to explore the app and answer questions related to its potential to support student learning, ease of use, and how well the AR content integrates with traditional teaching methods. The results of the expert evaluation are depicted as below.

Usability Evaluation:

Table 6-7 Expert Usability Evaluation Survey Result

Question Type	Question	Response
Scale: 1 – Very intuitive 5 – Very confusing	How intuitive do you find the app's user interface?	1
Scale: 1 – Very easy 5 – Very difficult	How easy is it to navigate through the different features of the app?	1
Multiple Choice: • Yes, completely • Yes, somewhat • Neutral • No, I needed some instructions • No, I needed significant support	Were you able to use the app effectively without needing instructions or support?	Yes, somewhat
Scale: 1 – Very responsive 5 – Very unresponsive	How responsive was the app to your inputs and commands?	2
Scale: 1 – Very easy 5 – Very difficult	How would you rate the ease of interacting with 3D models (e.g., rotating, zooming, moving) in the AR environment?	2
Scale: 1 – Very clear and helpful 5 – Very unclear and unhelpful	How clear and helpful are the textual information and annotations provided with the 3D models?	2

Interpretation

Based on the expert evaluation results in terms of the usability of the developed app, the expert thinks that the app is generally intuitive and easy to use. The user interface and navigation were rated as highly intuitive and straightforward, making it accessible without extensive instructions, though some minor guidance could enhance the experience. The app was found to be quite responsive to inputs and allowed for relatively easy interaction with 3D models, though there is room for improvement in responsiveness. The textual annotations were deemed clear and helpful, contributing to

the overall effectiveness of the app. While the evaluation is positive, slight enhancements in responsiveness, textual information and user support could further optimize the usability.

Educational Effectiveness:

Table 6-8 Expert Educational Effectiveness Evaluation Survey Result

Question Type	Question	Response
Scale: 1 – Very likely 5 – Very unlikely	How likely is this app to enhance students' understanding of biology concepts?	2
Multiple Choice: • Very effective • Very ineffective	How effective do you think the app is in making complex biological concepts more understandable through AR models?	Very effective
Scale: 1 – Very likely 5 – Very unlikely	How likely are students to remain engaged with the subject matter using this app?	1
Scale: 1 – Very likely 5 – Very unlikely	How likely is this app to help students to get more motivated and interested in learning in biology?	1
Multiple Choice: • Strongly aligns • Strongly misaligned	Does the app support and align with the learning objectives of the Form 4 biology curriculum?	Strongly aligns
Multiple Choice: • Yes • Maybe • No	Would you consider integrating this app into your regular teaching practices?	Maybe
Scale: 1 – Very useful 5 – Not useful at all	How useful is the quiz feature for assessing student understanding?	2
Scale: 1 – Very likely 5 – Very unlikely	How likely would you be to use the multiplayer quiz feature for collaborative learning in the classroom?	1
Open-ended	What do you consider to be the app's greatest strengths?	Might be able to integrate into teaching by projecting it

		to big screen. The multiplayer game is good for class participation.
Open-ended	What are the most significant areas for improvement?	For small phone screen size, might be difficult to play around with the 3D models. And the part highlight for information display can have further improvement.

Interpretation

The expert evaluation regarding educational effectiveness shows a positive outlook for the app's potential to enhance biology learning. The expert thinks that the app is considered effective in making complex biological concepts more understandable through AR models. The likelihood of students remaining engaged and motivated to learn biology using the app was rated as very high, highlighting the app's strong potential to keep students interested in the subject. Furthermore, the expert agrees that the app strongly aligns with the learning objectives of the Form 4 biology curriculum, suggesting its suitability for classroom use. However, the expert suggests that while the quiz feature is useful for assessing student understanding, there is room for improvement. Additionally, the multiplayer quiz is seen as a significant strength, particularly for encouraging classroom participation.

However, the expert also pointed out that interacting with 3D models on smaller phone screens may pose a challenge, which is valid as it might be struggling to perform precise gestures needed to interact with 3D models in detail. Misclicks, accidental rotations or difficulty selecting specific parts of the model could happen when the space is limited. The expert also suggested that how the specific parts of the model are highlighted to provide additional details could be improved. The current part highlight might not be visually distinct enough from the rest of the model, making it hard for users to focus on the relevant section. These two feedback reveals two critical issues that could hinder user experience and app effectiveness; therefore it is vital to refine both these areas for improvement in future work to ensure the app achieves its educational goals.

6.3 User Evaluation

To assess the effectiveness and usability of the app, a user evaluation with 20 secondary Form 4 students who are currently taking Biology was conducted, splitting into two groups equally and randomly: an experimental group and a control group. The purpose of this evaluation was to measure how the AR learning module impacts student achievement. Both groups have already studied the topics in traditional methods during their previous lessons. The experimental group used the AR learning module before attempting two sets of quizzes in the individual quiz module, while the control group took the same quizzes without using the AR module beforehand. This design allowed the comparison of the performance of both groups and evaluate the influence of the AR module on their learning outcomes.

The quiz delivered to students consists of 40 multiple-choice questions (MCQs), divided into two sets. Each question assesses a key biological concept, and is relevant and aligned with the content provided in the AR module of the app. Below are sample questions being assessed:

1. Which of the following is NOT a function of the Golgi apparatus?
   A) Processes carbohydrates
   B) Synthesizes proteins
   C) Modifies glycoproteins
   D) Packs chemicals for transport
   Answer: B) Synthesizes proteins
2. What is the primary function of mitochondria in animal cells?
   A) Photosynthesis
   B) Cellular respiration
   C) Protein synthesis
   D) Detoxification
   Answer: B) Cellular respiration

In the survey, students were asked to report their results for the two quizzes, which helped in comparing the effectiveness of the app in improving student achievement. Additionally, the second section of the survey focused on collecting the students'

opinions about the app's usability and its educational value. By gathering this data, the aim was not only to evaluate the app's performance as a learning tool but also to assess its user experience and overall effectiveness in enhancing education.

The experimental and evaluation process was depicted in the diagram below:

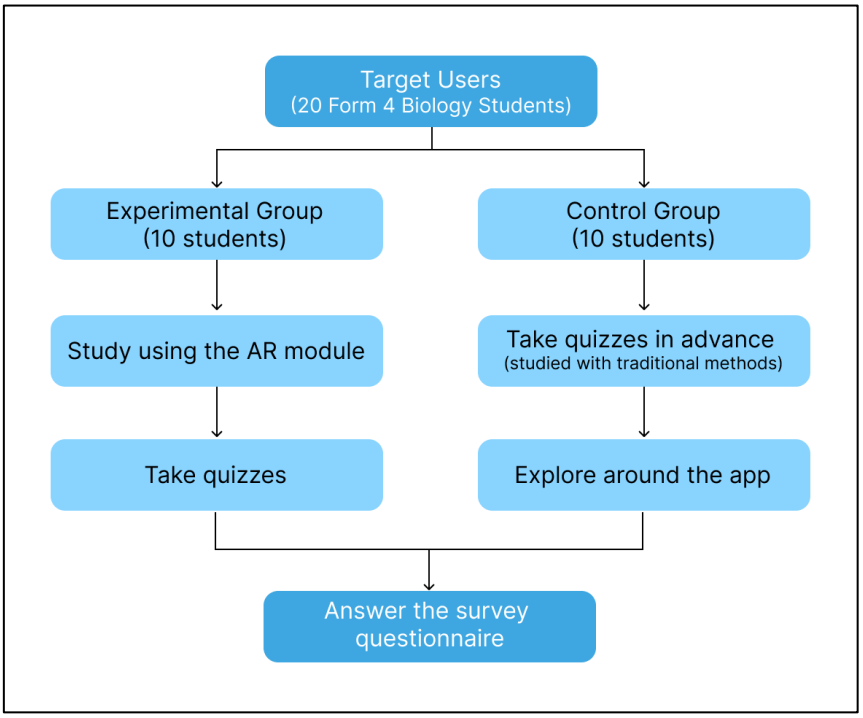


Figure 6-1 Experimental and Evaluation Process

6.3.1 Experiment Result

Based on the quiz scores replied by the students from the survey questionnaire, the raw results are summarized in the table below.

Experimental Group Result:

Table 6-9 Experiment Group Result

Student	Number of Correct Answers (Set 1)	Number of Correct Answers (Set 2)	Set 1 Score (%)	Set 2 Score (%)	Average Score (%)
1	18	19	90	95	92.5

2	8	13	40	65	52.5
3	13	16	65	80	72.5
4	13	13	65	65	65.0
5	17	15	85	75	80.0
6	17	17	85	85	85.0
7	10	14	50	70	60.0
8	12	15	60	75	67.5
9	20	18	100	90	95.0
10	11	12	55	60	57.5
				Group Average Score:	**72.75%**

Control Group Result:

Table 6-10 Control Group Result

Student	Number of Correct Answers (Set 1)	Number of Correct Answers (Set 2)	Set 1 Score (%)	Set 2 Score (%)	Average Score (%)
1	17	17	85	85	85.0
2	9	10	45	50	47.5
3	13	15	65	75	70.0
4	12	13	60	65	62.5
5	16	15	80	75	77.5
6	15	14	75	70	72.5
7	8	14	40	70	55.0
8	11	11	55	55	55.0
9	18	17	90	85	87.5
10	10	16	50	80	65.0
				Group Average Score:	**67.75%**

Overall Comparison:

Table 6-11 Overall Comparison

Group	Overall Average Score	Improvement
Experimental Group	72.75%	**+5%**
Control Group	67.75%	-

Discussion:

Based on the experiment results, the experiment group that utilized the AR module in addition to traditional study methods demonstrated a slight improvement in their quiz performance compared to the control group. The experiment group achieved an overall average score of 72.75%. In contrast, the control group, which did not use the AR module but studied the topic in traditional way, had an overall average score of 67.75%. This indicates a 5% improvement in the experiment group's performance, suggesting that the interactive and immersive nature of the AR app may have contributed to better knowledge retention and engagement, leading to higher quiz scores.

However, frankly speaking, the experiment environment and settings were not strictly controlled, and considering the several potential limitations in the experiment, the results are subjected to bias. Firstly, the sample size of the experiment was relatively small, and the experiment duration was also short. Additionally, there were some external influences such as prior knowledge of the topic, the students might be sharing the answers among themselves or looking for answers from other sources. Moreover, the way of the results was collected could be subjective and inaccurate. By acknowledging these weaknesses, the conclusion from this experiment serves only as an important initial step in evaluating the potential of AR educational app as a supplement tool in enhancing student learning and engagement in Biology by measuring the immediate effectiveness of the developed app.

6.3.2 Evaluation Result

From the second section of the survey that aimed to collect user opinions on the app's usability and educational effectiveness, the findings are summarized as follows.

Usability Evaluation:

Table 6-12 User Usability Evaluation Survey Result

Question Type	Question	Response
Scale: 1 – Very easy 5 – Very difficult	How easy was it to navigate through the app?	1: **10 respondents (50%)** 2: **7 respondents (35%)** 3: **3 respondents (15%)**

Scale: 1 – Very easy 5 – Very difficult	How easy was it to interact with the 3D models (e.g., rotating, zooming, moving)?	1: **4 respondents (20%)** 2: **12 respondents (60%)** 3: **3 respondents (15%)** 4: **1 respondent (5%)**
Scale: 1 – Very helpful 5 – Not helpful at all	How helpful were the textual information and annotations provided with the 3D models?	1: **2 respondents (10%)** 2: **10 respondents (50%)** 3: **7 respondents (35%)** 4: **1 respondent (5%)**
Scale: 1 – Very easy 5 – Very difficult	How easy was it to use the quiz feature within the app?	1: **14 respondents (70%)** 2: **5 respondents (25%)** 3: **1 respondent (5%)**
Scale: 1 – Very satisfied 5 – Very unsatisfied	How satisfied were you with the app's overall design and layout?	1: **3 respondents (15%)** 2: **10 respondents (50%)** 3: **7 respondents (35%)**

Interpretation:

The usability evaluation of the AR app from the users reveals generally positive feedback from respondents, although there are areas for improvement. Majority of users found it is very easy to navigate through the app and interact with 3D models (rotating, zooming, etc.), though some might have encountered minor challenges, suggesting room for improvement in the interactivity feature. When it comes to the clarity of textual information and annotations, more than half of users found them helpful, while others rated moderately helpful, indicating a need for better or more detailed textual explanations. The quiz feature received a strong positive response, with almost all respondents finding it very easy to use. In terms of the overall design and layout of the app, 15% were very satisfied, 50% were satisfied, though 35% rated it more moderately, showing that some users may expect a more modern or visually appealing design.

Educational Effectiveness:

Table 6-13 Expert Educational Effectiveness Evaluation Survey Result

Question Type	Question	Response
Scale: 1 – Very engaging 5 – Not engaging at all	How engaging did you find the learning experience?	1: **3 respondents (15%)** 2: **11 respondents (55%)** 3: **6 respondents (30%)**

Multiple Choice: • Yes • No • Maybe	Do you feel that the app helped you better understand the biology concepts compared to traditional study methods?	Yes: **12 respondents (60%)** Maybe: **8 respondents (40%)**
Scale: 1 – Very well 5 – Not well at all	How well do you think the quiz questions reflected the content you studied?	1: **4 respondents (20%)** 2: **8 respondents (40%)** 3: **8 respondents (40%)**
Scale: 1 – Much more effective 5 – Much less effective	Compared to traditional study methods, how much more (or less) effective was using the app for learning?	1: **6 respondents (30%)** 2: **7 respondents (35%)** 3: **7 respondents (35%)**
Multiple Choice: • Yes • No • Maybe	Did using the app make the learning process more enjoyable, motivated or interested for you?	Yes: **15 respondents (75%)** Maybe: **5 respondents (25%)**
Multiple Choice: • Yes • No • Maybe	Have you met any difficulties when using the app?	Maybe: **9 respondents (45%)** No: **11 respondents (55%)**
Multiple Choice: • Yes, navigating through the app was frustrating. • Yes, interacting with the 3D models was difficult. • Yes, the quizzes were confusing or hard to understand. • Yes, the app was too slow or unresponsive. • No, I did not find anything particularly frustrating.	Were there any specific features or aspects of the app that you found frustrating or difficult to use?	• No, I did not find anything particularly frustrating.: **12 respondents (60%)** • Yes, the app was too slow or unresponsive.: **5 respondents (25%)** • Yes, interacting with the 3D models was difficult.: **2 respondent (10%)** • Yes, the quizzes were confusing or hard to understand.: **1 respondent (5%)**
Multiple Choice: • App navigation and user interface.	Which of the following area do you think need the most improvement?	• Overall responsiveness and performance of the app. **8 respondents (40%)**

• Interaction with 3D models. • Clarity and helpfulness of textual information. • Quiz content and difficulty level. • Overall responsiveness and performance of the app. • Visual design and layout.		• App navigation and user interface. **3 respondents (15%)** • Interaction with 3D models. **3 respondents (15%)** • Visual design and layout. **3 respondents (15%)** • Quiz content and difficulty level. **2 respondents (10%)** • Clarity and helpfulness of textual information. **1 respondent (5%)**

Interpretation:

In terms of the educational effectiveness, the user feedback reveals a generally positive reception with a few areas for improvement. The majority of respondents found the learning experience engaging, with 60% admitting that the app helped them better understand biology concepts compared to traditional study methods. Furthermore, 75% of users stated that the app made the learning process more enjoyable and motivating. However, 40% felt that the quiz content moderately reflected what they studied, suggesting the need for better alignment between the content and the quizzes. While 30% found the app much more effective than traditional methods, 35% rated it somewhat effective and the remaining 35% rated neutral, highlighting that the app adds value but could have further refinements for broader impact.

For the areas for improvement, 40% of respondents felt that the overall responsiveness and performance of the app required the most attention, followed by 15% highlighting app navigation, interaction with 3D models, and visual design as areas that could be enhanced. The majority of users did not face significant difficulties using the app, though 45% mentioned they may have experienced some issues, such as the app being slow or interacting with 3D models being challenging. These findings suggest that while the app is largely effective in enhancing engagement and comprehension, it

could benefit from performance optimization and better alignment between quiz content and learning materials.

6.4 Objectives Evaluation

Evaluating based on the current deliverables from this project, the objectives have been achieved.

Objective 1:

- To investigate the current teaching methods used in secondary Biology education in Malaysia.

Based on research and survey, the majority of Malaysian secondary students still rely solely on traditional methods such as textbooks, lecture notes, or at most watching some educational videos during class. Educational apps, especially AR-based, are not commonly used in the teaching process in Malaysia. However, many respondents have used educational apps and AR apps such as Pokemon Go and IKEA Place before but might not have experience using AR-based educational apps for Biology.

Objective 2:

- To propose the development of an AR-based mobile application as a learning supplement that is integrated with the secondary Form 4 Biology curriculum.

An AR-based Biology learning app has been developed and the content are designed based on Form 4 Biology syllabus in Malaysia. The developed app consists of AR learning module and quiz module, combining immersive, interactive 3D visualization of biological concepts with gamified quizzes to reinforce student learning and enhance engagement. The integration of these modules aims to provide students with both hands-on exploration of biological structures and immediate feedback through assessments, promoting a deeper understanding of the subject matter.

Objective 3:

- To verify the effectiveness of the developed application as a supportive tool in secondary Biology education.

According to the comparison result of the quiz scores from the experimental and control group, the average performance for the students that used the AR module as a supplement tool in addition to their regular study was slightly better than those did not explore the AR module. Even though the accuracy of the result was influenced by many factors, it still suggests that the proposed app can provide a boost in immediate learning outcomes, making it a valuable supplement to traditional teaching methods. Most importantly, most respondents think that using the app can provide them more engaged and motivated learning experiences.

Chapter 7

Conclusion and Recommendation

In this chapter, the project is summarized in several consecutive aspects, including the problems identified, the motivation of carrying out the proposed work, the innovation as well as the evaluation of the final deliverables. Several suggestions for potential improvements in future work are provided in the final section.

7.1 Conclusion

Biology is a fundamental yet important subject as it encompasses the study of us, humans, and every living organism around us such as animals, plants and other microorganisms. It is crucial to have biologists with strong expertise in biology to contribute to fields such as medicine, agriculture, biotechnology and ecology. Therefore, it is essential to ensure that students are enthusiastic and interested in biology subject to cultivate talents in this field continuously. However, the biggest challenge in realizing this goal remains on the subject itself, that is, the difficulty of understanding and visualizing its abstract concepts under traditional learning approaches. Studying biology in textbook is still a common approach for most students now and students always find biology difficult and boring as they would need a lot of imagination and visualization along with extensive amounts of textual information they would need to relate and memorize. In view of this problem, Augmented Reality was introduced due to its engaging and immersive nature and its ability to help students visualize 3D objects and integrate the learning into real-world context with hands-on experiences.

The creation of a biology learning mobile application with the integration of AR has benefited students in the way that they can study with their mobile devices anytime and anywhere. Although the interactive application can arouse their interest in learning biology and enhance their learning experiences, here comes another problem that is related to the application, which is the relevancy of the content to their curriculum. Most existing applications that could be publicly acquired in the market such as AR biology applications that can be downloaded from the Android Play Store or Apple App

Store with free charges generally have very surface-level information. Hence, the effectiveness of these applications seems to be inadequate and limited since they do not fit any specific school syllabus.

Other than that, there are still spaces for improvement spotted from the existing applications that can be worked on for enhancement of the effectiveness of the application to the users. The deficiencies include the inadequacy of the UI and navigation design, the insufficient of engagement features and the lack of a feedback mechanism. If the learning application contains only the AR learning feature and without additional engaging features and feedback mechanism, it might not be able to retain the users over time. Therefore, it is worth proposing solutions that can maximize the effectiveness of the application that aims to boost the learning experiences of the students.

With the above-mentioned problems, the motivation to propose a solution arises. The proposed solution is to develop an AR-based mobile application that can serve as an educational supportive tool that comprises AR module and quiz module. This proposed application is targeted specifically for the Malaysia secondary school Form 4 biology syllabus with the integration of gamification learning approaches in the quiz module that aims to maximize the engagement level and track the learning effectiveness. This innovation contributes to the development of an application that narrows the gap between education and technology, providing a solution to overcome the problems of traditional learning approach and inadequacy of existing products in biology education by adopting advanced technology and integrating different learning approaches into the proposed application.

The proposed application progressed to development phase after the design specifications are confirmed. System validation and evaluation were then conducted to make sure the developed app aligned with the objectives. A comprehensive system testing was carried out to ensure the functionalities in each module function as expected. An expert evaluation by an experienced biology teacher further validated the app's usability and potential to enhance biology education. Additionally, an experiment with

students demonstrated the app's effectiveness in improving learning outcomes, with the experiment group showing higher performance than the control group. Finally, the user evaluation provided valuable insights into user satisfaction, highlighting strengths like interactivity and engagement while also identifying areas for improvement, such as performance and design.

7.2 Recommendation

In view of the fact that the experiment carried out in this project is not very strict and well-designed due to the constraints such as limited time, limited budget and inability to monitor the students throughout the process, a more rigorous and well-planned study with extended period and broader sample size should be conducted to assess the long-term impact of the AR app on student learning and retention in the future work in order to gain deeper insights into the app's effectiveness over time. The proper method of doing so would be tracking the same group of students over an extended period of time, such as a full academic term or year with the experiment group using the app as an additional tool aside from their regular study with traditional methods. Periodic assessments could be conducted at regular intervals to compare academic performance between students who consistently use the AR app with those who rely solely on traditional learning methods, allowing for a clearer picture of the app's overall educational value. Other than academic achievement, behavioral changes such as increased participation, curiosity, and engagement in biology-related activities should also be monitored to further investigate the impact of the app on enhancing learning motivation and outcomes.

Additionally, to further increase the educational value of the app, expanding content coverage is important in future development. The developed app currently only covered a few fundamental biological topics that are related to human body in Form 4 syllabus, such as blood cell, muscle tissue and digestive system. More complex topics or even topics in Form 5 syllabus can be incorporated in future work to benefit more students and allow them to explore wider area of the biology curriculum. Besides, the future app can also integrate interactive lab simulations where students can virtually simulate

biological experiments in a safe and controlled environment, further bridging the gap between theoretical knowledge and practical application.

Based on the expert feedback on the two areas for improvement, which are the usability of 3D model interaction on small screen and the effectiveness of the part highlighting, there are several suggestions for improvement. Firstly, simplified controls such as predefined views for the 3D models can be added in the AR scene. For example, adding three different views buttons (e.g. front, side, top) to make the interactions smoother by minimizing manual adjustment on the model's view. Moreover, a zoom lock feature can be integrated into the AR scene as well to allow users to lock the zoom level while reading the textual information to reduce any unintentional movements. Other than that, better visual cues for part highlights can be introduced by adding glowing effects and bolder colors to make the highlighted sections more prominent.

Based on user feedback, optimizing the app's performance—especially the responsiveness when interacting with 3D models—should be a priority. Reducing lag and improving load times can enhance the overall user experience. The UI design for AR scene can be further improved as devices with small screens might encounter difficulty to interact with the model and read the textual information displayed at the same time. To address feedback on the visual design, future work should aim for a more stylish and modern user interface, which will improve the overall appeal and attractiveness of the app.

To increase the personalization of the app for users, adaptive learning features could be introduced into the future app to allow dynamic adjustments of the quiz difficulty based on individual student performance. For example, if a student achieves good quiz scores consistently, the app can gradually increase the complexity of the questions to make the questions more challenging. In contrast, if a student keeps scoring badly, the app can offer simpler questions that help the student better understand the concepts or suggest additional learning resources. This personalized feature can increase students' engagement by reducing frustration for slower learners and at the same time challenge those advanced students, guaranteeing that the app caters to different types of learners.

In order to enhance the app’s inclusivity, a range accessibility features such as text-to-speech functionality, high-contrast mode and alternative input methods should also be prioritized to cater the needs for students with disabilities. The text-to-speech functionality would help students with visual impairments or reading difficulties by converting on-screen text into spoken words while high-contrast mode helps them with color-blindness or low vision by making the interface clearer and more readable. The alternative input methods such as voice commands could facilitate faster and more efficient input, improving the overall app experience. These features would ensure that the app is usable by students with varying physical and cognitive abilities, providing a more inclusive learning environment where all students can benefit from the app's educational resources.

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APPENDIX

User Requirements Gathering Survey Sheet

Biology AR Learning App - User Requirements Survey

Thank you for taking the time to participate in this survey. Your input is crucial in helping to design and develop a highly effective and user-friendly AR-based biology learning application. This survey aims to gather your preferences, experiences, and expectations related to augmented reality (AR) and educational technology in the Biology subject.

Your responses will provide invaluable insights into how the developed app can best meet the needs of learners like you, ensuring that the final product is engaging, intuitive, and accessible. Please be assured that all your answers will be kept confidential and used solely for the purpose of developing an application for Final Year Project.

* Indicates required question

1. How familiar are you with using AR applications? (e.g. Pokemon Go, IKEA Place, etc.) *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Not familiar at all

2. Have you used educational apps before? *

Mark only one oval.

- ◯ Yes
- ◯ No

User Interface and Functional Requirements

3. How do you prefer to interact with 3D models in an AR environment? (Select all that apply) *

Check all that apply.

- [ ] Rotate
- [ ] Zoom
- [ ] Move
- [ ] Select specific parts for more details
- [ ] Hide selected part
- [ ] Hide all except selected part

4. How useful would you find textual information displayed alongside AR models? *

Mark only one oval.

- ◯ Very useful
- ◯ Somewhat useful
- ◯ Not useful

5. Would you find a feature to save and view your favorite models useful? *

Mark only one oval.

- ◯ Yes
- ◯ No

6. What types of quizzes do you prefer in a learning app? (Select all that apply) *

Check all that apply.

- ☐ Individual quizzes
- ☐ Multiplayer quizzes
- ☐ Timed quizzes
- ☐ Open-ended quizzes

7. How often would you use a leaderboard or multiplayer quiz feature? *

Mark only one oval.

- ◯ Frequently
- ◯ Occasionally
- ◯ Rarely
- ◯ Never

8. Would you like the ability to join or create rooms for multiplayer quizzes? *

Mark only one oval.

- ◯ Yes
- ◯ No

Technology Preferences

9. Which technology would you prefer for interacting with AR models in an educational app? *

Mark only one oval.

- ◯ Marker-based AR (requires a physical marker on printed materials to view models)
- ◯ Markerless AR (does not require any physical markers)

10. What values do you prioritize the most in an AR-based educational app. (Select all that apply) *

Check all that apply.

- ☐ Interactive and Engagement
- ☐ Informative
- ☐ Convenience (Require only a mobile device)
- ☐ Social Interaction (Able to use the app together with others)
- ☐ Cost-Effectiveness (Free of charge)
- ☐ Ease of Use

Thank you for taking the time to complete this survey. Your feedback is invaluable in helping to develop a user-friendly and effective AR biology learning application.

Expert Evaluation Survey Sheet

Expert Evaluation - AR-Based Biology Learning App

Thank you for agreeing to participate in this expert evaluation of the AR-based biology learning application. Your feedback is crucial to ensuring that the app meets the highest standards of usability and educational effectiveness.

Before we proceed, I would like to inform you that the information you provide will be used solely for the purpose of improving the app. Your responses will remain confidential, and your identity will not be disclosed in any reports or publications resulting from this evaluation.

By continuing with this survey, you consent to participate in this evaluation process and agree to the use of your feedback for the purposes outlined above. Your participation is entirely voluntary, and you may withdraw from the survey at any time.

* Indicates required question

1. Years of Teaching Experience: *

Mark only one oval.

- ◯ Less than 5 years
- ◯ 5-10 years
- ◯ 10-15 years
- ◯ More than 15 years

2. Have you previously used AR or VR technology in your teaching? *

Mark only one oval.

- ◯ Yes
- ◯ No

Usability Evaluation

3. How intuitive do you find the app's user interface? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very confusing

4. How easy is it to navigate through the different features of the app? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very difficult

5. Were you able to use the app effectively without needing instructions or support? *

Mark only one oval.

- ◯ Yes, completely
- ◯ Yes, somewhat
- ◯ Neutral
- ◯ No, I needed some instructions
- ◯ No, I needed significant support

6. How responsive was the app to your inputs and commands? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very unresponsive

7. How would you rate the ease of interacting with 3D models (e.g., rotating, zooming, moving) in the AR environment? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very difficult

8. How clear and helpful are the textual information and annotations provided with the 3D models? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very unclear or unhelpful

Educational Effectiveness

9. How likely is this app to enhance students' understanding of biology concepts? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very unlikely

10. How effective do you think the app is in making complex biological concepts more understandable through AR models? *

Mark only one oval.

- ◯ Very effective
- ◯ Very ineffective

11. How likely are students to remain engaged with the subject matter using this app? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very unlikely

12. How likely is this app to help students to get more motivated and interested in learning in biology? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very unlikely

13. Does the app support and align with the learning objectives of the Form 4 biology curriculum? *

Mark only one oval.

- ◯ Strongly aligns
- ◯ Strongly misaligned

14. Would you consider integrating this app into your regular teaching practices? *

Mark only one oval.

- ◯ Yes
- ◯ Maybe
- ◯ No

15. How useful is the quiz feature for assessing student understanding? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Not useful at all

16. How likely would you be to use the multiplayer quiz feature for collaborative learning in the classroom? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very unlikely

17. What do you consider to be the app's greatest strengths? *

18. What are the most significant areas for improvement? *

Thank you for taking the time to provide your expert feedback. Your insights are invaluable in helping to evaluate the effectiveness of the app.

User Evaluation - AR-Based Biology Learning App

Thank you for agreeing to participate in this user evaluation of our AR-based biology learning application. Your feedback is crucial to ensuring that the app meets the highest standards of usability and educational effectiveness.

Before we proceed, I would like to inform you that the information you provide will be used solely for the purpose of improving the app. Your responses will remain confidential, and your identity will not be disclosed in any reports or publications resulting from this evaluation.

By continuing with this survey, you consent to participate in this evaluation process and agree to the use of your feedback for the purposes outlined above. Your participation is entirely voluntary, and you may withdraw from the survey at any time.

* Indicates required question

1. Which group are you in? *

Mark only one oval.

- ◯ Experiment Group (Study with the AR module in app before attempting the quizzes in the Individual Quiz in app)
- ◯ Control Group (Attempt the quizzes in the Individual Quiz module in app without using the AR module beforehand)

2. What is your result for Individual Quiz Set 1? (Correct answers/Total of 20 questions) *

_____

3. What is your result for Individual Quiz Set 2? (Correct answers/Total of 20 questions) *

_____

Usability Evaluation

4. How easy was it to navigate through the app? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very difficult

5. How easy was it to interact with the 3D models (e.g., rotating, zooming, moving)? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very difficult

6. How helpful were the textual information and annotations provided with the 3D models? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Not helpful at all

7. How easy was it to use the quiz feature within the app? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very difficult

8. How satisfied were you with the app's overall design and layout? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very unsatisfied

Educational Effectiveness

9. How engaging did you find the learning experience? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Not engaging at all

10. Do you feel that the app helped you better understand the biology concepts compared to traditional study methods? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

11. How well do you think the quiz questions reflected the content you studied? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Not well at all

12. Compared to traditional study methods, how much more (or less) effective was using the app for learning? *

Mark only one oval.

	1	2	3	4	5	
Muc	◯	◯	◯	◯	◯	Much less effective

13. Did using the app make the learning process more enjoyable, motivated or interested for you? *

Mark only one oval.

- ◯ Yes
- ◯ Maybe
- ◯ No

14. Have you met any difficulties when using the app? *

Mark only one oval.

- ◯ Yes
- ◯ Maybe
- ◯ No

15. Were there any specific features or aspects of the app that you found frustrating or difficult to use? *

Mark only one oval.

- ◯ Yes, navigating through the app was frustrating.
- ◯ Yes, interacting with the 3D models was difficult.
- ◯ Yes, the quizzes were confusing or hard to understand.
- ◯ Yes, the app was too slow or unresponsive.
- ◯ No, I did not find anything particularly frustrating.

16. Which of the following area do you think need the most improvement? *

Mark only one oval.

- ◯ App navigation and user interface.
- ◯ Interaction with 3D models.
- ◯ Clarity and helpfulness of textual information.
- ◯ Quiz content and difficulty level.
- ◯ Overall responsiveness and performance of the app.
- ◯ Visual design and layout.

Thank you for participating in this evaluation. Your feedback is incredibly valuable in helping to evaluate the effectiveness of this app.

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: 3, 3	**Study week no.:** 2
Student Name & ID: Yong Mei Ting 2105921	
Supervisor: Dr. Lim Ean Heng	
Project Title: Development of Augmented Reality Application as a Learning Tool in Biology Education	

1. WORK DONE Completed initial design phase, including UI mockups and system architecture.
2. WORK TO BE DONE Begin the development of core AR functionality in the next two weeks.
3. PROBLEMS ENCOUNTERED No critical issues encountered.
4. SELF EVALUATION OF THE PROGRESS Progress is on schedule, and the design phase went smoothly.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: 3, 3	**Study week no.:** 4
Student Name & ID: Yong Mei Ting 2105921	
Supervisor: Dr. Lim Ean Heng	
Project Title: Development of Augmented Reality Application as a Learning Tool in Biology Education	

1. WORK DONE

Started development of the AR learning module and basic user authentication.

2. WORK TO BE DONE

Continue development of the AR module and begin working on the quiz module**.**

3. PROBLEMS ENCOUNTERED

Minor issues with Firebase integration but resolved.

4. SELF EVALUATION OF THE PROGRESS

Slight delay due to technical challenges, but overall progress is steady.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: 3, 3	**Study week no.:** 6
Student Name & ID: Yong Mei Ting 2105921	
Supervisor: Dr. Lim Ean Heng	
Project Title: Development of Augmented Reality Application as a Learning Tool in Biology Education	

1. WORK DONE

Completed the initial version of the AR learning module and progressed on quiz module development.

2. WORK TO BE DONE

Continue refining the AR module and complete quiz module integration.

3. PROBLEMS ENCOUNTERED

No critical issues encountered.

4. SELF EVALUATION OF THE PROGRESS

The project is back on track and progressing well after overcoming early challenges.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: 3, 3	**Study week no.:** 8
Student Name & ID: Yong Mei Ting 2105921	
Supervisor: Dr. Lim Ean Heng	
Project Title: Development of Augmented Reality Application as a Learning Tool in Biology Education	

1. WORK DONE

Quiz module is fully functional, and initial testing of the AR module has been completed.

2. WORK TO BE DONE

Focus on implementation of leaderboard and favorite feature in the next two weeks.

3. PROBLEMS ENCOUNTERED

Encountered errors during multiplayer quiz game integration with Fusion Quiz Network, dragged the schedule for a few days, but resolved.

4. SELF EVALUATION OF THE PROGRESS

Progress is considered fine, and major components are near completion.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: 3, 3	**Study week no.:** 10
Student Name & ID: Yong Mei Ting 2105921	
Supervisor: Dr. Lim Ean Heng	
Project Title: Development of Augmented Reality Application as a Learning Tool in Biology Education	

1. WORK DONE Completed the leaderboard and favorite feature. Basic system testing started.
2. WORK TO BE DONE Conduct thorough system testing and prepare for the evaluation phase.
3. PROBLEMS ENCOUNTERED No critical issues encountered.
4. SELF EVALUATION OF THE PROGRESS Slightly behind of schedule but still fine.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: 3, 3	**Study week no.:** 12
Student Name & ID: Yong Mei Ting 2105921	
Supervisor: Dr. Lim Ean Heng	
Project Title: Development of Augmented Reality Application as a Learning Tool in Biology Education	

1. WORK DONE

Completed system testing and evaluation and started report documentation.

2. WORK TO BE DONE

Finalize documentation and design the project poster.

3. PROBLEMS ENCOUNTERED

No critical issues encountered.

4. SELF EVALUATION OF THE PROGRESS

The project is nearing completion, and the progress has been satisfactory with all major milestones achieved.

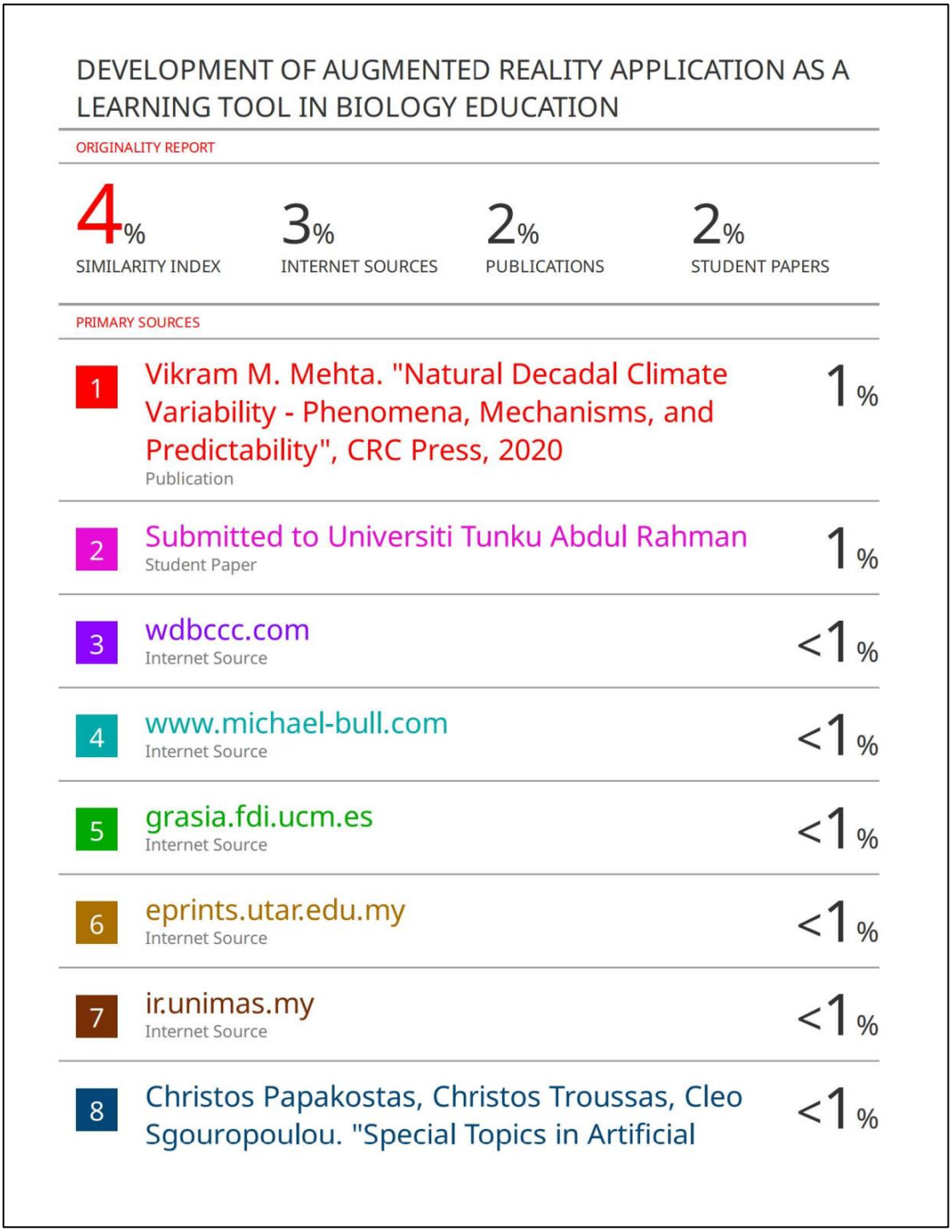
Supervisor's signature

Student's signature

POSTER


FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY
BACHELOR OF INFORMATION SYSTEMS (HONS) INFORMATION SYSTEMS ENGINEERING
AR-BASED BIOLOGY LEARNING MOBILE APPLICATION
Traditional Biology teaching in Malaysia faces challenges due to difficulties in visualizing abstract concepts, hindering students' learning engagement and motivation. AR technology emerges as a promising solution, blending virtual and real environments to enhance understanding and interaction. This project builds an AR-based mobile app and evaluates its effectiveness as a supportive tool in Biology secondary education.
OBJECTIVE
• To investigate the current teaching methods used in secondary Biology education in Malaysia.
• To propose the development of an AR-based mobile application as a learning supplement that is integrated with the secondary Form 4 Biology curriculum.
• To verify the effectiveness of the developed application as a supportive tool in secondary Biology education.
METHODS
• ADDIE Model
• Block Diagram:
Unity
EasyAR
photon Fusion
Backend
Database
Application Logic
Frontend
User Authorization/ Authentication
App Settings
Account Management
Favourites
AR Learning Module
Scan Environment
Move 3D Models
Search 3D Models
Rotate 3D Models
Sort 3D Models
Zoom 3D Models
Filter 3D Models
Highlight 3D Models Parts
Display Textual Information
Quiz Module
Quiz Type
Individual
Competition
Leaderboard
Points Reward
Join Room
Real-Time Voice Chat
network communication
update/ retrieve data
request/ serve content
Mobile Devices
CONCLUSION
• User Feedback: Majority thinks the app could be effective to improve learning engagement, motivation and performance.
• Expert Feedback: Overall great, potential to integrate into teaching.
• Recommendations:
• Conduct more rigorous long-term studies to better evaluation
• Expand content coverage
• Enhance app functionalities, responsiveness and interfaces design
• Integrate personalization and adaptive learning feature into Quiz module.
AUTHOR: YONG MEI TING
SUPERVISOR: DR. LIM EAN HENG

PLAGIARISM CHECK RESULT



DEVELOPMENT OF AUGMENTED REALITY APPLICATION AS A LEARNING TOOL IN BIOLOGY EDUCATION

ORIGINALITY REPORT

4%	3%	2%	2%
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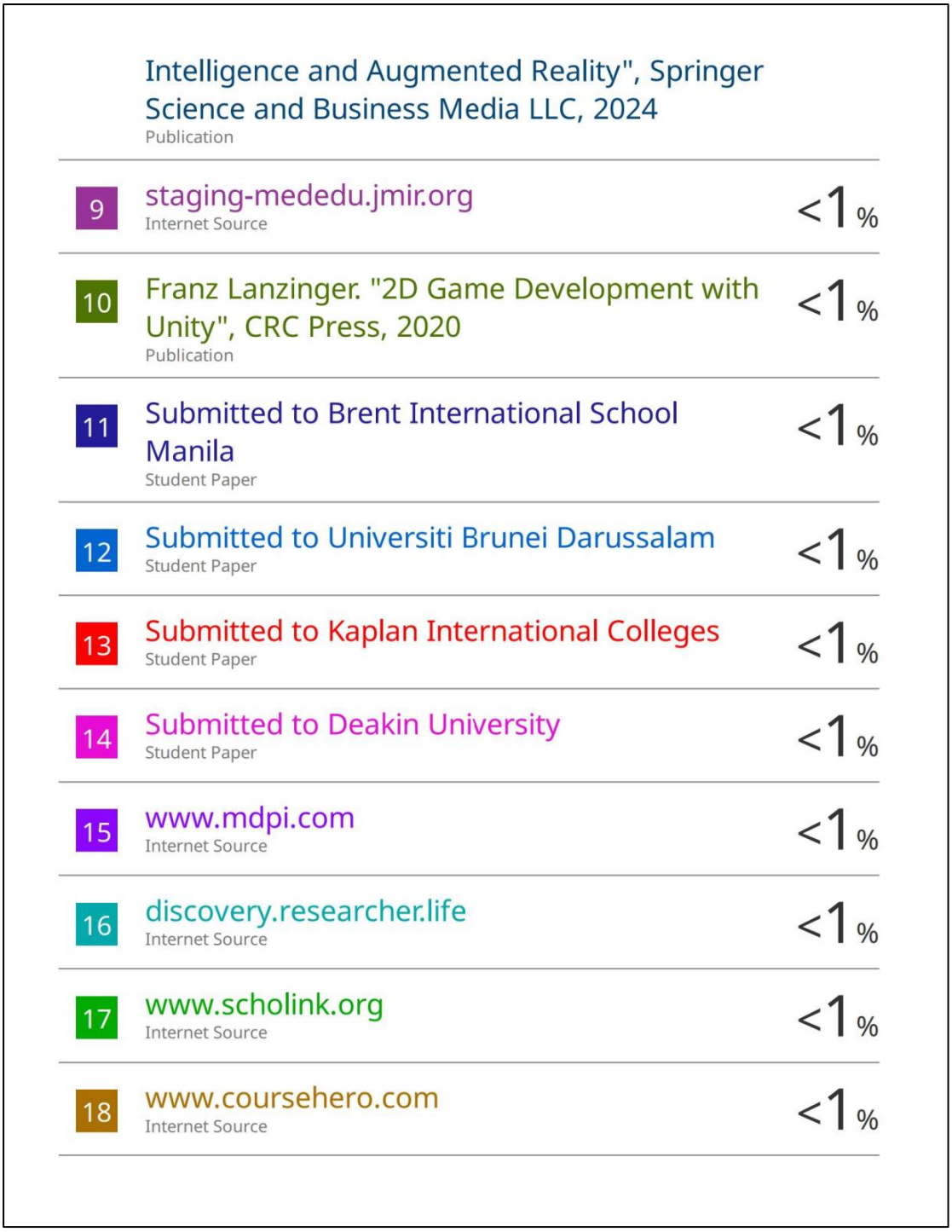

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APPENDIX

Universiti Tunku Abdul Rahman			
Form Title : Supervisor's Comments on Originality Report Generated by Turnitin for Submission of Final Year Project Report (for Undergraduate Programmes)			
Form Number: FM-IAD-005	Rev No.: 0	Effective Date: 01/10/2013	Page No.: 1of 1

FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY

Full Name(s) of Candidate(s)	YONG MEI TING
ID Number(s)	21ACB05921
Programme / Course	IA
Title of Final Year Project	DEVELOPMENT OF AUGMENTED REALITY APPLICATION AS A LEARNING TOOL IN BIOLOGY EDUCATION

Similarity	**Supervisor's Comments (Compulsory if parameters of originality exceeds the limits approved by UTAR)**
Overall similarity index: 4 % **Similarity by source** Internet Sources: 3 % Publications: 2 % Student Papers: 2 %	
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Note Supervisor/Candidate(s) is/are required to provide softcopy of full set of the originality report to Faculty/Institute

Based on the above results, I hereby declare that I am satisfied with the originality of the Final Year Project Report submitted by my student(s) as named above.

lim

Signature of Supervisor

Name: LIM EAN HENG

Date: 12/9/2024

Signature of Co- Supervisor

Name: _____

Date: _____

UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF INFORMATION & COMMUNICATION TECHNOLOGY

(KAMPAR CAMPUS)

CHECKLIST FOR FYP2 THESIS SUBMISSION

Student Id	21ACB05921
Student Name	YONG MEI TING
Supervisor Name	DR. LIM EAN HENG

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√	Title Page
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√	List of Tables (if applicable)
√	List of Symbols (if applicable)
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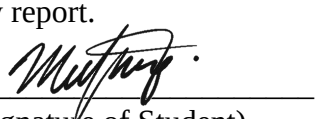

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