THE DEVELOPMENT OF 3D ELECTROLYSIS USING AUGMENTED REALITY

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This report is submitted in partial fulfillment of the requirements for the Bachelor of Computer Science (Interactive Media) with Honours.

FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY
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2021

DECLARATION

I hereby declare that this project report entitled

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is written by me and is my own effort and that no part has been plagiarized

without citations.

STUDENT : _____ Date : 02/09/2021

(HOO HUI YING)

I hereby declare that I have read this project report and found

this project report is sufficient in term of the scope and quality for the award of

Bachelor of Computer Science (Interactive Media) with Honours.

SUPERVISOR : _____ Date : 08/09/2021

(TS DR IBRAHIM BIN AHMAD)

DEDICATION

This report is dedicated foremost to my beloved family and my supervisor who has guided and motivated me throughout the project.

ACKNOWLEDGEMENTS

Foremost, I would like to express my special thanks of gratitude to my supervisor, Ts Dr Ibrahim bin Ahmad for his invaluable guidance and advice throughout this project. His generosity on his time, knowledge, and guidance had become the pillar of mine to ensure my project is completed successfully. I do not have an idea of how to thank Dr Ibrahim enough for all his guidance and assistance he gave me, and it is an honour to have him as my supervisor.

Next, I would like to convey my gratefulness to my family members, especially my parents for giving me endless words of encouragement while conducting this project and support me through my degree life. Besides, their financial supports on my final year project also acts as one of the reasons that help me finish the project without much more difficulties. Their endless support has made it possible to complete my study.

Last but not least, I would like to show my appreciation towards my friends, for their kindness and mental support when I was dispirited and needed help the most. They were always there to give encouragement as well as assistance that I need. Their willingness to cheer me up and their help also become one of the support that led me to overcome all the difficulties throughout the project.

ABSTRACT

In the era of science and technology, augmented reality (AR) has become one of the faster-growing fields of technology. As a result of its expansion, it is now used in a variety of human activities. AR make life's activities easy and fun. Education is one of the fields where AR has a huge impact. There are some students are hard to understand and imagine the theory by themselves, especially in chemistry. Hence, this project is developed to help student more understand the theory. The target audience in this project is the students, who take chemistry subject in school. The development of 3D electrolysis using AR is a system that implemented to help the students to have a better understanding of the topic. The interesting 3D model in AR will attract student's attention and make them more focused in class. AR in education can help teachers to make the lessons more interactive and easier for students to understand. The objectives of this to study augmented reality requirement and technique in 3D electrolysis application and develop a prototype of AR based on 3D electrolysis. The expected outcome of the project is that the target audience might have a better understanding. The users can scan the marker on the card and the 3D electrolysis model will be visualized. This will help the audience to understand the movement of ions in the electrolysis process.

ABSTRAK

Dalam era sains dan teknologi, *augmented reality* (AR) telah menjadi salah satu bidang teknologi yang berkembang pesat. Perkembangan ini telah mendorong penggunaannya dalam pelbagai bidang aktiviti manusia. AR menjadikan aktiviti hidup lebih mudah dan menarik. Pendidikan adalah salah satu bidang di mana AR mempunyai kesan yang besar. Terdapat sebilangan pelajar sukar memahami dan membayangkan teori itu sendiri, terutamanya dalam bidang kimia. Oleh itu, projek ini dibangunkan untuk membantu pelajar lebih memahami teori. Sasaran audiens dalam projek ini adalah pelajar yang mengambil subjek kimia di sekolah. Perkembangan elektrolisis 3D menggunakan AR adalah sistem yang dilaksanakan untuk membantu para pelajar untuk lebih memahami topik tersebut. Model 3D yang menarik dalam AR akan menarik perhatian pelajar dan menjadikan mereka lebih fokus dalam kelas. AR dalam pendidikan dapat membantu guru menjadikan pelajaran lebih interaktif dan lebih mudah difahami oleh pelajar. Objektif ini untuk mengkaji keperluan dan teknik augmented reality dalam aplikasi elektrolisis 3D dan mengembangkan prototaip AR berdasarkan elektrolisis 3D. Hasil yang diharapkan dari projek ini adalah bahawa khalayak sasaran mungkin mempunyai pemahaman yang lebih baik. Pengguna boleh mengimbas penanda pada kad dan model elektrolisis 3D akan dapat dilihat. Ini akan membantu penonton memahami pergerakan ion dalam proses elektrolisis.

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LIST OF ABBREVIATIONS

3D	**-**	**3 Dimension**
2D	**-**	**2 Dimension**
AR	**-**	**Augmented Reality**
VR	**-**	**Virtual Reality**
STEM	**-**	**Science, Technology, Engineering and Mathematic**
CER	**-**	**Chemistry Education Research**
ICT	**-**	**Information Communication Technology**
IT	**-**	**Information Technology**
SME	**-**	**Subject-Matter Expert**
SD	**-**	**Standard Deviation**

LIST OF ATTACHMENTS

CHAPTER 1: INTRODUCTION

1.1 Introduction

In the 21st century, computer science is becoming increasingly relevant in this age of information technology. Augmented Reality (AR) is a part of computer science and is one of the biggest technology trends nowadays. AR is a technology that combines real-world objects with computer-generated objects. The usage of augmented reality is not restricted to a specific subject, age group or educational level. Education is one of the fields where AR has a huge impact. As AR technology is integrated with educational material, it provides a new form of automated application that improves the efficiency and attractiveness of teaching and learning for students in real life. (Singaravelu, 2020) Augmented reality can make classes more engaging and allow students to concentrate on experience rather than theory. Some educational materials are quite costly, and not all schools or educational institutions can afford to purchase and retain them. Students only need mobile devices and AR applications to use AR for learning.

The development of 3D electrolysis using augmented reality (AR) is an application that is implemented to help the students to have a better understanding of the electrochemistry topic. The interesting 3D model in AR will attract student's attention and make them more focused in class. AR in education can help teachers to make the lessons more interactive and easier for students to understand. The electrochemistry topic is uneasy to understand by only read the theory in the textbook. (Muzammila Akram, Johari Bin Surif & Murad Ali, 2014) Not every school provide the opportunity for students to do experiments. Thus, The Development of 3D

Electrolysis using AR is an Electrolysis AR application built to help high school students who study chemistry subjects. There are 3D models, electrolysis simulations and simple quizzes produced in the application. Therefore, with the existence of the development of 3D electrolysis using AR, students can observe the process and the movement of the ion during electrolysis without experimenting.

1.2 Problem Statement

In any field of study, a textbook gives instructions or information. However, it fails to capture the attention of the majority of the new generation students. Some students have a poor command of languages. It would be difficult for them to understand topics learned as they are not able to get a clear image or picture of the topic that they are learning by just reading the words inside the textbook. Low operation, interest and student's chemistry results are caused by general difficulties in solving problems related to chemical reactions and chemical counting (Sunyono, 2005). This indicates that chemistry is difficult to learn for a variety of reasons, one of the reasons is that most chemical concepts are abstract. Hence, students are unable to imagine the molecular structure clearly. Besides, the chemical experiment in schools cannot be achieved optimally because it takes time for preparation within a limited period and resulting in inefficient use of student learning time. Therefore, secondary school students will anxiety to learn chemistry. According to the study by Jegede (2007), the causes of student's concerns are a broad syllabus, their teacher's teaching approaches and a lack of teaching materials and laboratories.

1.3 Objective

This project embarks on the following objectives:

- To identify augmented reality requirements and techniques in 3D electrolysis application
- To develop a prototype of marker-based AR on 3D electrolysis
- To evaluate the effectiveness of the prototype in 3D electrolysis topic

1.4 Scope

The marker-based AR of 3D electrolysis is developed for form 4 students in secondary school. They can learn basic electrolysis concepts through the development of 3D electrolysis using AR. This project uses a marker-based AR approach to deliver content using a booklet as a medium. The target is recognized and tracked using the Vuforia Augmented Reality SDK. Blender and Unity were used to create 3D models and build up the scene. The Android platform will be the focus of this project. This project's modules involve scanning target images in the booklet and displaying AR contents with animations, images, video and audio. Displaying 3D objects through the booklet and a simple quiz activity to track user's knowledge and understanding.

1.5 Project Significance

The development of 3D electrolysis using AR will help students who take chemistry subjects in secondary school to learn chemistry interesting. This AR project provides 3D objects instead of 2D pictures, which will help students to achieve better results through visualization and full immersion in the subject. A simulation of ion movement during electrolysis will develop using AR in this project. This enables students to observe the process and the movement of the ion during electrolysis. Therefore, they will have a better understanding of the electrolysis topic.

1.6 Conclusion

This chapter is briefly explained the background and purpose of the project that will be carried out. These are to ensure that the development of AR runs smoothly and any development planning can be completed on time. The expected outcome will be the prototype of marker-based AR of 3D electrolysis. The users can scan the marker on the card and the 3D electrolysis model will appear on the screen. This prototype will help the user to understand the movement of ions in the electrolysis process. It will be very useful for students who do not understand the electrolysis topic. This project is also able to make the user have a better understanding of what is augmented reality. Next, this project will be continued with the literature review and project methodology that has been chosen to ease the completion of this project.

CHAPTER 2: LITERATURE REVIEW AND PROJECT METHODOLOGY

2.1 Introduction

This chapter focus on the review of similar studies by other researchers. This will help in the generation of ideas on how to carry out this project. A methodology is the combination of logically related methods and step by step techniques for the successful planning, control and delivery of the project. It is a scientifically proven, systematic and disciplined approach to project development and implementation. This chapter will also determine the project methodology that use to develop and the project requirement. The software and hardware requirements are defined in the early stage of development plans.

2.2 Domain

2.2.1 Augmented Reality

Augmented reality is an immersive experience of a real-world environment in which computer-generated perceptual information enhances the objects in the real world. AR allows for seamless overlaying of digital content, and views of the physical world are mixed. VR simulates the real world, while augmented reality takes everything from the real world and incorporates it into a video or architecture. The fundamental principles of augmented reality have been used in many movies and science fiction stories. The real-time use of information in the form of text, graphics, audio and other virtual enhancements combined with real-world objects is known as augmented reality.

2.2.2 Augmented Reality in Education

AR is the technology that has the most potential to captivate student's interest in learning. These days, AR is gaining popularity in schools all around the world. In education, AR can be used for a variety of purposes. It helps students in quickly acquiring, processing and remembering knowledge. Besides, AR makes learning more interesting and enjoyable. Educators can use AR to enhance learning outcomes by increasing interaction and interactivity. AR has been accepted as an effective learning tool, especially in chemistry. AR has been found to have a lot of potential for making learning more dynamic, effective and engaging (Nor Farhan Saidin & NoorDayana Abd Halim, 2015). Students can learn abstract concepts including chemical elements, compounds and reactions by using the AR application. An AR application allows computer-generated objects to appear and coexist in the same space as the real world. This characteristic of AR is hypothesized to be able to provide an interactive learning experience and captivate student's interest in learning better than dull traditional textbooks. Images and 3D models created by using AR technology allow students to learn and understand more of a topic in a certain field of study because students are able to watch and learn from the images and models instead of imagining it based on the words in the textbooks. One of the benefits of AR technology for learning is that it can provide 3D visualization and can be employed in a variety of Android-based devices used by students (Irwansyah, Yusof & Farida, 2017).

2.2.3 Chemistry Education

The study of teaching and studying chemistry is known as chemistry education. It is a subset of STEM education. Understanding how students learn chemistry and deciding the most effective teaching methods are two topics in chemistry education. Based on the results of CER, there is a persistent need to develop chemistry curricula and learning outcomes. Changes in teaching methods and proper preparation for chemistry teachers can enhance chemistry education in a variety of ways, including classroom lectures, presentations, demonstrations and laboratory activities. Chemistry education is important because chemistry is a foundational science of our society. Chemistry is referred to as the "central science" because it connects physical, life, and applied sciences. Food, medicine, manufacturing, the atmosphere, and other fields all

use chemistry, according to Pauling. Students can learn about the scientific method and develop logical thought, deductive reasoning and problem-solving skills through studying chemistry. Students' interest in STEM professions can be piqued by teaching chemistry to them at a young age. Chemistry also teaches students a variety of transferable skills that can be used in a variety of careers. Chemistry education has been created to provide opportunities for students to acquire scientific information and abilities, develop thinking skills and strategies, and apply the knowledge and skills in daily life (Mahzan, 2005).

2.3 Existing System

2.3.1 Interactive Multimedia Module with Pedagogical Agent in Electrochemistry

Figure 2.1: Interface of IMMPA in Electrochemistry Example (Kamisah Osman & Lee, 2012)

(Kamisah Osman & Lee, 2012) was doing this study in order to develop Interactive Multimedia Module with Pedagogical Agent(IMMPA). IMMPA is a computer-based learning environment that developed by using animated life-like characters to enhance the learning of electrochemistry. IMMPA's goal is to use animations and simulations to assist students to visualize abstract concepts in electrochemistry. The interface of IMMPA is user friendly. Users can simply navigate using the button provided in the system. The experiment provided in the system is done

through the 2D simulation. There was a model name ‘Micro-World’ as shown in Figure 2.1. This section will show the movement of electrons and ions at the microscopic level. According to the findings, models, simulations and games are used to help interpretation and clarification of concepts and processes in Information and Communication Technology. As a result, creating instructions with multimedia has become popular in this ICT age.

2.3.2 FuseSchool

Figure 2.2: What is Electrolysis (FuseSchool, 2016)

According to Josh (2014), a set of 68 short animations that explain the chemistry concepts has been released on YouTube by FusaSchool, a global education initiative. The Chemistry Journal is the name of the project and the goal is to provide costless and comprehensive educational resources for the teachers and students. The video is easy to understand and provide compact revision aids for the learner. Chemistry syllabus from the fundamentals to applied concepts, such as how ions form and the process of electrolysis is included in the YouTube channel.

2.3.3 Electrolysis-Flip eBook

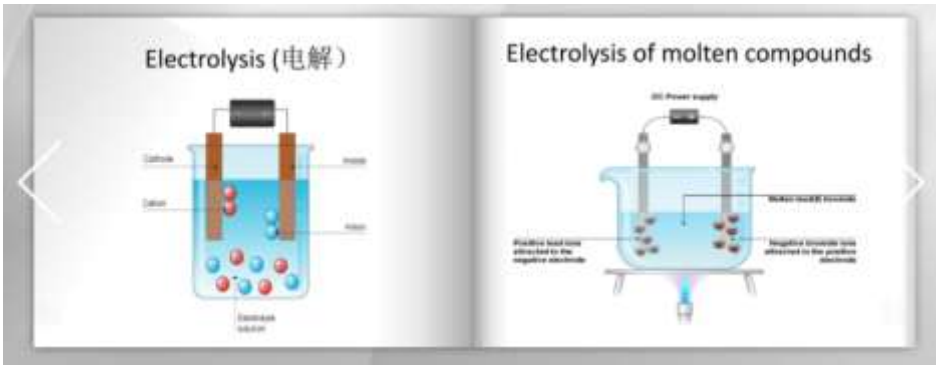


Figure 2.3: Electrolysis-Flip eBook Interface Example

Electrolysis-Flip eBook is published on the Anyflip platform in 2020. It is developed for middle school students to learn simple electrolysis concepts. The learning goal of this application is to gain a basic understanding of electrolysis. Electrolysis-Flip eBook provides learning content using text and some simple images. The eBook contains the important key points only and it is easy to understand. It is good for the students as quick notes.

2.3.4 Comparison of Existing System

Table 2.1: Comparison Between the Existing System

Aspect	Interactive Multimedia Module with Pedagogical Agent	FuseSchool (YouTube channel)	Electrolysis-Flip eBook
Concept	User can read the information and view the simulation of electrolysis.	User can view the short animation and learn electrolysis.	User can flip the eBook in order to read the contents.

Digital Element	Image, audio and video is included. There is no 3D model and animation.	Video, audio and animation is included. There is no image and 3D model.	Only image is included. There is no audio, video, animation and 3D model.
Advantage	It is user friendly as it allow user to interact with the content by using the buttons.	The content is easy to understand and the animation is interesting.	It can save user learning time because the contents are straight to the point.
Disadvantage	The application is discontinued.	User cannot interact with the system.	The eBook is not interesting because it only contain of images

2.4 Project Methodology

Before beginning the development process for the augmented reality application, significant planning is essential to make sure that this project is completed successfully. The methodology that will be used in this project is ADDIE Instructional Design Model. ADDIE model is an instructional design framework for organizing and streamlining course content creation. The ADDIE model has five steps processes which are analysis, design, development, implementation and evaluation.

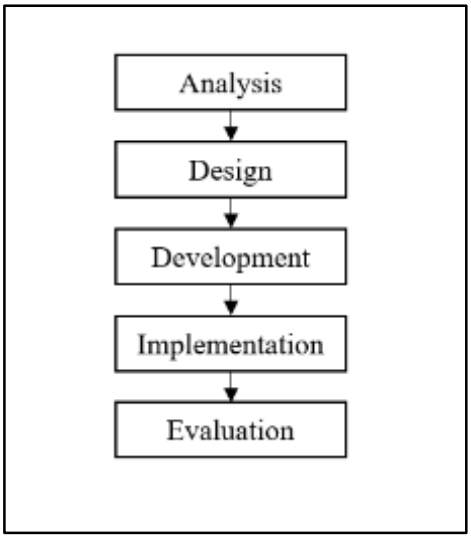


Figure 2.4: ADDIE Model

The first phase in the ADDIE model is analysis. During this phase, an analysis was carried out to determine the necessity for the Electrolysis AR application to be developed. Hardware requirement analysis, software requirement analysis and project requirement analysis are all part of the analysis step. Identifying the problem statement, existing system or any other relevant criteria, as well as the content of the Electrolysis AR application, are among the activities involved in the analysis phase. The AR application was developed with electrolysis learning content, specifically for secondary school students studying chemistry. The investigation is also conducted out thorough research of any courseware or AR application, particularly in the field of electrolysis learning. The weaknesses of the current electrolysis learning courseware or application can be detected through the research.

The design phase is the second phase of the ADDIE model. The specifications of the project architecture, appearance and material requirements are made. Identifying the scope of the content, identifying the use of media and tools required for media editing, and sketching the interactions that will occur within the content were all part of the design phase. To be suited to students with diverse learning styles, educational materials should include a variety of multimedia elements, such as text, image, animation, video and audio. A storyboard is an important component of the multimedia design process. The storyboard depicts the appearance of the application that will be

created. In this phase, the draft of the storyboard, marker, booklet and user interface design were all created.

The development phase involved creating multimedia components that would later be incorporated during the implementation phase. The marker image will be the starting point for the development. The display of the virtual information is triggered by AR markers. The markers will be created by using Adobe Photoshop. Then, the marker will be put inside the booklet and along with some simple descriptions. The booklet will be created using Adobe InDesign. Moreover, a simple video introduction will be created by using Adobe After Effect. In this stage, the 3D models will be created using Blender software. 3D modelling is a computer graphics technique for creating the 3D digital representation of the real object. By deforming the mesh or manipulating vertices, the 3D objects are generated. After the model is created, texturing is needed to carry out. A texture should add to the object to apply color, brightness or roughness for the object. Texturing is the process of assigning textures or materials to the faces of the object. Finally, the textured 3D model should export to an FBX file.

After developed all the multimedia elements, all the assets will be needed to integrate into the Unity software. The prototype will be developed by using Unity. Unity is a product developed by Unity Technologies. It is mostly used to create video games and simulations for computers and mobile applications. In this stage, a database should create in Vuforia and all the markers that had been created before are required to upload into the database as a target. In addition, the database is needed to download and import into Unity. After that, the conversion of the 3D model into an interactive AR element will be carried out. During this phase, some C# coding is needed in order to control the AR with some menu buttons.

The last phase is the evaluation phase. The functionality of the developed Electrolysis AR application was evaluated after the implementation phase. In this stage, all the development of the application is done. The Electrolysis AR application will build and run on an Android smartphone to test the functionality and check whether any errors exist. If the application got any error or problem, the problem will be fixed in this phase. In addition, the evaluation will also be carried out by collecting

feedback from the users, who are teachers and the students who are learning electrolysis using the Electrolysis AR application. The prototype will be tested to verify the product functionality and capability.

2.5 Project Requirements

2.5.1 Software Requirement

Software requirement is a functional or non-functional need to be implemented in the system. In this project, some software is used to complete the tasks such as:

- Unity
- Visual Studio 2019
- Vuforia
- Blender
- Audacity
- Adobe Photoshop CS6
- Adobe After Effects CS6
- Adobe InDesign CS6
- Microsoft Word 2016

2.5.2 Hardware Requirement

Hardware analysis encapsulates electronic and mechanical design and serves to minimize project risk while maximizing confidence in pending hardware build and verification efforts. Some hardware required to carry out the project, including:

- ✓ Laptop
- ✓ Android smartphone
- ✓ External Hard Disk

2.6 Conclusion

In conclusion, this chapter discussed the literature review and the project methodology. The domains related to the project are the definition and concept of

augmented reality, augmented reality in education and the definition and concept of chemistry education. Then, the methodology used in this project is a simple and intuitive approach, which consist of two steps. The first step is the creation of 3D models from real objects using a 3D modelling tool and the second step is the conversion of the 3D model into an AR element using an AR authoring tool. The next chapter is going to the analysis.

CHAPTER 3: ANALYSIS

3.1 Introduction

This chapter will go through the current scenario analysis and project analysis, as well as the requirements for the project. The requirements included in this project are project requirements, hardware requirements, software requirements and other requirements. Also, the project schedule and milestones are included in this chapter.

3.2 Current Scenario Analysis

According to the previous chapter, Interactive Multimedia Module with Pedagogical Agent, FuseSchool and Electrolysis-Flip eBook are three existing systems that are linked to this project. But there are not current systems that will be analyzed. The mobile augmented reality for biology learning, augmented reality to support geometry learning and virtual butterfly ecological system based on augmented reality are the current systems to be analyzed.

3.2.1 Mobile Augmented Reality for Biology Learning

According to the research, the mobile augmented reality for biology learning is an immersive AR tool that allows students to explore the various structures of the cardiovascular system and blood flow simulation. This application is designed to assist students who are having trouble recognizing heart circulation. The AR application allows students to communicate dynamically with the system's 3D models. It can also be used to simulate heart function. By offering 3D visuals more tangibly, this application has made this challenging subject more intuitive.

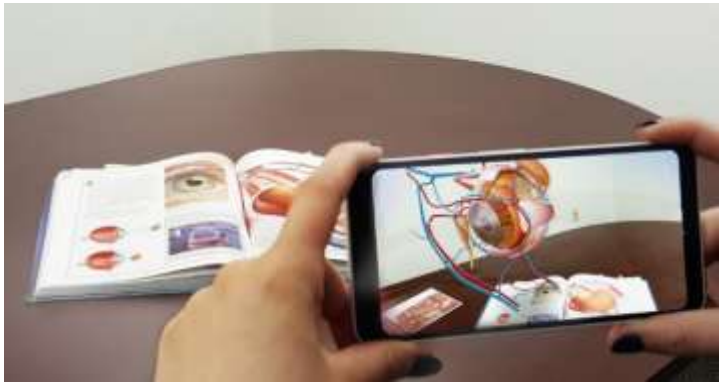


Figure 3.1: The Human Anatomy Atlas App Example (Mohd H. A. Kalana, Syahrul N. Junaini & Ahmad H. Fauz, 2019)

3.2.2 Augmented Reality to Support Geometry Learning

Veronica, Rosa, Antonio and Teresa (2020) is doing this study in order to design and create an augmented reality (AR) application for teaching solid geometry to third and fourth grade primary school children. The knowledge content for augmented reality to support geometry learning was created in partnership with primary school teachers. The learning goal of this application is to gain a basic understanding of the main solid figures. The aim is to use this method to supplement conventional solid geometry lessons.

Figure 3.2: Interface of Geo+ AR Application (Veronica, Rosa, Antonio and Teresa, 2020)

3.2.3 Campus Butterfly Ecology Learning System based on Augmented Reality and Mobile Learning

According to the findings, the campus butterfly ecology learning system based on augmented reality and mobile learning was designed to provide a context-aware learning environment using the built-in functions of smartphones. The AR butterfly ecological learning system was developed for fourth-grade students in elementary schools based on the learning unit “Butterfly’s Life Cycle” in nature science. Students can feed caterpillars on host plants and watch butterfly on nectar plant in the system. They can also learn more about butterfly by visiting the virtual greenhouse.

Figure 3.3: Interface of Virtual Green House (Tarng & Ou, 2015)

3.3 Requirement Analysis

3.3.1 Project Requirement

In this project, the process of data gathering is done by using the most commonly used technique which is a questionnaire. A questionnaire is a study tool that consists of a set of questions designed to collect primary data from respondents. It is a form of the written interview that can be conducted over the phone, computer or in person. In this project, the questionnaire that consisted of 11 questions is done by using Google Form. It was distributed to 30 respondents through online communication platforms such as WhatsApp, Messenger and Telegram.

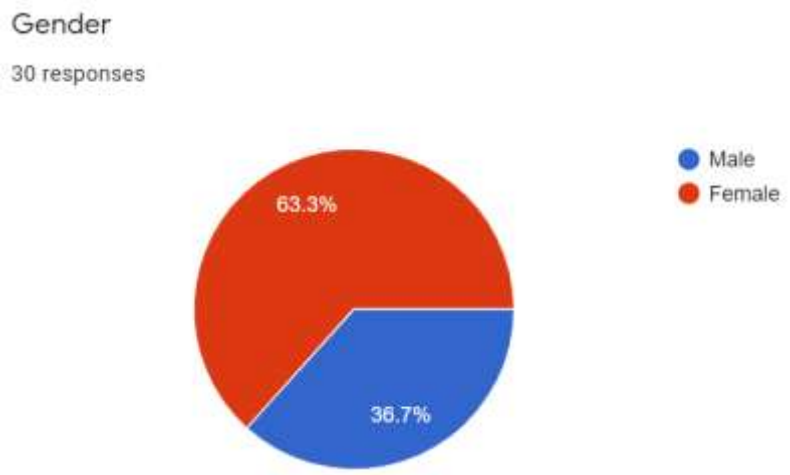


Figure 3.4: Respondent's Gender

From the data collected, 19 female respondents make up 63.3% of the total and 11 male respondents made up 36.7% of the total. The number of female respondents to this survey is higher than the number of male respondents.

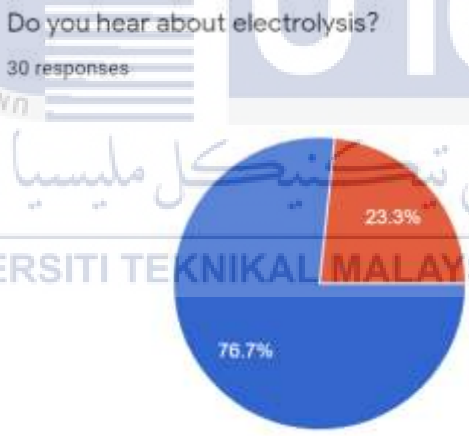


Figure 3.5: Do Respondents Hear About Electrolysis

According to the survey, the results indicated that 23 respondents (76.7%) heard about electrolysis and 7 respondents (23.3%) who do not hear about it.

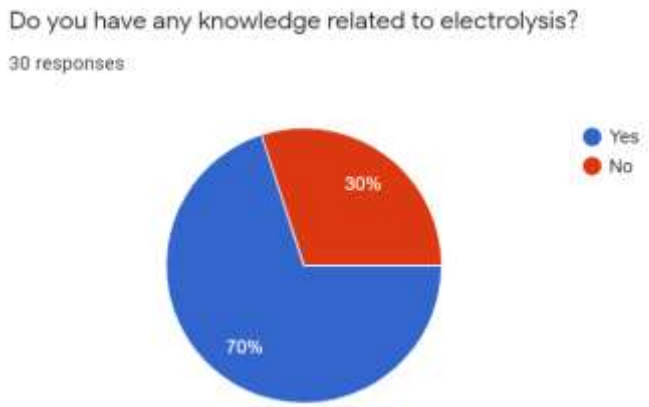


Figure 3.6: Do Respondents Have Any Knowledge About Electrolysis

The data demonstrate that 70 percent of respondents, which is 21 respondents had knowledge related to electrolysis, whereas 30 percent, which is 9 respondents have no understanding of electrolysis.

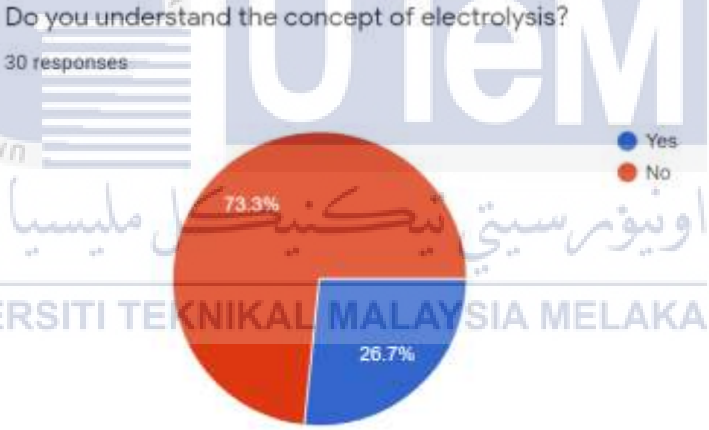


Figure 3.7: Is the Concept of Electrolysis Clear to Respondents

There were 8 respondents (26.7%) who understand the concept of electrolysis. The remaining 73.3% of respondents or 22 out of a total of 30 do not understand the concept of electrolysis.

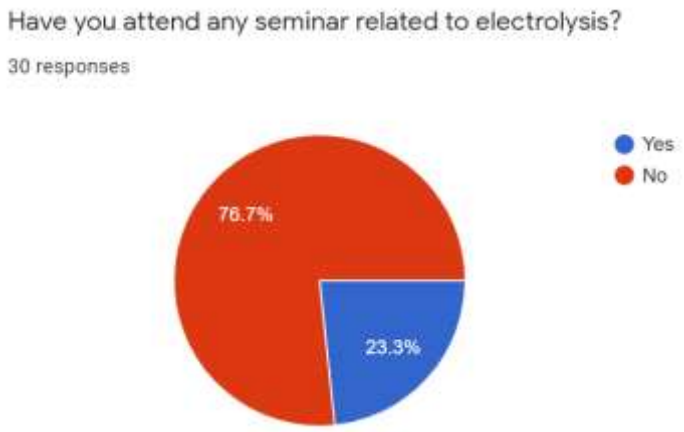


Figure 3.8: Have Respondents Attend Any Electrolysis-Related Seminar

The respondents who have to attend seminar related to electrolysis only 23.3% which is 7 people among all the respondents. And the rest of the respondents never have attended any seminar related to electrolysis.

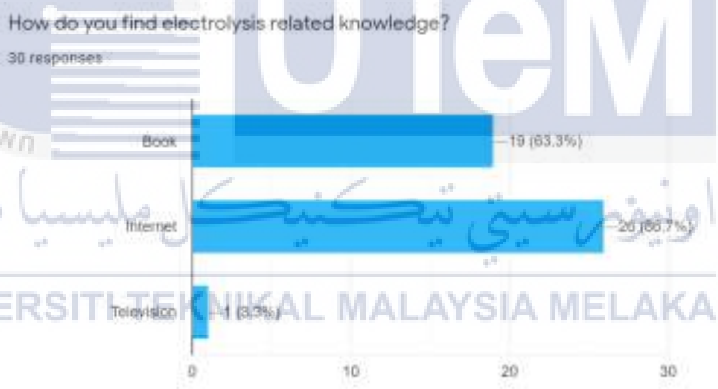


Figure 3.9: What Sources Do Respondents Use to Learn About Electrolysis

The largest proportion of people learn about electrolysis through internet is 86.7% (26 respondents), while the lowest percentage of people get electrolysis related knowledge through television show is only 3.3% (1 respondents). Bok is the second popular alternative for the respondents to find the knowledge of electrolysis which consist of 19 respondents with a percentage of 63.3%.

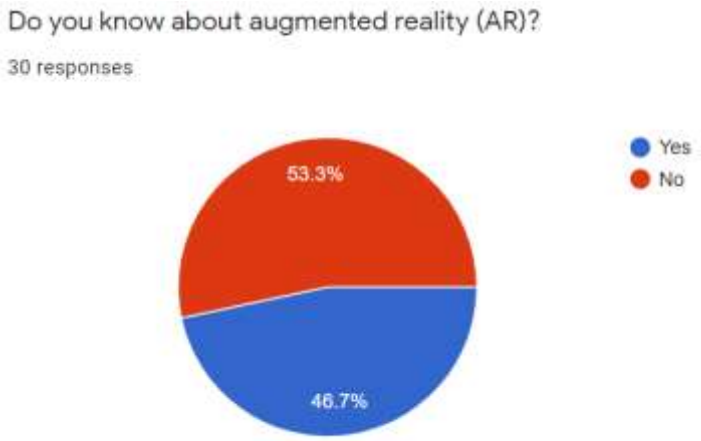


Figure 3.10: Are the Respondents Familiar with Augmented Reality

According to the results of the study, there were 16 respondents (53.3%) are unfamiliar with this technology. Meanwhile, there were more than half of the respondents from this are familiar with augmented reality(AR).

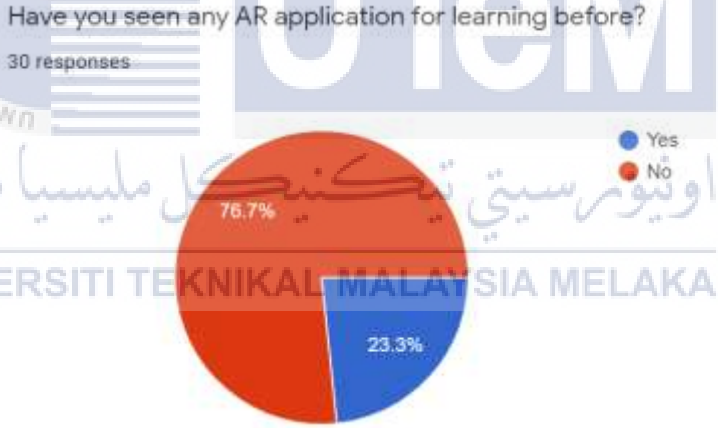


Figure 3.11: Have Respondents Seen Any AR Learning Applications Before

76.7 percent of the respondents (23 out of 30) had never seen an AR learning application before. However, 23.3 percent of the respondents (7 out of 30) had seen AR learning application before.

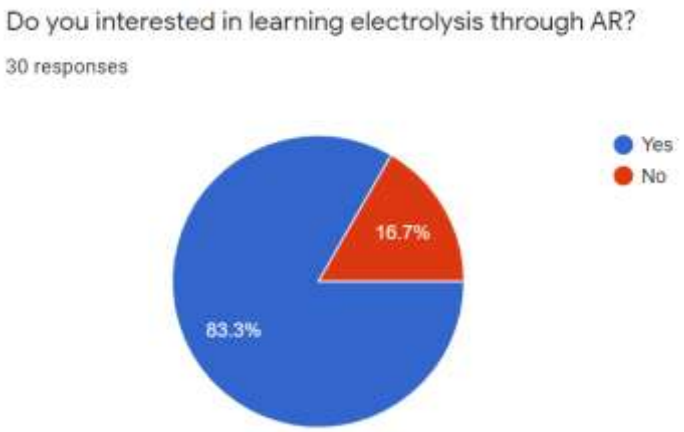


Figure 3.12: Do Respondents Would Like to Learn About Electrolysis through Augmented Reality

The survey showed that 25 respondents who are interested in learning electrolysis through AR, with a rate of 83.3%, and 5 respondents who are not interested in learning electrolysis through AR, with a rate of 16.7%.

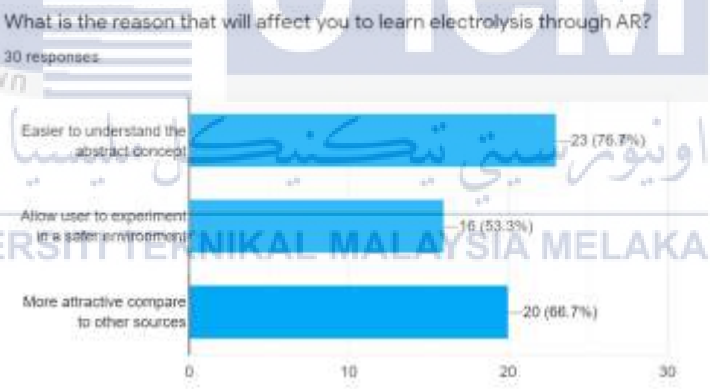


Figure 3.13: What is the Reason that Respondents will be Influenced to Learn Electrolysis via Augmented Reality

The reason that has the most impact on respondent's decision to study through AR is that it is easier to understand the abstract concept, according to 23 respondents (76.7%). The other choice that influences respondent's willingness to learn through AR is more appealing than other sources, which has 20 respondents with a 66.7% response rate. The safer environment provided for the experiment will affect almost

half of the respondents to learn electrolysis through AR, which is 53.3% of the respondent.

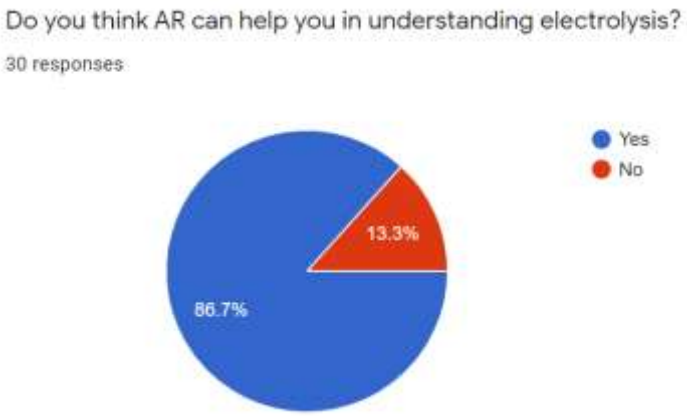


Figure 3.14: Do Respondents Believe Augmented Reality Will Aid Them in Their Comprehension of Electrolysis

Generally, majority of the respondents think that AR can help in understanding electrolysis, which consist of 26 respondents (86.7%). Only 4 respondents (13.3%) do not believe that AR can bring benefit in learning electrolysis.

3.3.2 Software Requirement

This project will make use of some tools for the development and documentation of the project. The software that will be used in this project includes Unity, Vuforia, Blender, Adobe Photoshop CS6 and Adobe After Effect CS6 for project development while Microsoft Word 2016 for project documentation.

- **Unity**

  Unity is used to develop the augmented reality experience in 3D for electrolysis.

- **Visual Studio 2019**

  Visual Studio 2019 is used to do coding for the 3D models.

- **Vuforia**

  Vuforia is used to help the creation of augmented reality application. It recognizes and tracks planar images in real-time using computer vision technology.

- **Blender**

  Blender is used to create the 3D object in this project. Modelling, animation, simulation and rendering are all supported in this software.

- **Audacity**

  Audacity is used to edit the audio that will be used in this project.

- **Adobe Photoshop CS6**

  Adobe Photoshop CS6 is used to design the marker for the AR application.

- **Adobe After Effect CS6**

  Adobe After Effect CS6 is used to create the video for this project.

- **Adobe InDesign CS6**

  Adobe InDesign CS6 is used to design and create a booklet that contains the marker for the AR application.

- **Microsoft Word 2016**

  Microsoft Word 2016 is used to do documentation, including proposal, logbook and report.

3.3.3 Hardware Requirement

When it comes to developing a project, hardware is crucial. The laptop, android smartphone and external hard disk are the hardware that will be used in this project. Below is the hardware requirement for developing the project.

- **Laptop**

  The laptop is used to carry out the project as well as do the documentation such as the report.

  - ✓ Intel Core M3-7Y30 / 1.0 GHz Max Turbo Speed 2.6 GHz Processor
  - ✓ 8GB RAM, 128GB SSD
  - ✓ 13.3" QHD + Display (3200 x 1800) Resolution

- **Android Smartphone**

  The smartphone is used to run and test the AR application.

  - ✓ Android OS 9.0
  - ✓ 4GB RAM + 64GB ROM

- **External Hard Disk**

The external hard disk is used to back up the project during development.

3.3.4 Other Requirement

The other requirement that needed in this project is printer. The printer is used to print the marker for the Electrolysis AR application. Besides, the online communication and meeting platform like Google Meet is also required in order to communicate and meet our supervisor.

3.4 Project Schedule and Milestones

Table 3.1: Milestones Details

Event	Start Date	End Date
Preparing proposal	1/3/2021	8/3/2021
Approving proposal	9/3/2021	14/3/2021
Project planning	15/3/2021	21/3/2021
Design marker and 3D object	22/3/2021	29/3/2021
Implementation of database	30/3/2021	7/4/2021
Implementation of marker and 3D object	8/4/2021	24/4/2021
Integrate 3D object with the marker	25/4/2021	31/5/2021
Project testing	1/6/2021	12/6/2021
PSM report writing	29/3/2021	19/6/2021
Presentation and demonstration	20/6/2021	25/6/2021

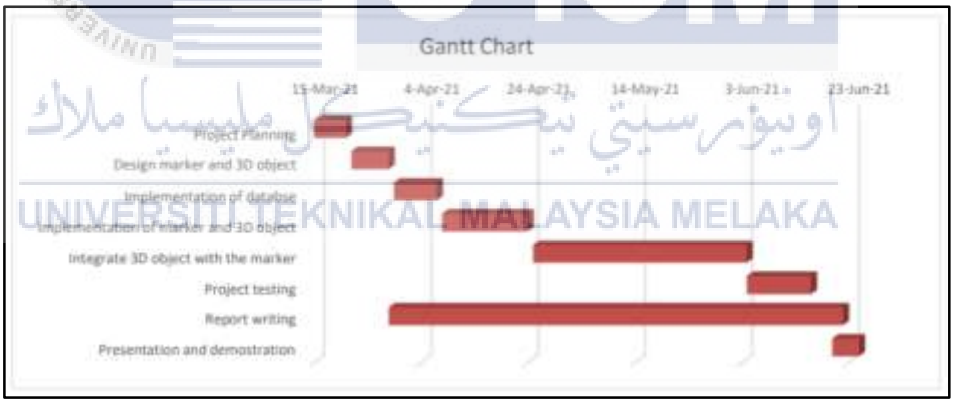


Figure 3.15: Gantt Chart

3.5 Conclusion

To sum up, this chapter had discussed the analysis of the current system. Moreover, the project, software, hardware and other requirements were also explained in this chapter. The questionnaire technique is used for the data collection and data analysis. In addition, milestone details and the Gantt chart are also included in this chapter.

CHAPTER 4: DESIGN

4.1 Introduction

The system architecture and the preliminary design analysis with the detailed design outcome will be described in this chapter. A design is a concept or drawing created to demonstrate how a project will look or work before it is built. In this chapter, a quick overview of the project will be provided.

4.2 System Architecture

The overall system will be outlined in the system architecture. The 3D electrolysis that will be developed has the goal of assisting users in gaining the basic concept of electrolysis especially for those who learn chemistry subject in their secondary school. The electrolysis will be displayed in a unique way, which is in 3D and simulate the electrolysis process. The 3D electrolysis can be a useful educational method since they are easy to attract the user's attention. Furthermore, there will also some simple explanation and description included in the system.

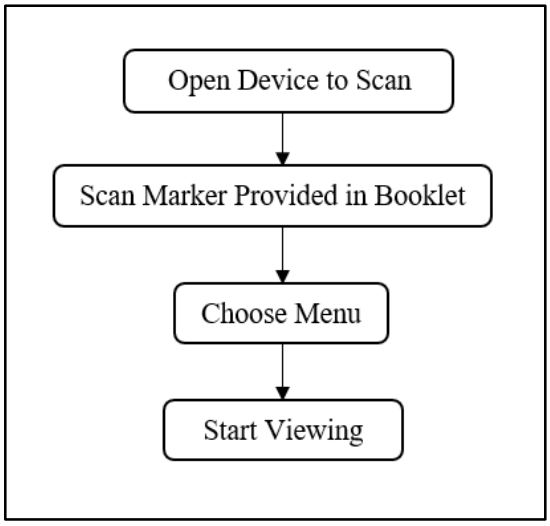


Figure 4.1: System Architecture

4.3 Preliminary Design

4.3.1 Storyboard Design

The multimedia design process includes creating a storyboard. The storyboard depicts the appearance of the application that will be developed. The full storyboard can refer to appendix.

4.3.1.1 Storyboard Design for AR application

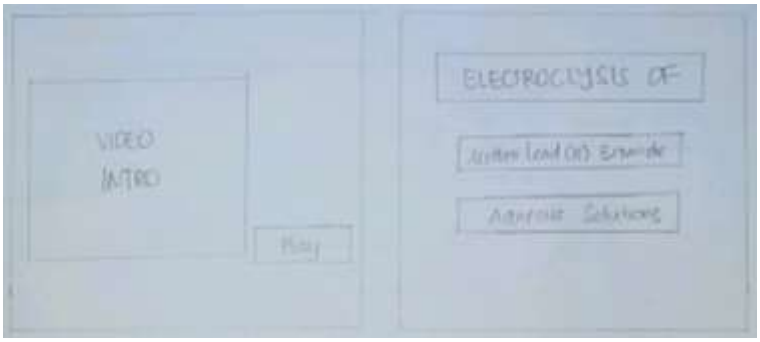


Figure 4.2: Storyboard 1

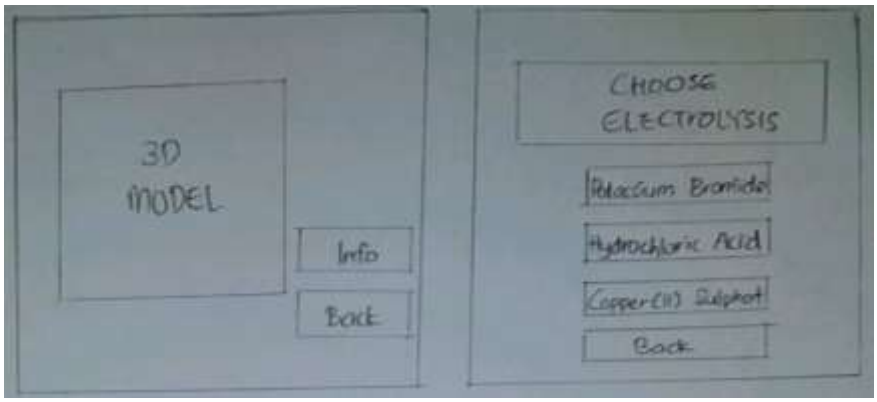


Figure 4.3: Storyboard 2

4.3.1.2 Storyboard Design for Animation of 3D Model

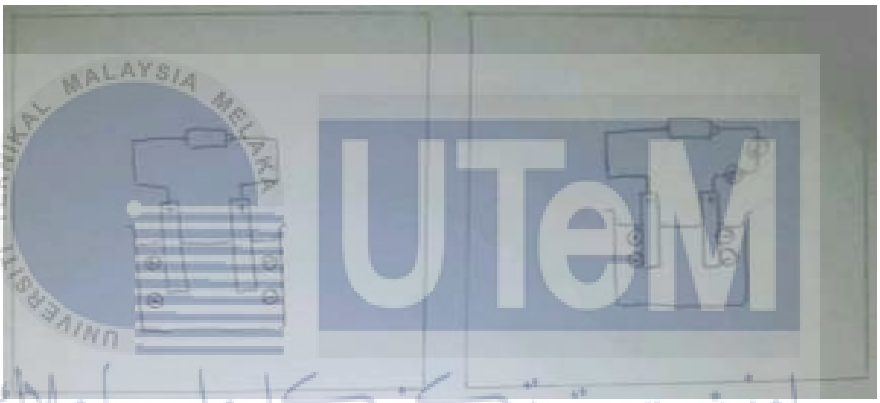


Figure 4.4: Storyboard 3

4.4 User Interface Design

A booklet will design as a user interface for the user to interact with the AR application. In this project, there are four marker created for the AR application. All the marker will include in the booklet. In addition, some key points will also provide in the booklet. Users can read the key points and scan the marker in the booklet to view the 3D electrolysis process. Besides, users can also press the buttons provided in the AR application in order to view the description and interact with the AR. Users can view the simulation of the electrolysis process and interestingly learn electrolysis through AR.

4.4.1 Navigation Design

Navigation design will help the user use the system easily. This design ensures that users can interact with the system. Firstly, users need to scan the marker provided in the booklet. After scan the marker, a simple menu will appear on the screen. There are some buttons provided in this interface. Therefore, users are required to click the button to interact with the AR. Users can simply navigate to another interface by using the button provided. The navigation flow provided in this project is as below.

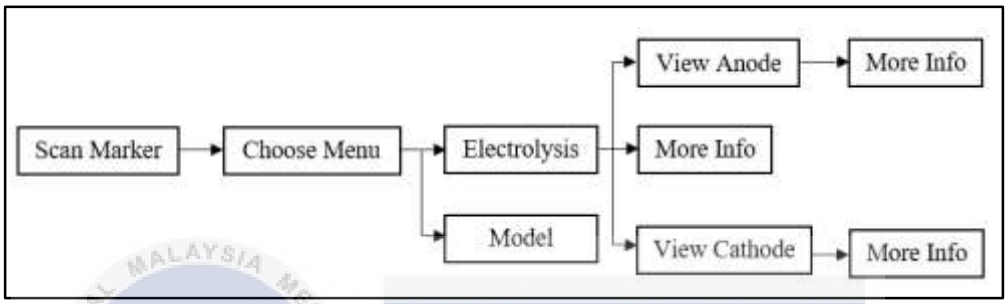


Figure 4.5: Navigation Design 1

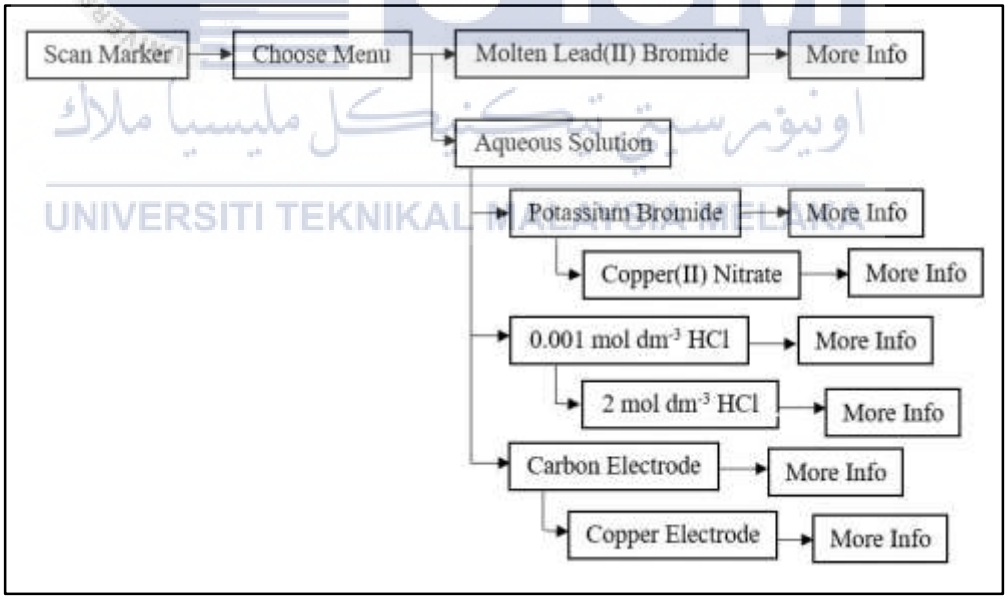


Figure 4.6: Navigation Design 2

4.5 Conclusion

In a nutshell, the system architecture, preliminary design and user interface design was described in this chapter. This chapter was created to provide more details on the design of the application. Thus, both users and developers will have a better understanding of the overall design. The design phase is important for a developer to design an efficient outcome application.

In the next chapter, the activity involved in the implementation phase and what is the expected output after the implementation phase will briefly describe. The media creation such as production of texts, graphics, videos and animations will be covered. Besides, the production configuration management and implementation status will also discover in the next chapter.

CHAPTER 5: IMPLEMENTATION

5.1 Introduction

The media creation, media integration and product configuration management will be discussed briefly in this chapter. Furthermore, the implementation process of the project will be addressed. Besides, the expected outcomes will also describe once this phase is completed.

5.2 Media Creation

There are five elements included in the multimedia. The most common multimedia element is text. The text conveys the content that the developer wanted to express to their audience. An image is the second multimedia element. An image captures the interest of the audience far more easily than text. Audio is the third multimedia component. Audio files are usually played using plug-in media players. Video is the fourth multimedia element. The web is the most popular place where videos with multimedia elements can be found. Animation is the fifth multimedia element. Animations are the most creative and interesting type of multimedia.

5.2.1 Production of Text

Text plays an important role in project development. Text is one of the types of information source. It is good in delivering simple information. Users can get a better understanding from the text provided. When the user has no audio system, text can be utilized to send messages to the user. This section will go through different types of texts, fonts handling and text formats. The diagrams below depict the stages

involved in making various types of texts, as well as the fonts that are applied in various situations.

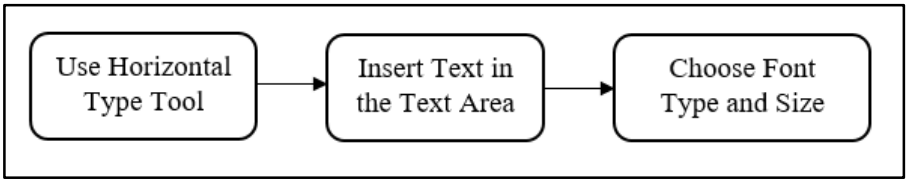


Figure 5.1: Production of Text Steps in Adobe Photoshop

Table 5.1: Example of Text Produced in Adobe Photoshop

Text Type	Example	Font Type	Font Size
Title	Cathode	Tw Cen MT Condensed Extra Bold	48 pt
Content	- Electrons are received by	Tw Cen MT Condensed	36 pt

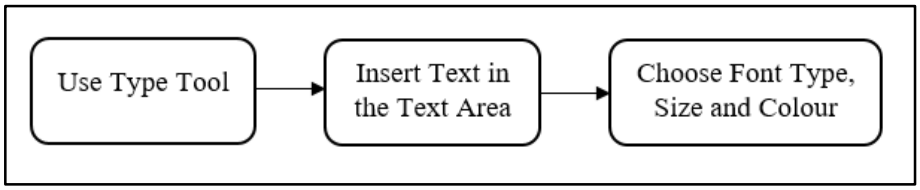


Figure 5.2: Production of Text Steps in Adobe InDesign

Table 5.2: Example of Text Produced in Adobe InDesign

Text Type	Example	Font Type	Font Size
Title	Electrolysis Process	Agency FB	24 pt
Content	- Electrolytes are made up of	Agency FB	36 pt

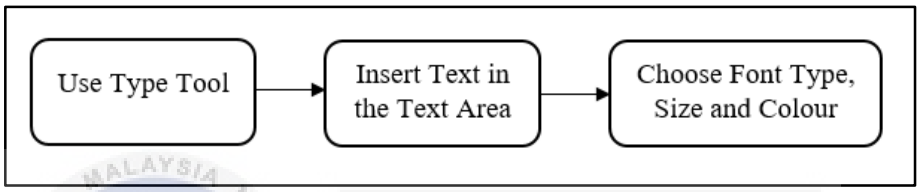


Figure 5.3: Production of Text Steps in Adobe After Effect

Table 5.3: Example of Text Produced in Adobe After Effect

Text Type	Example	Font Type	Font Size
Explanation	Anions	Impact	60 px

5.2.2 Production of Graphics

Graphics are visual elements that are usually used to guide readers and viewers to certain information. They are also applied to complement the text in order to help readers to understand an idea or make it more clear or engaging. The graphics used in the marker, booklet and AR application are raster-based, which are made up of pixels. The production of graphics is not only restricted to 2D images, but also the production of the 3D model. The 3D representation of an object is created by using specific

software. The model is a representation that can express the size, shape and texture of the object. The diagrams below depict the stages involved in making graphics that used in the Electrolysis AR application.

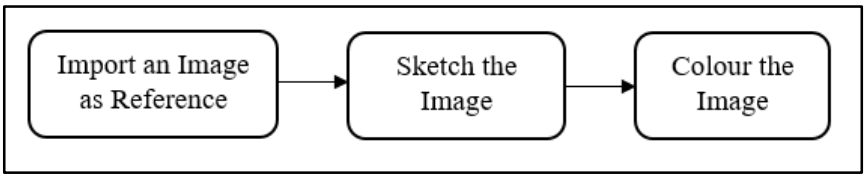
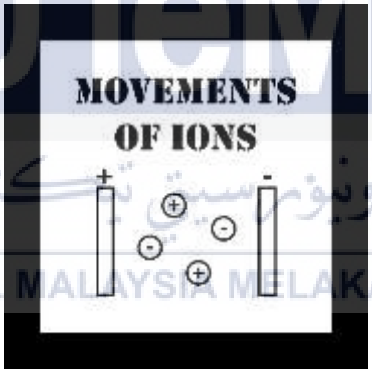
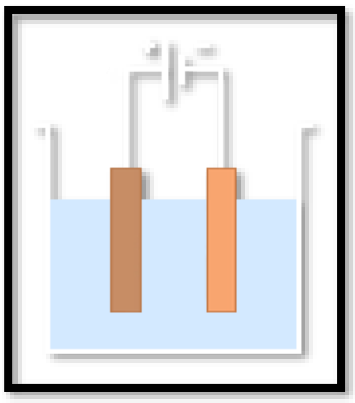


Figure 5.4: Production of Graphics Steps in Adobe Photoshop

Table 5.4: Example of Graphics

Type of Image	Example
Marker	
Electrolysis in video introduction	

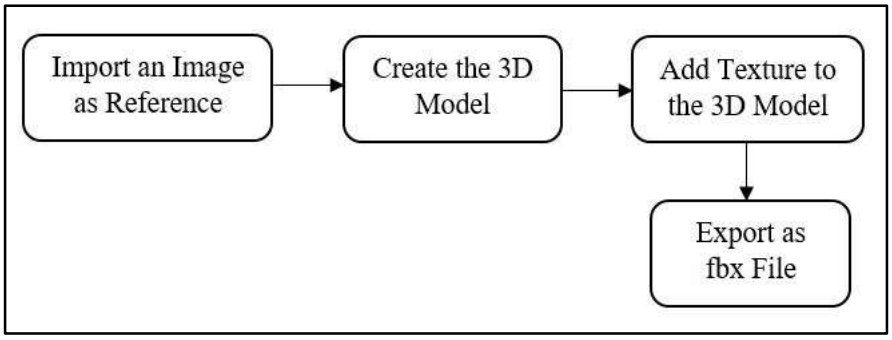


Figure 5.5: Production of 3D Model Steps in Blender

Table 5.5: Example of 3D Model

Type of 3D Model	Example
Tripod	
Bunsen Burner	

5.2.3 Production of Audio

Audio plays an important role in interactive media. It can help users to reinforce the understanding of information, which is represented in another kind of multimedia element. The audio source may good insight into the scene's circumstance and allow the user to feel as if they are in the same situation, making the scene more appealing because the user can feel the situation through the production of audio, rather than just reading the text. This can help the user to have a better understanding and comprehension of the application. The diagram below depicts the steps involved in creating audios that are used in the Electrolysis AR application.

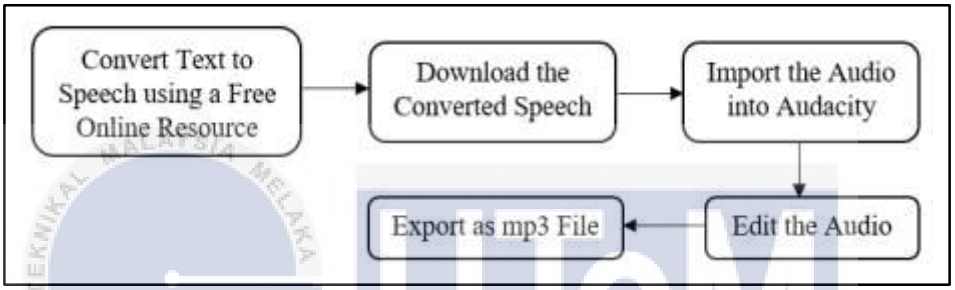


Figure 5.6: Production of Audio Steps in Audacity

5.2.4 Production of Animation

Animation production includes modelling and texturing, which is more appealing and can attract users if compared to text alone. There are two types of animation used in this project, which are 2D animation and 3D animation. The art of producing movement in a 2D space is known as 2D animation. Individual graphics are sequenced together over time in order to create the illusion of movement. When computer-generated objects appear to move in 3D, this is known as 3D animation. 3D animation using the same concepts as in real life. The diagram below depicts the steps involved in creating animations that are used in the Electrolysis AR application.

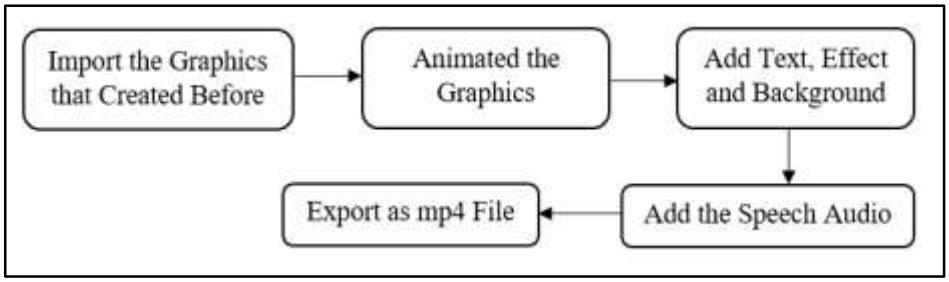


Figure 5.7: Production of 2D Animation Steps in Adobe After Effects

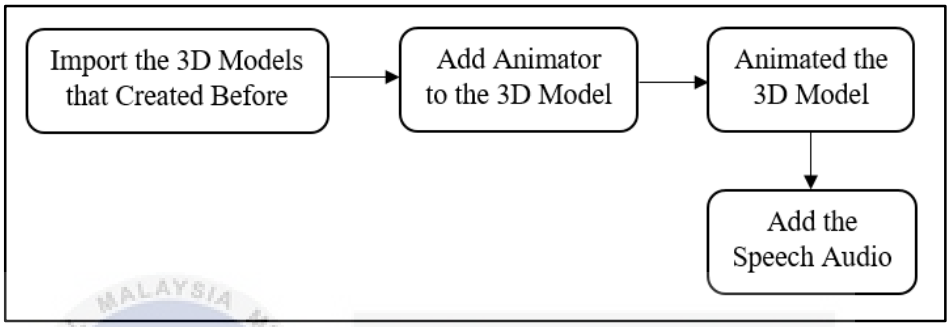


Figure 5.8: Production of 3D Animation Steps in Unity

5.3 Media Integration

This section will discuss the combining of all the productions used during the implementation and development phases. In order to build a better AR application, the production of text, graphics, audio and animation were used to develop the Electrolysis AR application. First and foremost, the markers and graphics that will be used in the Electrolysis AR application are designed by using Adobe Photoshop. As a reference, an image is imported into Adobe Photoshop for sketching. Then, sketching and coloring of the markers and all the graphics will be done and export as jpeg files in Adobe Photoshop.

After all of the graphics have been done, the graphics that will be used in the animation will be imported as composition into Adobe After Effects, where the animation and audio will be added. In order to generate a short animation, Audacity is used to alter the audio, which is then will be exported as an mp3 file and import into Adobe After Effects. The animation will be imported into Unity as a video introduction for the Electrolysis AR application after it has been edited.

Furthermore, the 3D models will be created by using Blender. As a reference, an image will be imported into Blender for creating. After that, the process of modelling and texturing will be done and the 3D models will be export as fbx files. Then, all the 3D models will be imported into Unity after the process of modelling and texturing are done. Besides, all the markers that have been created before will be upload into Vuforia as a target image and the database should be download and import into Unity.

After that, the animation of the 3D models will be done in Unity. An animator will be added to an object in order to create movement. In another hand, the C# coding will also be done to animate and create an effect onto the objects by using Visual Studio 2019. Additionally, as the final combination of the Electrolysis AR application, the audio sources and sound effects that are recorded and edited by using Audacity will be imported into Unity.

5.4 Product Configuration Management

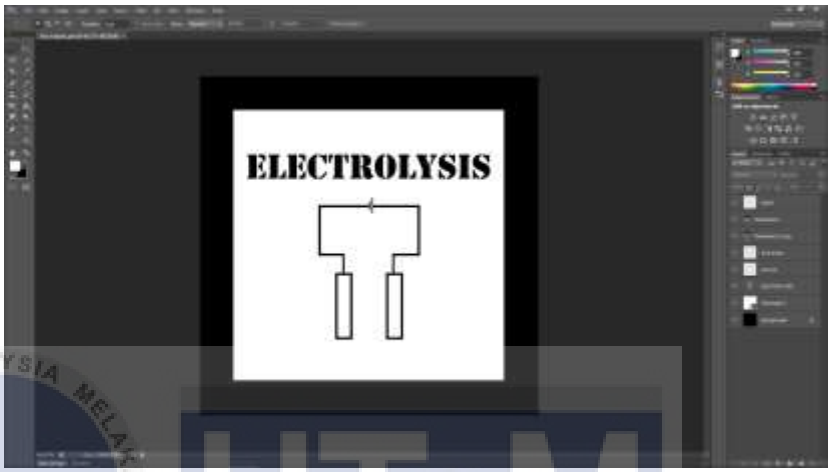
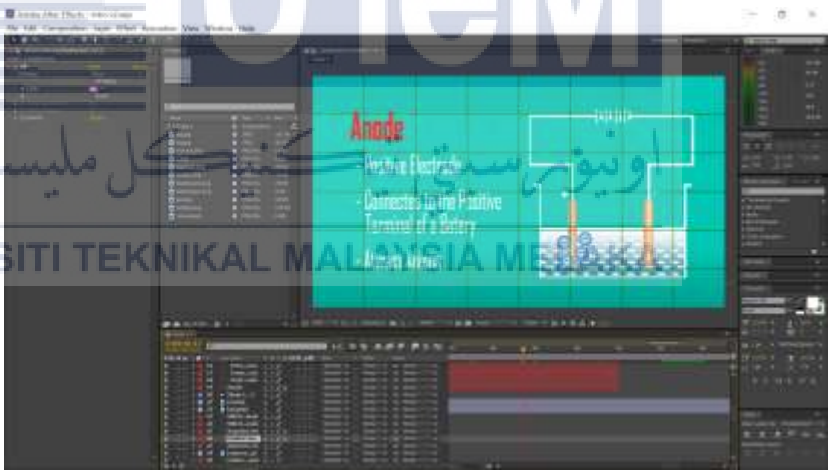
This section will cover the configuration environment setup and also the version control procedure. There is a lot of software utilized during the implementation phase to develop the augmented reality project.

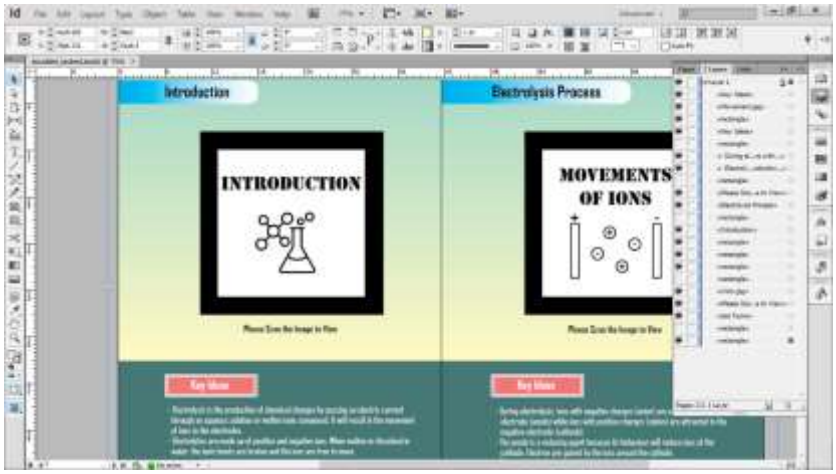
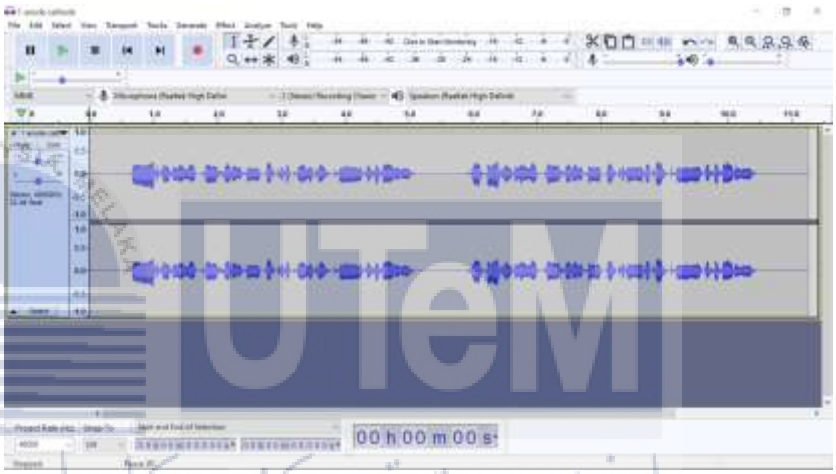
Firstly, the markers, graphics and explanation cards are designed and created by using Adobe Photoshop. Adobe Photoshop was used to sketch and color the markers, graphics and explanation cards. After the graphics are done, they are imported into Adobe After Effects to create a simple video introduction for the Electrolysis AR application. After the markers are created, they are uploaded to Vuforia as a database. Aside from that, they are also imported into Adobe InDesign to create a booklet for the application.

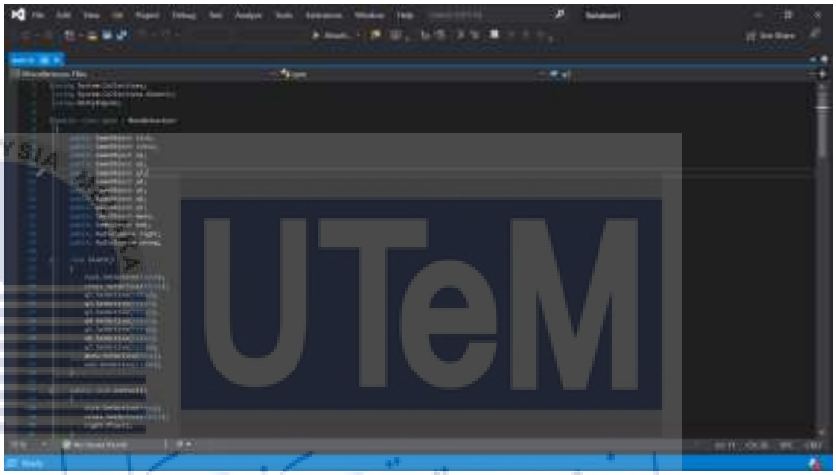
Furthermore, Audacity was used to edit the audio sources and sound effects. After the audio was edited, they are imported into Unity. Besides, Blender was used to create the 3D objects. The 3D objects were modelling and texturing in Blender. After the 3D objects were created, they are imported into Unity. The animation of the 3D objects will be done by using Unity. In addition, Visual Studio 2019 was also used

to create the movement and effects for the 3D objects. All the elements were required import into Unity in order to develop the Electrolysis AR application.

Table 5.6: Configuration Environment Setup for Each Software

Software	Configuration
Adobe Photoshop CS6	
Adobe After Effects CS6	

Adobe InDesign CS6	
Audacity	
Blender	

Unity	
Visual Studio 2019	

5.5 Implementation Status

This section will describe the progress of the development status for each component and module of the AR project. The project's development progress is tracked and recorded using the implementation status. Before starting the development phase, the storyboard must be created. The storyboard is necessary for an interactive media project since it represents the appearance and design of the application that will be developed. In order to produce a successful Electrolysis AR application, the idea and concept must be collected when creating the storyboard. The storyboard sketching began after the idea and concept were finalized. For this AR project, the storyboard for the AR interface and the animation of the 3D models are created. The storyboard has to be sketched out in great detail. Therefore, it could be easily understood when

developing the Electrolysis AR application. The development status of the storyboard is on time.

The implementation of the Electrolysis AR application begins after the storyboard was sketched. Adobe Photoshop was used to design and sketch the markers and explanation cards. After the markers and cards had been created, they needed to be colored. Then, the markers were uploaded into Vuforia as the image target for the Electrolysis AR application. The database in Vuforia needed to be downloaded and imported into Unity. The explanation cards were also required to import into Unity. In addition, the 3D models were also designed and created after the storyboard had been created. The modelling and texturing of the 3D models were done in Blender. All the 3D models were exported as fbx file format and imported into Unity. All the activities included creating the AR markers, downloading the database from Vuforia, creating the explanation cards and 3D models for the Electrolysis AR application were on time.

Furthermore, a simple booklet for the Electrolysis AR application was created using Adobe InDesign. The booklet plays an important role as a medium for the users to interact with the Electrolysis AR application. All the markers are included in the booklet. Moreover, there are some explanations about the content of the markers were also included in the booklet. Hence, the users can read the descriptions before they scan the markers. Following the completion of the booklet, audio source and sound effects were required to make the application more interesting. Thus, the audio sources and sound effects were edited using Audacity and imported into Unity. All the activities above were completed on time.

After all the components were done and imported into Unity, the animation of 3D models was created in Unity. The animation was created by using a different animator to control the movement of each model. The animation of the models was simulated the real concept during the electrolysis process. By doing this, users can observe and learn the abstract concept of electrolysis topic easily. The process of coding was required in order to control the interaction of the application with the users and to add some effects to the application. Finally, the development status of the Electrolysis AR application is on time. The Electrolysis AR application was developed successfully after the integration of all the multimedia elements created.

5.6 Conclusion

To sum up, this chapter covered all steps used for the development of the Electrolysis AR application. The media creation, media integration, product configuration management and implementation status are the activity included in the implementation stage. The next chapter is testing, where the activity that involved in testing phase and the testing strategy will briefly describe.

CHAPTER 6: TESTING

6.1 Introduction

The testing plan will be outlined in this chapter. This testing chapter will go over a complete test plan, including the test user, test environment and test schedule. Besides, the test strategy, test implementation, test results and analysis for the Electrolysis AR application will also be carried out. The testing phase is used to determine whether the project's goal of evaluating the effectiveness of the Electrolysis AR application in chemistry education was met.

6.2 Test Plan

6.2.1 Test User

The test user plays an important role in the testing phase. The test user is required to assist in the testing of the application. The test users who participated in the testing phase can be separated into two groups. The first group is the expert, who will involve in the evaluation of electrolysis AR application testing. The second group is users, who will undergo the pre-post testing and evaluation of electrolysis AR application testing. After the users complete the pre-post testing, a comparative analysis of the results and independent t-test will be obtained. The expert perspective of evaluation of electrolysis AR application testing will be given to 4 different people to test the application. There will have 2 IT experts and another 2 subject-matter experts (SME). Furthermore, 18 users will participate in pre-post testing. All of the users were 16 and 17 years old students, who study the subject of chemistry in secondary school. After the pre-post testing is completed, they will undergo the evaluation of electrolysis AR application testing.

6.2.2 Test Environment

The instrument that used for the testing is an online questionnaire. There are four questionnaires that have been distributed. Among them is the Evaluation of Electrolysis AR Application for user and expert. In this questionnaire has two main parts, namely focus and usability. Part focus includes questions on interaction design, information design and interface design. While the usability part includes questions about effectiveness and satisfaction. But the questionnaire for user and expert there is little difference. In addition, there are two quizzes that have been produced for the pre-post testing. The questions for pre-test and post-test are different but have the same level of difficulty.

The test environment consists of aspects that enable the execution of the test with software and hardware. It is a software and hardware setup that enables test scenarios to be conducted. Both the expert and the user will be tested individually over a period of time. Before the evaluation of electrolysis AR application testing, a demonstration video will provide to the experts. For the users, pre-post testing will be given to them before the evaluation of electrolysis AR application testing. The users are required to answer a quiz for the pre-test before they use the application. After that, users can explore the application and then answer another quiz for the post-test. Following the pre-post testing, the evaluation of electrolysis AR application testing will be given to the users to test the effectiveness of the application. The testing environment is necessary to measure the effectiveness of the Electrolysis AR application. The hardware required to evaluate the effectiveness of the Electrolysis AR application is Android smartphones.

6.2.3 Test Schedule

The test schedule is used to keep track of how long each user test lasts. In order to finish the testing effectively in the time given, the users are managed to be followed the time given to complete the testing. Furthermore, each of the tasks must be scheduled into the test timetable in order to complete the testing successfully.

All testing was conducted within a week through social media platforms such as WhatsApp, Messenger and Telegram. In table 6.1, the test schedule will be shown.

Table 6.1: Test Schedule for Electrolysis AR Application

Test	Date	Duration
Evaluation of Electrolysis AR Application Testing (Expert's Perspective)	15th August 2021 – 21st August 2021	7 days
Pre-post Testing	15th August 2021 – 21st August 2021	7 days
Evaluation of Electrolysis AR Application Testing (User's Perspective)	15th August 2021 – 21st August 2021	7 days

6.3 Test Strategy

6.3.1 Test Strategy for Expert

The evaluation of electrolysis AR application testing is the test that the expert will conduct during the testing phase. The demo video for the AR application will be given to the experts as a reference. After that, the experts are required to explore and carry out the application effectiveness testing. The application effectiveness testing involves 4 experts, which are 2 IT experts and 2 SMEs. The purpose of the expert perspective evaluation of electrolysis AR application testing is to evaluate the effectiveness of Electrolysis AR application in the education of chemistry. The interaction design, information design, interface design, effectiveness and satisfaction of the AR application were all tested as part of the testing. General information, interaction design, information design, interface design, effectiveness, satisfaction and comment & feedback are the sections of the expert testing questionnaire. The questionnaire for the evaluation of electrolysis AR application testing for experts can refer in the appendix.

6.3.2 Test Strategy for User

The user's testing will be separated into two parts. The first is the pre-post testing and the second of which is the evaluation of electrolysis AR application testing. A total of 18 users participated in the testing from secondary school students who have studied chemistry. The pre-post testing will be divided into two portions. Before

exploring the Electrolysis AR application, the users are required to answer the pre-test questionnaire. After completing the pre-test questionnaire, the users will be given the opportunity to explore the AR application. After the user has explored the application, the post-test questionnaire will be presented to them. The questions provided in the pre-post testing has the same difficulty level. After completing both questionnaires, the users will be given the evaluation of electrolysis AR application testing to evaluate the effectiveness of the Electrolysis AR application. The pre-post testing and the evaluation of the electrolysis AR application testing questionnaire for users are attached in the appendix.

6.4 Test Implementation

6.4.1 Test Description

In this section, the testing cases, objectives and expected results for each module are designed. There are two testing cases used in the testing phase. The first one is the testing on the expert's perspective. For the experts testing, a video demonstration will be given to the expert. Then, the experts can explore the AR application on their own. After exploring the application, the experts are required to complete an evaluation of the electrolysis AR application questionnaire, which consist of interaction design, information design, interface design, effectiveness, satisfaction and feedback.

The second test case is the testing from the user's perspective. For the user testing, a total of 18 users participated in the testing. The respondents can start to explore the application once they finished the pre-test. After they explored the application, they are required to answer a post-test. Following the pre-post testing, the respondents need to complete an evaluation of the electrolysis AR application questionnaire, which consist of interaction design, information design, interface design, effectiveness, satisfaction and feedback.

6.4.2 Test Data

When the testing section is finished, all the data will document and collect. All the test results and data are from real-life situations. In the next section, which is test

results and analysis, all of the data will be collected and analyzed. The following information was gathered through evaluation of electrolysis AR application from the expert's perspective testing and evaluation of electrolysis AR application from the user's perspective testing. Likert Scale is the approach, which used for obtaining results. The five-point Likert Scale was used in the questionnaire to collect the data. In the evaluation of the electrolysis AR application questionnaire, respondents can choose from 5 ratings. For the rating, 1 strongly disagree, 2 disagree, 3 not sure, 4 agree and 5 strongly agree. In addition, the average point of the pre-post testing that the respondents completed will be displayed and analyzed in the next section.

6.5 Test Results and Analysis

6.5.1 Evaluation of Electrolysis AR Application from Expert's Perspective

The outcome of the analysis for evaluation of the Electrolysis AR application from the expert's perspective is obtained through the use of a questionnaire as a tool. The evaluation of Electrolysis AR application questionnaire was created in order to collect expert's feedback on the effectiveness of the Electrolysis AR application. The survey was conducted over the phone or computer. It was distributed to 4 respondents included 2 IT experts and 2 SMEs through online communication platforms such as WhatsApp and Telegram.

The questionnaire is separated into three parts. The first part collects demographic information from experts. The focus for the effectiveness of the Electrolysis AR application is the second part, and it is divided into three sections, each representing interaction design, information design and interface design. The last part is the usability of the Electrolysis AR application, which consist of the effectiveness and satisfaction sections. After all the data are collected, these data will be analyzed with mean and standard deviation calculations.

6.5.1.1 Demographic Information

According to the evaluation of the Electrolysis AR application from the expert's perspective questionnaire, the questionnaire consists of nine items relating to demographic data to gather information about the respondent's background and

opinions. The following table displays the demographic information of respondents who participate in the survey.

Table 6.2: Demographic Information about Expert's Background

Name	Race	Gender	Age	Occupation
Maizatu Saufia Binti Salleh	Malay	Female	35	Teacher
Leng Siew Lian	Chinese	Female	38	Teacher
Kang Chian Le	Chinese	Male	33	Software Engineer
Kang Chian Gim	Chinese	Male	41	Software Engineer

Total respondents: 4

Based on the findings, the application effectiveness testing involves 4 experts. Out of 4 experts, there are 3 Chinese while only one of them is Malay. Two of the male experts are software engineers from Intel Corporation while another two female experts are SMEs, secondary school chemistry teachers from SMK Dato Haji Hassan Yunos.

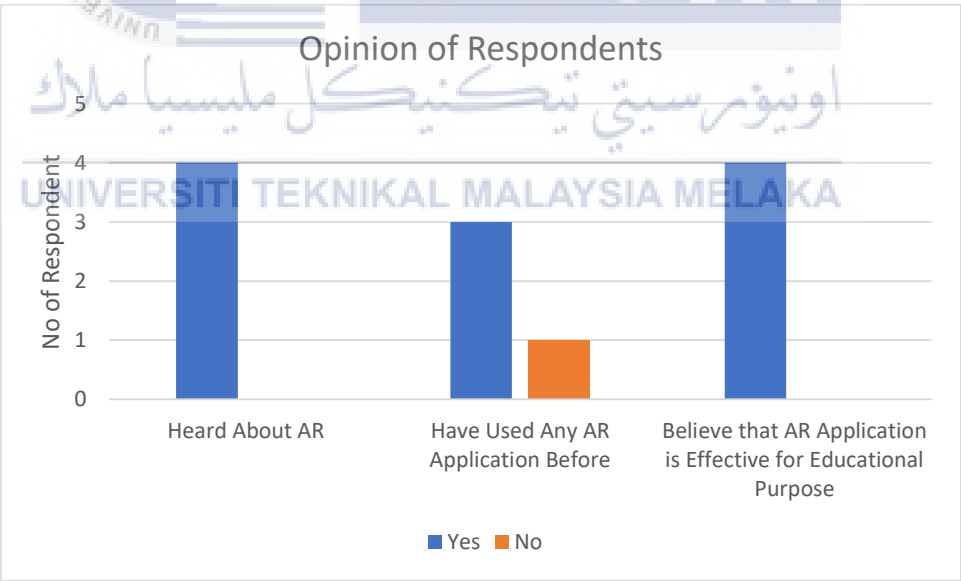


Figure 6.1: Demographic Information about Expert's Opinion

Based on Figure 6.1, all of the respondents (4 respondents, 100%) have heard about augmented reality. Meanwhile, almost all the respondents (3 respondents, 75%) have experience in using AR application, while just one respondent (25%) have no

experience in using AR application. The last question is about the respondent's perceptions of believing in the effectiveness of AR application for educational purposes. Four of respondents (100%) were believed that the AR application is effective for educational purposes.

6.5.1.2 Focus

The interaction design, information design and interface design are three sections that consist in the focus of the evaluation of Electrolysis AR application from the expert's perspective. There were seven questions each for the evaluation of interaction design, information design and interface design for the expert's perspective.

Interaction design is the first section in the focus for the evaluation of Electrolysis AR application from the perspective of the expert's questionnaire. All the results of the evaluation of Electrolysis AR application in interaction design from the perspective of experts will be shown in the following figure.

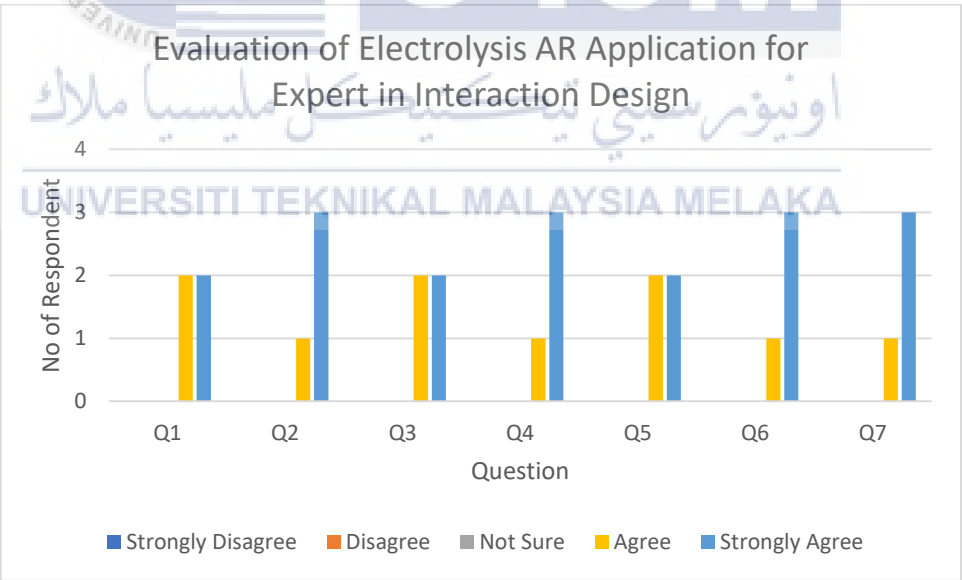


Figure 6.2: Result of Evaluation for Expert in Interaction Design

Figure 6.2 shows a graph of the result of interaction design for evaluation of Electrolysis AR application from the perspective of the experts. This interaction design section contains 7 questions. The first statement is whether the AR marker can detect

by the camera of the device easily. Half of the respondents (2 respondents, 50%) strongly agree and half of them (2 respondents, 50%) agree that the markers can be detected easily. This is because the users can simply scan the marker using their camera without taking a long time.

The usage of buttons to pause and resume the video is convenient is the second question. The statement is supported by all of the respondents, who 1 agree (25%) and 3 strongly agree (75%) with it. This is because the pause and resume buttons are effective for users to control the video. On the other hand, two respondents (50%) agree that simulations' loop for continuous play is efficient, while the other two (50%) strongly agree that the continuous loop of the simulation is more convenient for users. This will enable users to observe the simulation continuously without clicking any button.

Menu buttons provided enable users to control the application easily is the next question. The majority of respondents (3 respondents, 75%) strongly agree and only one respondent (25%) agree with the statement because the menu buttons allow users to navigate freely when using the application. The fifth criterion concerns whether the size of the 3D model is appropriate for viewing on the device's screen. Half responders (2 respondents, 50%) strongly agree with the statement, while the other two (50%) agree.

The following consideration is the integration of multimedia elements help receive information more effectively. 25% which is one respondent that agrees the information can be received effectively with the integration of multimedia elements and 75% of respondents, which is three respondents strongly agree with that.

Meanwhile, more than half of respondents (3 respondents, 75%) strongly agree the AR application is able to promote enjoyment for users during the learning process, while only one respondent (25%) agree with that. This is because the multimedia elements used in this application not only contain text and image, but also audio, video and animation. Hence, this application will enable users to learn electrolysis more interestingly and effectively. According to the test results, the interaction design of the application is appropriate and convenient for users.

The mean and standard deviation values for the interaction design of the application are shown in the following table.

Table 6.3: Mean and SD of Interaction Design from Expert's Perspective

Interaction Design			
No.	**Statement**	**Mean**	**Standard Deviation**
1.	The AR marker can detect by the camera of the device easily.	4.50	0.58
2.	The usage of buttons to pause and resume the video is convenient.	4.75	0.50
3.	The simulations' loop for continuous play is efficient.	4.50	0.58
4.	Menu buttons provided enable users to control the application easily.	4.75	0.50
5.	The 3D model's size is appropriate for viewing on the device's screen.	4.50	0.58
6.	The integration of multimedia elements help receive information more effectively.	4.75	0.50
7.	The AR application promotes enjoyment for users during the learning process.	4.75	0.50

Total respondents: 4

According to Table 6.3, the mean values of all the statements are above 4. This indicated that the experts are agreed with all the statements in the interaction design section. Statement 2, 4, 6 and 7 have the highest mean value which is 4.75, extremely close to 5 (strongly agree). Hence, the Electrolysis AR application can be said as a convenient application since menu buttons were provided for users to control. Besides, the integration of multimedia elements in this application helps users to learn electrolysis more effectively and enjoy learning. With a full score of 5 representing strongly agree, all mean calculation results show that all experts agree that the interaction design for this application is very good. As for the standard deviation, the data shows that the data collected is in low variability.

After the interaction design section, the second section in the focus for the evaluation of Electrolysis AR application from the perspective of the expert's questionnaire is the information design. All the results of the evaluation of Electrolysis AR application in information design from the perspective of experts will be shown in the following figure.

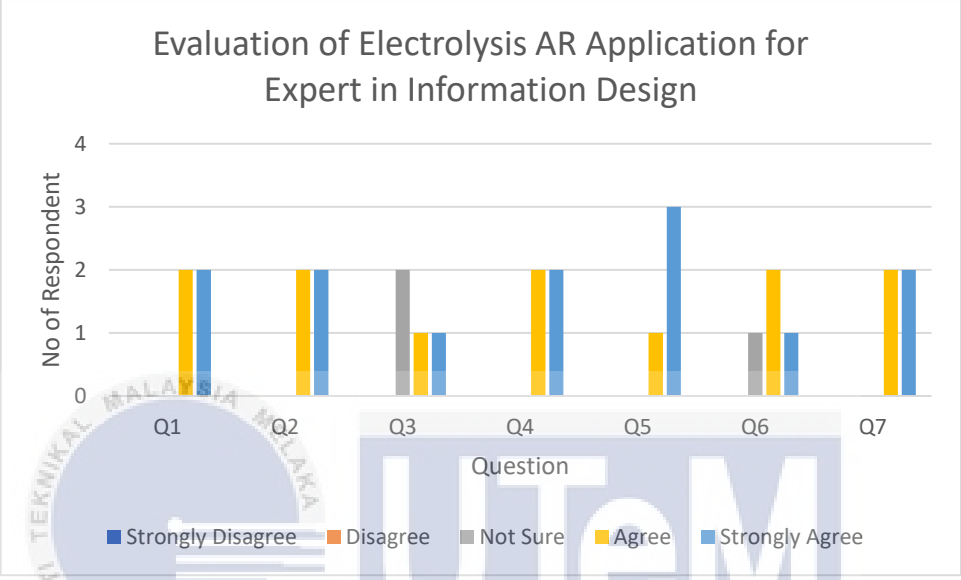


Figure 6.3: Result of Evaluation for Expert in Information Design

Based on Figure 6.3, the result for the evaluation of Electrolysis AR application in information design from the perspective of experts was shown. There are seven questions in this section about information design of the application. The first issue concerns if the content is easy to understand, while the second concerns whether the AR application has a good integration of contents with the curriculum. For these two questions, the number of respondents who agree and strongly agree is the same, with two respondents (50%) agree and the other two (50%) strongly agree. This is because the content of the application is created following the teaching materials and the users can acquire the information through the 3D animation.

The third question concerns whether or not the AR application has a clear classification of specific focuses. Two of the respondents (50%) are not sure whether the application has a clear classification or not. But there were two respondents (25%) who agree and (25%) strongly agree with the statement respectively. This is because the content of the application only recovered the main idea of each subtopic. The AR

application enhances the user's attention or concentration in the lesson is the next question in the questionnaire. Half of the respondents (2 respondents, 50%) agree while another half (2 respondents, 50%) strongly agree with the above statement.

There was a respondent (25%) who agree with the use of interaction and animation enables to visualize the abstract concept of electrolysis. Then another 75% of respondents (3 respondents) strongly agree with that because the simulation by using 3D animation enables users to observe the movement of ions and electrons during electrolysis. The sixth consideration is about the explanation for the electrolysis is clear and detailed or not. Half respondents (2 respondents, 50%) agree that the explanation is clear and detailed. Besides, the statement was strongly agreed by one of the respondents (25%). However, there was a respondent (25%) not sure whether the explanation is clear and detailed or not. Lastly, 50% of respondents (2 respondents) agree and 50% of respondents (2 respondents) strongly agree with the quiz in the AR application can help to reinforce the user's knowledge. As seen in the results above, the majority of respondents are satisfied with the information design of the application.

The mean and standard deviation values for the information design of the application are shown in the following table.

Table 6.4: Mean and SD of Information Design from Expert's Perspective

Information Design			
No.	**Statement**	**Mean**	**Standard Deviation**
1.	The content is easy to understand.	4.50	0.58
2.	The AR application has a good integration of contents with the curriculum.	4.50	0.58
3.	The AR application has a clear classification of specific focuses.	3.75	0.96
4.	The AR application enhances the user's attention or concentration in the lesson.	4.50	0.58
5.	The use of interaction and animation enables to visualize the abstract concept of electrolysis.	4.75	0.50

6.	The explanation for the electrolysis is clear and detailed.	4.00	0.82
7.	The quiz in the AR application helps to reinforce the knowledge.	4.50	0.58

Total respondents: 4

With the exception of statement 3, Table 6.4 obviously demonstrates that the experts were agreed with all of the statements in the information design section because the mean values were 4 and above. The mean value for statement 3 suggests that the experts were not sure whether the application has a clear classification of specific focuses since the mean value does not exceed 4, which has a mean value of 3.75. Nevertheless, the mean value is close to 4, as agreed. 4.75 is the highest mean value in the information design section. This analysis shows that all experts support information design for this application. In addition, two questions have a higher standard deviation than the other questions. This shows that the experts' respond for these two questions is very different. Thus, the Electrolysis AR application can be said as effective in learning chemistry since the abstract concepts of electrolysis were visualized.

Interface design is the last section in the focus for the evaluation of Electrolysis AR application from the perspective of the expert's questionnaire. All the results of the evaluation of Electrolysis AR application in interface design from the perspective of experts will be shown in the following figure.

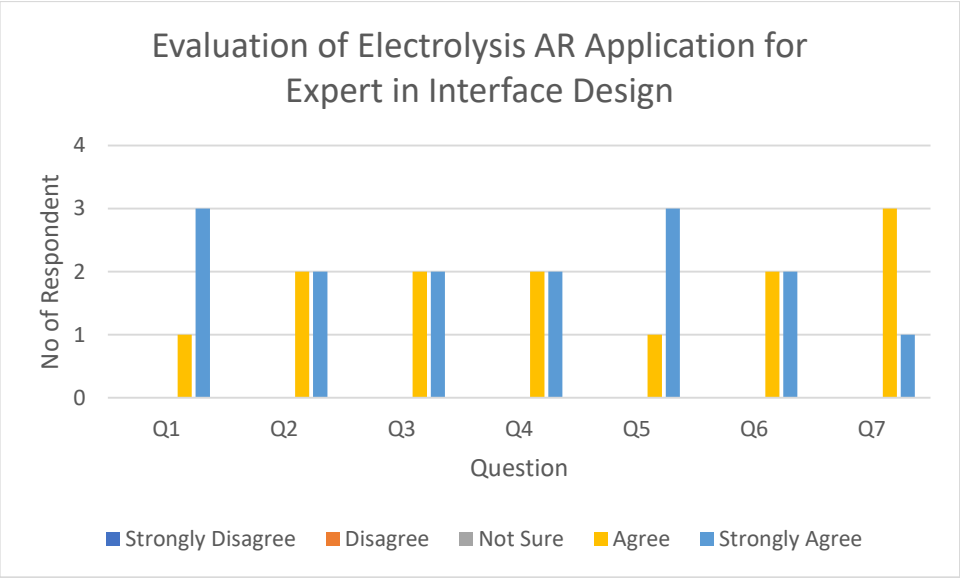


Figure 6.4: Result of Evaluation for Expert in Interface Design

Figure 6.4 depicts a graph of the interface design outcome for evaluating the Electrolysis AR application from the expert's perspective. According to Figure 6.4, this section contains seven questions. One respondent (25%) agree that the booklet and AR marker's interface design is appropriate and appealing, while the other three (75%) strongly agree. This is because the design of the booklet and AR marker is related to the theme of the content and the designs are unique and clear. The follow-up question is whether or not the use of color is appealing. Half of the respondents (2 respondents, 50%) agree, while half (2 respondents, 50%) strongly agree that the color used is appealing since it can draw individuals from a visual standpoint.

The third question is about whether or not the font used is appropriate and recognized. Because different types of the typeface are applied in different situations, half of the respondents (2 respondents, 50%) strongly agree and another half (2 respondents, 50%) agree with the claim. There are two respondents (50%) who agree that the animation of 3D models is clear and interesting, while the other two (50%) strongly agree. For the position of the buttons, there are three respondents (75%) who strongly agree that the position of the buttons is appropriate and recognizable. Out of four respondents, 25% which is one respondent agrees with the claim above.

The next concern is about the arrangement of the content is appropriate and delivers the information effectively or not. Two of the respondents (50%) agree that

the arrangement of the content is appropriate and efficiently conveys information, while two respondents (50%) strongly agree that the arrangement of the content makes it easier for the users to comprehend. The last question for interface design is whether the user interface is attractive and user-friendly. All of the respondents agree with the statement. However, only one of them (25%) strongly agree that the application has an appealing and user-friendly's user interface design. As a result, the majority of respondents are pleased with the outcome of the Electrolysis AR application's interface design.

The mean and standard deviation values for the interface design of the application are shown in the following table.

Table 6.5: Mean and SD of Interface Design from Expert's Perspective

Interface Design			
No.	**Statement**	**Mean**	**Standard Deviation**
1.	The interface design of the booklet and AR marker is suitable and attractive.	4.75	0.50
2.	The use of color is attractive.	4.50	0.58
3.	The font used are suitable and recognizable.	4.50	0.58
4.	The animation of 3D models are clear and interesting.	4.50	0.58
5.	The position of the buttons are appropriate and recognizable.	4.75	0.50
6.	The content arrangement is appropriate and delivers the information effectively.	4.50	0.58
7.	The user interface is attractive and user-friendly.	4.25	0.50

Total respondents: 4

Table 6.5 illustrates that all of the statements have mean values greater than 4. The Electrolysis AR application can be said to have an appropriate and attractive user interface for the booklet and AR marker, as well as the application. This is because statement 1 and statement 5 have the highest mean value, 4.75, which is highly near to 5 (strongly agree). Although statement 7 has the lowest mean value in this section,

which is 4.25, it is still more than 4. The rest of the statements all have the same mean value of 4.50. Since all mean values are higher than 4, then this assumes that the experts agree with the interface design for this application. For standard deviation, the data show that the result is in low variability. In a nutshell, this suggested that all of the claims in the section on interface design were agreed upon by the experts.

Table 6.6: Mean and Standard Deviation for Focus Evaluation of Expert

Section	Mean	Standard Deviation
Interaction Design	4.64	0.49
Information Design	4.36	0.68
Interface Design	4.54	0.51

Total respondents: 4

The data retrieved from Table 6.6 revealed that all sections for the evaluation on the focus of the Electrolysis AR application have mean values greater than 4. The section with the greatest mean value is the interaction design section, which has a mean value of 4.64. Furthermore, the construct of the information design, which has a mean value of 4.36, is the lowest mean value derived from this instrument. The data reveals that the data obtained has a low variability, as measured by the standard deviation. As a result, this shows that experts agree with all the designs for interaction, information and interface, especially for interaction design. Experts are able to interact well with the Electrolysis AR application and are pleased with the interaction design.

6.5.1.3 Usability

The effectiveness and satisfaction are two sections that consist in the usability part of the evaluation of the Electrolysis AR application from the expert's perspective. There were seven questions each for the evaluation of effectiveness and satisfaction from the expert's perspective.

The first section in the usability for the evaluation of Electrolysis AR application for the expert is effectiveness. All the results of the evaluation of Electrolysis AR application in the effectiveness from the perspective of experts will be shown in the following figure.

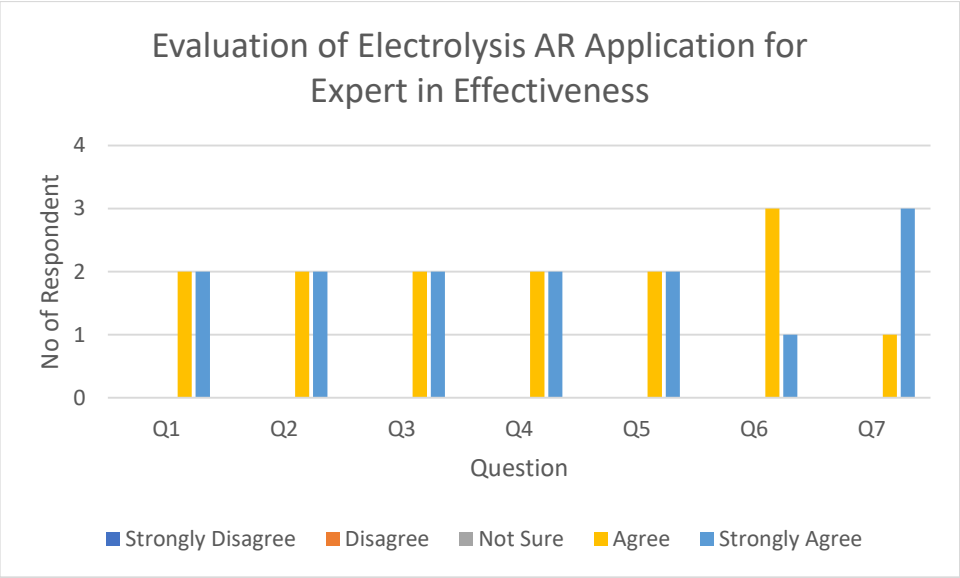


Figure 6.5: Result of Evaluation for Expert in Effectiveness

Figure 6.5 depicts the outcome of the evaluation of Electrolysis AR application from the perspective of the experts in the effectiveness. The effectiveness section consists of seven questions. All the questions will use the 'After using this Electrolysis AR application, I found that…' statement as the opening. This application was easy to use is the first question in this section. 2 respondents (50%) agree that the application was easy to use while the rest (2 respondents, 50%) strongly agree with the statement. The application was function well is the second statement in the effectiveness part. There are two respondents (50%) who agree with the application was work well, and the remaining (2 respondents, 50%) strongly agree with the statement, since the application can be installed and ran properly on their smartphones.

The application was suitable to learn electrolysis as a learning platform is the third question, while the user can interact with the application easily is the fourth question. The following question is about whether the user can understand the abstract concept of electrolysis. These three questions have the same number of respondents in strongly agree and agree, which is half (2 respondents, 50%) for each. The application was appropriate to use as a learning platform because the experts consider that using the AR application to convey information is an effective method. The abstract concept of electrolysis can easily understand because the animation is geared specifically toward the topic of electrolysis.

The application can consolidate the user's memory of electrolysis is the next issue. All the respondents agree (3 respondents, 75%) or strongly agree (1 respondent, 25%) that the content can help users to consolidate their memory of the topic. This is because they believe that the information in the form of animation is more effective than only text. The last question for the effectiveness part is whether the application can motivate users to learn electrolysis. A quarter of the respondent (1 respondent, 25%) agree with this assertion, stating that the application can motivate users to study. The rest of the respondents (3 respondents, 75%) strongly agree that users could be encouraged to learn electrolysis by using this application. Overall, the respondents agree that the Electrolysis AR application is easy to use and effective for learning.

The mean and standard deviation values for the effectiveness of the application are shown in the following table.

Table 6.7: Mean and SD of Effectiveness from Expert's Perspective

Effectiveness			
No.	**Statement**	**Mean**	**Standard Deviation**
After using this Electrolysis AR application, I found that ...			
1.	This application was easy to use.	4.50	0.58
2.	This application was function well.	4.50	0.58
3.	This application was suitable to learn electrolysis as a learning platform.	4.50	0.58
4.	I can interact with this application easily.	4.50	0.58
5.	I understood the abstract concept of electrolysis.	4.50	0.58
6.	This application can consolidate user's memory of electrolysis.	4.25	0.50
7.	This application can motivate users to learn electrolysis.	4.75	0.50

Total respondents: 4

The mean values of all the statements in Table 6.7 are much more than 4. The Electrolysis AR application can be said as an effective learning platform to motivate users to learn electrolysis. This is due to the fact that statement 7 have the greatest

mean value, 4.75, which is quite close to 5 (strongly agree). Despite the fact that statement 6 has the lowest mean value (4.25) in this section, it is still higher than 4. The remaining statements all have a mean value of 4.50. As a result, this indicated that the experts agreed on all of the claims in the section on effectiveness. The mean value greater than 4 indicates that this application is effective from the perspective of the experts. As indicated by the standard deviation, the data obtained exhibits a low level of variability.

Satisfaction is the last section in the questionnaire for the evaluation of Electrolysis AR application from the expert's perspective in satisfaction. All the results of the evaluation of Electrolysis AR application in satisfaction from the perspective of experts will be displayed in the following figure.

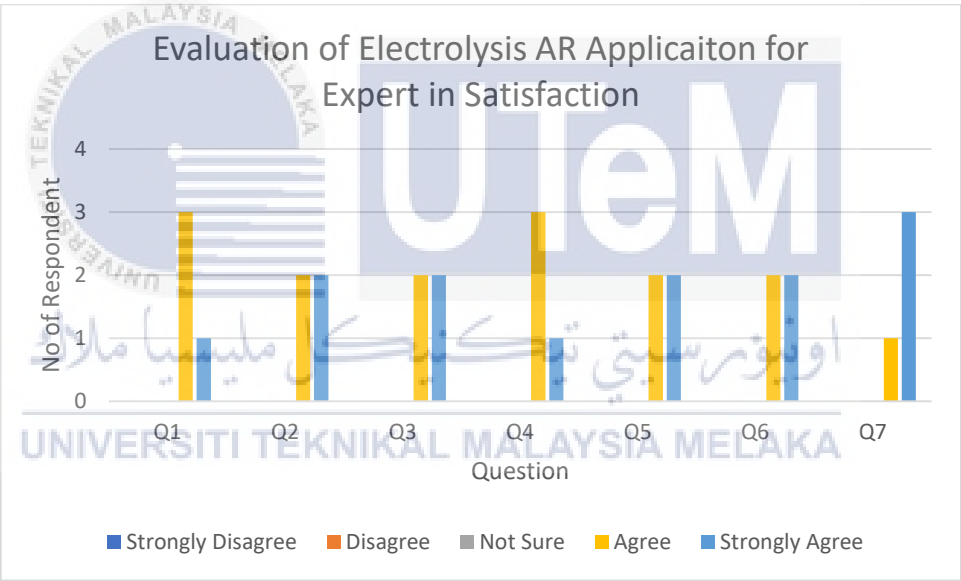


Figure 6.6: Result of Evaluation for Expert in Satisfaction

The result of the evaluation of Electrolysis AR application in satisfaction from the perspective of the expert is displayed in Figure 6.6. The satisfaction of the application section contains seven questions. The starting line for all inquiries will be 'After using this Electrolysis AR application, I …'. The respondents felt excited when using the application is the first statement in the questionnaire. A quarter of the respondents (1 respondent, 25%) strongly agree that they felt excited when using the application. Then, there are another 75% of respondents (3 respondents) who agree.

The next questions are whether the respondents enjoyed exploring the application and the respondents were satisfied with the simulation of electrolysis or not. The quantity of respondents who agree and strongly agree on these two questions is the same, with two respondents (50%) agree and the other two (50%) strongly agree. This is because the simulation of the electrolysis is clear and easy to understand by users. The fourth question is whether the respondents felt immersed in the application. Only one respondent (25%) strongly agree with the statement, while the bulk of respondents (3 respondents, 75%) agree.

The following questions in the survey are whether or not the respondents were satisfied with the user interface design and enjoyed doing the quiz as a revision. The aforementioned statements are agreed upon by half of the respondents (2 respondents, 50%) and strongly agreed upon by the other half (2 respondents, 50%) of the respondents. The respondents would like to use the application for educational purposes is the last question in the satisfaction part of the questionnaire. A quarter of the respondents (1 respondent, 25%) agree that they will use the application for educational purposes. Another 75% (3 respondents) strongly agree. In a nutshell, all the respondents were satisfied with the usability of the AR application.

The mean and standard deviation values for the satisfaction of the application are shown in the following table.

Table 6.8: Mean and SD of Satisfaction from Expert's Perspective

Satisfaction			
No.	**Statement**	**Mean**	**Standard Deviation**
After using this Electrolysis AR application, I ...			
1.	Felt excited when using this application.	4.25	0.50
2.	Enjoyed exploring this application.	4.50	0.58
3.	Satisfied with the simulation of electrolysis.	4.50	0.58
4.	Felt immersed in this application.	4.25	0.50
5.	Satisfied with the user interface design.	4.50	0.58
6.	Enjoyed doing the quiz as a revision.	4.50	0.58

7.	Would like to use this application for educational purpose.	4.75	0.50

Total respondents: 4

All of the statements in Table 6.8 have mean values that are substantially higher than 4. The Electrolysis AR application can be considered as satisfied by all the experts because statement 7 has the highest mean value, 4.75, which is almost identical to 5 (strongly agree). This suggests that the application can be used for educational purposes. Despite having the lowest mean value (4.25) in this section, statement 1 and statement 4 are nevertheless greater than 4. The mean value of the remaining statements is 4.50. Based on the analysis, we can say that the experts are satisfied with this application because the mean value is high. The data obtained has a low amount of variability, as demonstrated by the standard deviation. Consequently, all of the statements in the section on satisfaction were agreed upon by the experts.

Table 6.9: Mean and Standard Deviation for Usability Evaluation of Expert

Section	Mean	Standard Deviation
Effectiveness	4.50	0.51
Satisfaction	4.46	0.51

Total respondents: 4

All of the sections for the evaluation on the usability of the Electrolysis AR application have mean values greater than 4, according to Table 6.9. The mean value for the effectiveness section (4.50) is higher than the satisfaction section (4.45). However, these two mean values are about the same. Therefore, this suggests that experts agree with the Electrolysis AR application is an effective software for learning purposes and are satisfied with the application. Overall, this application has a high rating in the effectiveness and satisfaction of the expert, with a low variability for the standard deviation.

Aside from the quantitative information gathered from the instruments, qualitative information was gathered from experts. The experts' qualitative feedback was acquired by including open-ended questions in the evaluation of Electrolysis AR application from the expert's perspective questionnaire. The table below displays the

experts' overall opinions on the Electrolysis AR application. All of the experts' feedbacks have indicated that they are more positive with this prototype. There were also some suggestions given by the experts for future improvement. The expert's feedbacks have been gathered and are listed below.

Table 6.10: Comments and Feedbacks from Expert

Expert	Comment and Feedback
1	"*Soalan perlu mempunyai tahap kesukaran yang berbeza dan merangkumi soalan KBAT*."
2	"The overall design is great. But I suggest to add more language like Malay and Chinese, so student can choose their preferred language and can learn more effective."
3	"All is good. Improvement can be made on the explanation part however, because the explanation content seemed to be repeated."
4	"Quiz can be improved to more interactive."

6.5.2 Evaluation of Electrolysis AR Application from User's Perspective

The outcome of the analysis for evaluation of the Electrolysis AR application from the user's perspective is obtained through the use of a questionnaire as a tool. The evaluation of Electrolysis AR application questionnaire was created in order to collect user's feedback on the effectiveness of the Electrolysis AR application. The survey was conducted over the phone, computer or in person. It was distributed to 18 respondents through online communication platforms such as WhatsApp, Messenger and Telegram.

The questionnaire is separated into three parts. The first part collects demographic information from respondents. The focus for the effectiveness of the Electrolysis AR application is the second part, and it is divided into three sections, each representing interaction design, information design and interface design. The last part is the usability of the Electrolysis AR application, which consist of the effectiveness and satisfaction sections. After all the data are collected, these data will be analyzed with mean and standard deviation calculations.

6.5.2.1 Demographic Information

According to the evaluation of the Electrolysis AR application from the user's perspective questionnaire, the questionnaire consists of five items relating to demographic data to gather information about the respondent's background and opinions. This demographic information will also be utilized in the pre-post testing. The following table displays the demographic information of respondents who participate in the survey.

Table 6.11: Demographic Information about User's Background

Demographic Characteristics	Variables	Frequency	Percentage
Gender	Male	8	44.4%
	Female	10	55.6%
Race	Malay	6	33.3%
	Chinese	10	55.6%
	Indian	2	11.1%

Total respondents: 18

The population of respondents who responded to the questionnaire is 18. According to the statistics in the Table 6.11, there were 8 male and 10 female respondents. There were 10 Chinese and 6 Malay among the 18 respondents, with only 2 Indians.

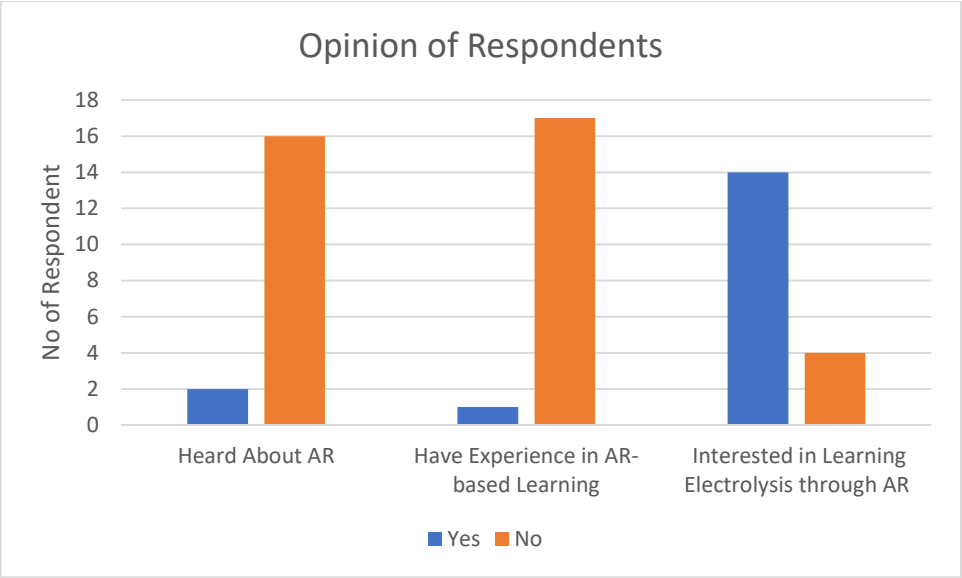


Figure 6.7: Demographic Information about User's Opinion

Based on Figure 6.7, the majority of the respondents (88.9%), 16 in total, who never heard about augmented reality technology. The remaining respondents (11.1%) have heard about augmented reality. Meanwhile, almost all the respondents (17 respondents, 94.4%) have no experience in AR-based learning, while just one respondent (5.6%) have experience in AR-based learning. The last question inquires about the respondent's perceptions of interest in learning electrolysis through AR application. There were 14 respondents (77.8%) interested in learning electrolysis through AR and only 4 respondents (22.2%) who do not interest in learning electrolysis through AR.

6.5.2.2 Focus

The interaction design, information design and interface design are three sections that consist in the focus of the evaluation of Electrolysis AR application from the user's perspective. There were seven questions each for the evaluation of interaction design, information design and interface design for the user's perspective.

Interaction design is the first section in the focus for the evaluation of Electrolysis AR application from the perspective of the user's questionnaire. All the results of the evaluation of Electrolysis AR application in interaction design from the perspective of experts will be shown in the following figure.

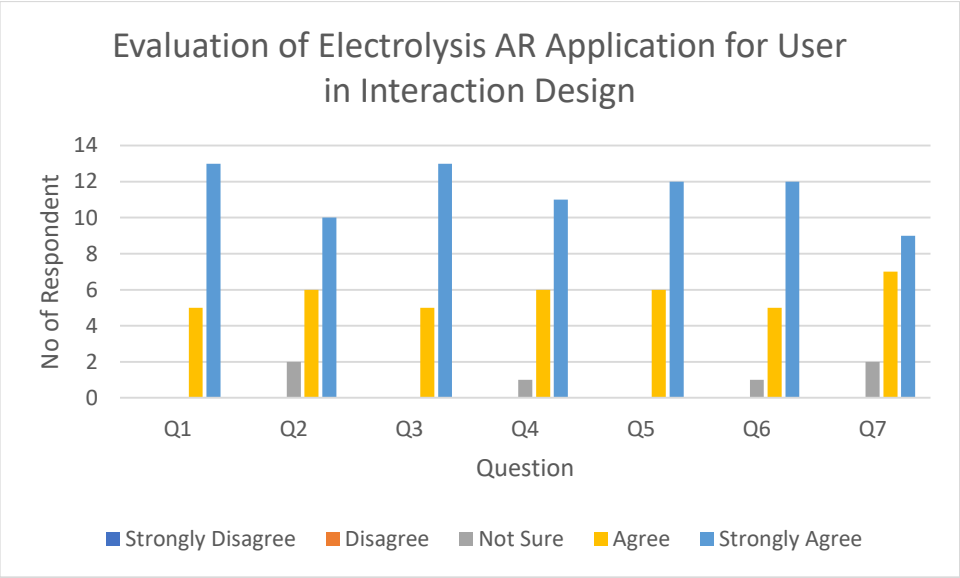


Figure 6.8: Result of Evaluation for User in Interaction Design

Figure 6.8 shows a graph of the result of interaction design for evaluation of Electrolysis AR application from the perspective of the users. This interaction design section contains 7 questions. The first statement is whether or not the AR marker can detect by the camera of the device easily. The quantity of respondents who strongly agree that the markers can be detected easily by the camera (13 respondents, 72.2%) is higher than the number of respondents who agree (5 respondents, 27.8%). This is because users simply scan the marker with their camera in a short amount of time.

The 3D model's size is appropriate for viewing on the device's screen is the second question in the questionnaire of interaction design from the perspective of the users. There are 2 respondents (11.1%) who are not sure with the statement that the size of the 3D model is appropriate for viewing on the device's screen, another 6 (33.3%) who agree, and the other 10 who strongly agree. For the design of the pause and resume buttons provided in the video, the majority, which is 13 respondents (72.2%) strongly agree that the buttons are convenient for them. The remaining 5 respondents (27.8%) agree.

The following question is about the loop of the simulations to play continuously is more efficient. A respondent (5.6%) is not sure whether the loop for the simulation is efficient or not. The rest respondents agree (6 respondents, 33.3%) or strongly agree (11 respondents, 61.1%) that the continuous loop of the simulation is

more efficient for them. This is because users are able to watch the simulation without having to press any buttons. Users can easily view the explanation by clicking the button provided is the fifth question in the questionnaire of interaction design. Because the buttons provided allow users to control freely when using the application, the majority of respondents (12 respondents, 66.7%) strongly agree, while only 6 respondents (33.3%) agree.

The incorporation of multimedia elements is the next point to consider because it can help users receive information more effectively. 27.8% of respondents or 5 respondents agree that information may be conveyed successfully with the use of multimedia elements, while 66.7% of respondents, or 12 respondents, strongly agree. However, there is a respondent not sure whether the integration of multimedia elements is effective or not. Half of the respondents (9 respondents, 50%) strongly agree that the AR application promotes enjoyment for them in learning, while 7 respondents (38.9%) agree. This is because the multimedia elements used in this application include audio, video, and animation in addition to text and image. Nevertheless, there are 2 respondents who are not sure about it. The application's interaction design is appropriate and convenient for users, according to the test results.

The following table displays the mean and standard deviation figures for the interaction design.

Table 6.12: Mean and SD of Interaction Design from User's Perspective

Interaction Design			
No.	**Statement**	**Mean**	**Standard Deviation**
1.	The AR marker can easily detect by the camera of the device.	4.72	0.46
2.	The size of the 3D model is suitable for viewing on the screen of the device.	4.44	0.71
3.	It is convenient to use buttons to pause and resume the video.	4.72	0.46
4.	The loop of the simulations to play continuously is efficient.	4.56	0.62

5.	Users can easily view the explanation by clicking the button provided.	4.67	0.49
6.	The integration of multimedia elements help receive information more effectively.	4.61	0.61
7.	The AR application promote enjoyment for users in learning process.	4.39	0.70

Total respondents: 18

According to Table 6.12, all of the statements in this interaction design have a mean value of 4.0 or higher. It can be stated that the majority of users agree with all of the statements in the interaction design section. Statement 1 and statement 3 have the greatest mean value, which is 4.36. The users, on the other hand, are agreed on the remaining items. The mean value for interaction design indicates that all users agree that interaction design for this application is good. For the standard deviation, there are 4 questions that have higher variability if compared to the others. Therefore, the Electrolysis AR application can be said as an application that is convenient and easy to use for users, where users can interact with the application easily.

After the interaction design section, the second section in the focus for the evaluation of Electrolysis AR application from the perspective of the user's questionnaire is the information design. All the results of the evaluation of Electrolysis AR application in information design from the perspective of users will be shown in the following figure.

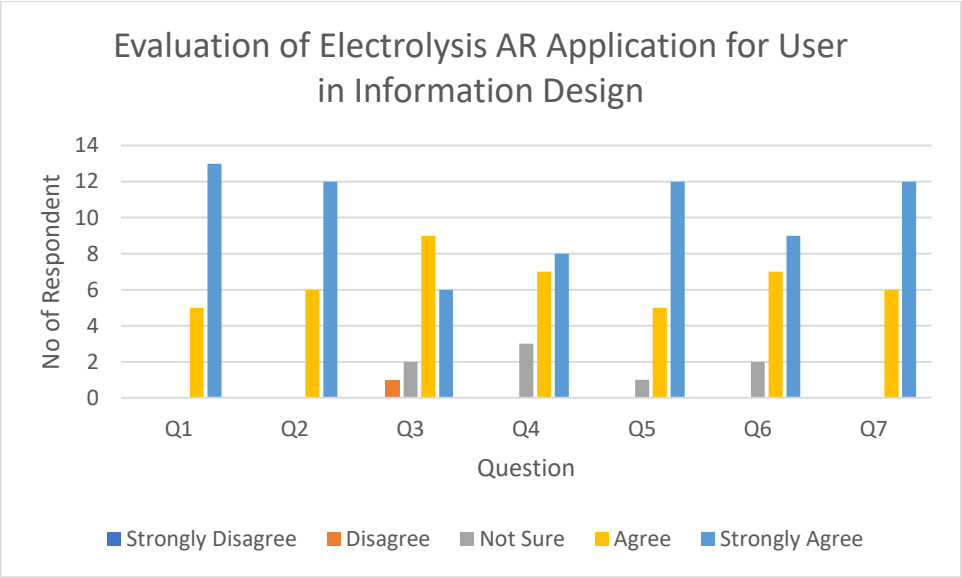


Figure 6.9: Result of Evaluation for User in Information Design

The result of the evaluation of Electrolysis AR application in information design from the perspective of users is displayed in Figure 6.9. This section of the application's information design contains 7 questions. The first question is about the content is easy to understand. 72.2% (13 respondents) strongly agree with the content can understand easily, whereas 27.8% (5 respondents) agree. Meanwhile, almost half of the respondents (12 respondents, 66.7%) strongly agree that the content in the application is suitable for learning electrolysis, while the remaining 6 (33.3%) agree. This is due to the fact that the application's content is based on educational materials, and users can obtain information through 3D animation.

Furthermore, half of the respondents (9 respondents, 50%) agree with the content can help to clarify user's misunderstanding of the abstract concept, while 33.3%, which is 6 respondents strongly agree. Nevertheless, out of 18, there are 2 respondents (11.1%) who are not sure and a respondent (5.6%) disagree with the statement. The fourth question is whether the electrolysis explanation is clear and precise. The explanation is clear and precise, according to 7 respondents (38.9%). 8 of the respondents (44.4%) strongly agree with the statement. However, there is 16.7%, or 3 respondents are undecided about whether the explanation is clear and detailed.

Besides, almost a quarter of the respondents (5 respondents, 27.8%) agree that using interaction and animation to visualize the abstract notion of electrolysis is

beneficial. Another 66.7% (12 respondents) strongly agree since the simulation allows users to witness the movement of ions and electrons during electrolysis via 3D animation. Nevertheless, there is a respondent (5.6%) who is not sure about it. The next question is whether the quiz in the application is effective to reinforce the acquired knowledge. 2 out of 18 respondents (11.1%) are unsure whether the quiz is effective or not. However, half of the respondents (9 respondents, 50%) strongly agree and the remaining 38.9% (7 respondents) agree with the statement.

The simulation of the electrolysis is clear and easy to understand is the last question in the questionnaire of information design. One-third of respondents (6 respondents, 33.3%) agree with the electrolysis simulation is clear and understandable, whereas two-thirds of respondents (12 respondents, 66.7%) strongly agree. As can be observed from the findings, the majority of respondents are pleased with the application's information design.

The mean and standard deviation values for the information design are shown in the following table.

Table 6.13: Mean and SD of Information Design from User's Perspective

Information Design			
No.	**Statement**	**Mean**	**Standard Deviation**
1.	The content is easy to understand.	4.72	0.46
2.	The content is suitable for learning electrolysis.	4.67	0.49
3.	The content helps to clarify user's misunderstanding of the abstract concept.	4.11	0.83
4.	The explanation for the electrolysis is clear and detailed.	4.28	0.75
5.	The use of interaction and animation enables to visualize the abstract concept of electrolysis.	4.61	0.61
6.	Quizzes in AR application is effective to reinforce the acquired knowledge.	4.39	0.70
7.	The simulation of the electrolysis is clear and easy to understand.	4.67	0.49

Total respondents: 18

Table 6.13 reveals that all statements in the information design section have a mean value greater than 4. The mean value indicates that all of the statements for this section are agreed upon by all of the users. The first statement has the highest mean value (4.72). Therefore, the Electrolysis AR application can be said as having understandable content and allow users to learn easily. Despite having the lowest mean value in this section (4.11), the mean value for statement 3 is still greater than 4. All of the remaining statements also have a mean value between 4 and 5. This analysis shows that the majority of users agree with the information design for this application. However, 4 questions have a higher standard deviation than the other questions. This indicates that the user's response to these questions is very different.

Interface design is the last section in the focus for the evaluation of Electrolysis AR application from the perspective of the user's questionnaire. All the results of the evaluation of Electrolysis AR application in interface design from the perspective of users will be shown in the following figure.

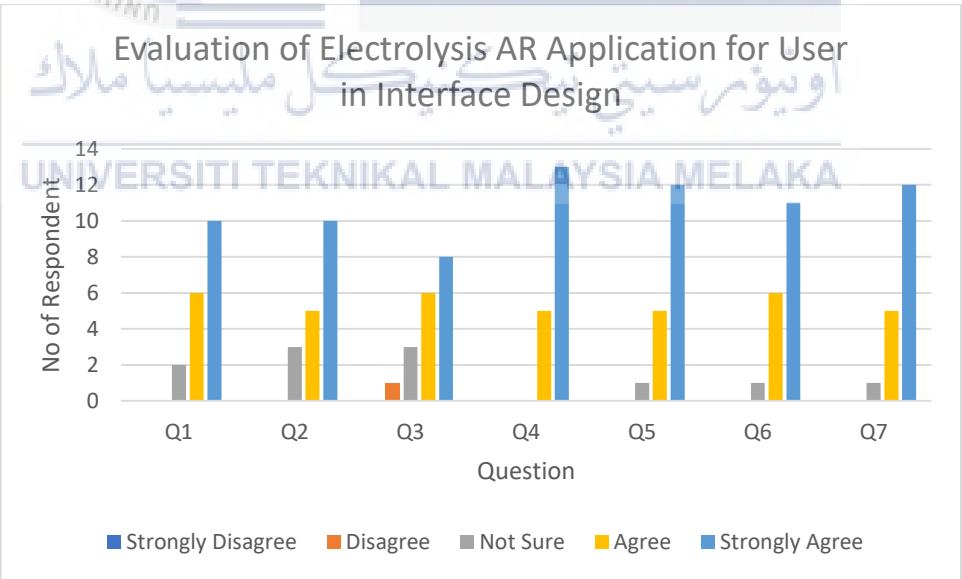


Figure 6.10: Result of Evaluation for User in Interface Design

Figure 6.10 is a graph for the evaluation of the Electrolysis AR application's interface design results from the user's perspective. This part has 7 questions, as seen in Figure 6.10. For the interface design of the booklet and AR marker, 2 respondents

(11.1%) are not sure whether the design is attractive or not. One-third of respondents (6 respondents, 33.3%) agree that the interface design of the booklet and AR marker is acceptable and appealing, while the other 10 (55.6%) strongly agree. The use of color that is pleasing to the eye is the next question. The color used is appealing since it can draw folks from a visual aspect, according to 27.8% (5 respondents) agree and 55.6% (10 respondents) strongly agree. The remaining 16.7% (3 respondents) are not sure.

For the font used in the application, there are 3 respondents (16.7%) who are not sure whether the font is suitable and recognizable or not. 44.4% (8 respondents) strongly agree while one-third of respondents (6 respondents, 33.3%) are agree with the statement. However, there is a respondent (5.6%) who think that the font is not suitable. Out of 18, 13 respondents (72.2%) strongly agree that the animation of 3D models is clear and interesting, and 5 respondents (27.8%) agree. For the button's design, two-third of respondents (12 respondents, 66.7%) strongly agree with the design of the buttons are appropriate and recognizable, 5 respondents (27.8%) agree and 1 respondent (5.6%) is not sure.

Question 6 is the arrangement of the content is appropriate and delivering more effectively. A respondent (5.6%) is not sure about it. Almost half of the respondents with a percentage of 61.1% (11 respondents) strongly agree and one-third of respondents (33.3%) agree that the content structure is suitable and is being delivered more effectively. For the last question, which is the navigation design is clear and easy to understand, the results gained from the survey is the same as question 5's result. The navigation is very clear and understandable, according to two-thirds of respondents (12 respondents, 66.7%). 5 respondents (27.8%) agree, while one respondent (5.6%) is unsure. As an outcome, the Electrolysis AR application's interface design has received positive feedback from the majority of responders.

The following table shows the mean and standard deviation figures for the application's interface design.

Table 6.14: Mean and SD of Interface Design from User's Perspective

Interface Design			
No.	**Statement**	**Mean**	**Standard Deviation**
1.	The interface design of the booklet and AR marker is attractive.	4.44	0.70
2.	The use of color is attractive.	4.39	0.78
3.	The font used are suitable and recognizable.	4.17	0.92
4.	The animation of 3D models are clear and interesting.	4.72	0.46
5.	The design of the buttons are appropriate and recognizable.	4.61	0.61
6.	The arrangement of the content is appropriate and being deliver more effectively.	4.56	0.62
7.	The navigation design is clear and easy to understand.	4.61	0.61

Total respondents: 18

The mean value for all statements was in the range of 4 and beyond, which was agreed upon, as shown in Table 6.14. From the perspective of users, the Electrolysis AR application can be said to be an interesting learning application with the integration of 3D animation and learning materials. This is due to the fact that statement 4 is found to have the highest mean value of 4.72. Despite the fact that statement 3 has the lowest mean value in this section (4.17), it is still higher than 4. The remaining statements all have a mean value among 4 to 5. Since all mean values are higher than 4, then we can assume that the users agree with the interface design for this application. The majority of questions for interface design have a standard deviation of more than 0.6. Only one question has lower variability. In a summary, this meant that the users agreed on all of the claims in the section on interface design.

Table 6.15: Mean and Standard Deviation for Focus Evaluation of User

Section	Mean	Standard Deviation
Interaction Design	4.59	0.58
Information Design	4.49	0.65
Interface Design	4.50	0.69

Total respondents: 18

According to Table 6.15, the majority of users agree that the Electrolysis AR application has the features that are needed for a learning application, with all sections achieving above 4 on the mean value. The interaction design section received the greatest mean value of 4.59, while the information design section received the lowest mean value of 4.49. As a consequence, this suggests that users agree with all of the interaction, information, and interface designs, particularly the interaction design. The Electrolysis AR application is well-received by users, who like the interaction design. As measured by the standard deviation, the data obtained exhibits a low variability.

6.5.2.3 Usability

The effectiveness and satisfaction are two sections that consist in the usability part of the evaluation of Electrolysis AR application from the user's perspective. There were seven questions each for the evaluation of effectiveness and satisfaction for the user's perspective.

The first section in the usability for the evaluation of Electrolysis AR application for the user is effectiveness. All the results of the evaluation of Electrolysis AR application in the effectiveness from the perspective of users will be shown in the following figure.

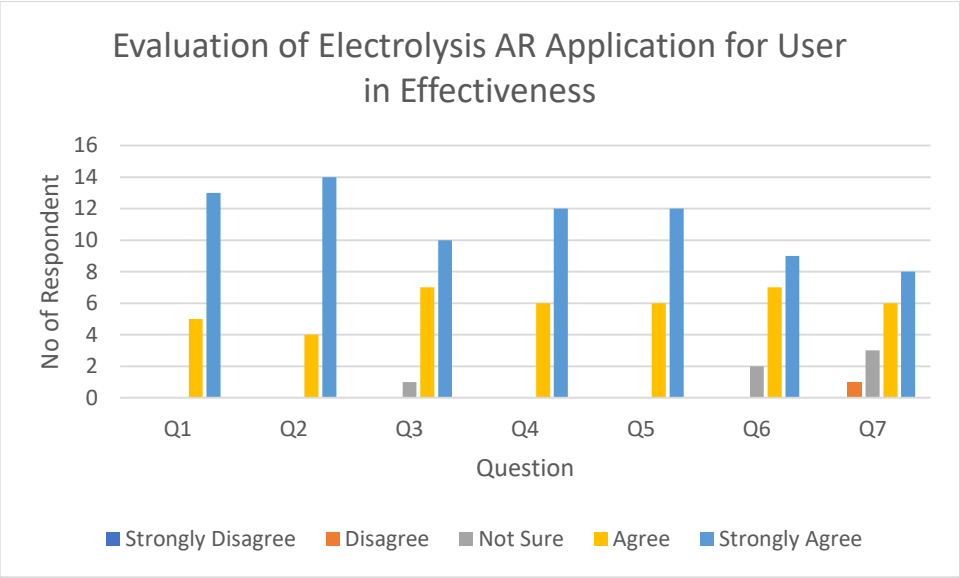


Figure 6.11: Result of Evaluation for User in Effectiveness

The outcome of the Electrolysis AR application evaluation from the standpoint of users in the effectiveness is depicted in Figure 6.11. There are 7 questions in the effectiveness section. The starting line for all inquiries will be 'After using this Electrolysis AR application, I found that …'. The first question in this section is whether this application is easy to use while the application has functioned well is the second question. Almost all the respondents strongly agree with these two statements, which is 13 respondents (72.2%) for the first question and 14 respondents (77.8%) for the second question. The number of respondents who agree with these two statements are 5 respondents (27.8%) for the first and 4 respondents (22.2%) for the second respectively.

For the third question, there is a respondent (5.6%) who is unsure that whether the application is suitable to use as a learning platform or not. However, almost half of the respondents (10 respondents, 55.6%) strongly agree and the remaining 7 respondents (38.9%) agree that the application is suitable for learning electrolysis. Question 4 is the users can interact with the application easily and question 5 is the users can understand the abstract concept of electrolysis. These two questions have the same results, which are one-third of respondents with a percentage of 33.3% (6 respondents) agree with the statements, and two-third with a percentage of 66.7% (12 respondents) strongly agree.

The application's ability to consolidate the user's electrolysis memory is the following question in the questionnaire. The content can assist users to consolidate their memory of the topic, according to 7 respondents (38.9%) agree and 9 respondents (50%) strongly agree. This is because they feel that information conveyed through animation is more effective than information conveyed through text alone. However, 2 out of 18 respondents with a percentage of 11.1% unsure about it. For the last question, almost half of respondents (8 respondents, 44.4%) strongly agree, one-third of respondents (6 respondents, 33.3%) agree and 3 respondents (16.7%) are unsure about whether the application can motivate the user to learn electrolysis. Out of 18, one of the respondents (5.6%) disagree with the statement. Generally, the Electrolysis AR application is straightforward to use and beneficial for learning, according to the respondents.

The mean and standard deviation values for the effectiveness of the application are shown in the following table.

Table 6.16: Mean and SD of Effectiveness from User's Perspective

Effectiveness			
No.	**Statement**	**Mean**	**Standard Deviation**
After using this Electrolysis AR application, I found that ...			
1.	This application was easy to use.	4.72	0.46
2.	This application was function well.	4.78	0.43
3.	This application was suitable to learn electrolysis as a learning platform.	4.50	0.62
4.	I can interact with this application easily.	4.67	0.49
5.	I understood the abstract concept of electrolysis.	4.67	0.49
6.	My memory of electrolysis is consolidated.	4.39	0.70
7.	I have the motivation to learn electrolysis.	4.17	0.92

Total respondents: 18

According to the analysis in Table 6.16, the mean value for all statements was higher than 4, which was agreed upon. The Electrolysis AR application can be said as a well-function application since the mean value of statement 2 is the greatest, at 4.78.

Statement 7 is also greater than 4 despite having the lowest mean value (4.17) in this section. The remaining statements all have a mean value of 4 to 5. The mean value greater than 4 indicates that the user agrees that this application is effective. 3 questions have a higher standard deviation than the rest of the questions. This demonstrates that each user's response to these questions is quite unique. Consequently, this suggests that the functionality and learnability of the Electrolysis AR application are effective.

Satisfaction is the last section in the questionnaire for the evaluation of Electrolysis AR application from the user's perspective in satisfaction. All the results of the evaluation of Electrolysis AR application in satisfaction from the perspective of users will be displayed in the following figure.

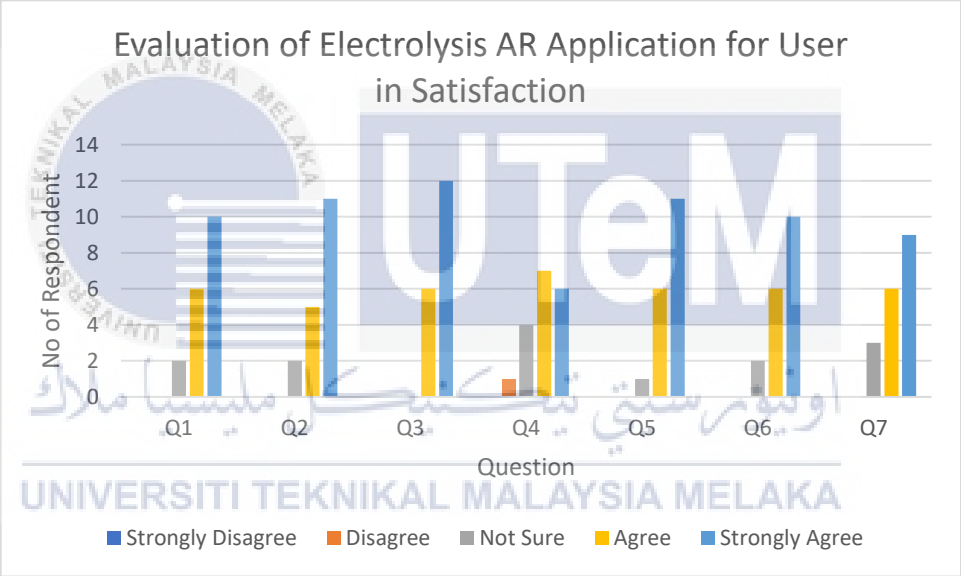


Figure 6.12: Result of Evaluation for User in Satisfaction

Figure 6.12 represents the outcome of the user's evaluation of the Electrolysis AR application in terms of satisfaction. There are 7 questions in the application satisfaction section. All the statements in the questionnaire will begin with the phrase 'After using this Electrolysis application, I…'. The first question in this part is whether the users felt excited when using the application, while the second question is whether the users enjoyed exploring the application. On these two questions, the number of respondents who are unsure about the statements is the same, with 2 respondents (11.1%) for each. Almost half of the respondents strongly agree with these two assertions, with 10 respondents (55.6%) strongly agree with the first and 11

respondents (61.1%) strongly agree with the second. There are 6 respondents (33.3%) who agree with the first statement and 5 respondents (27.8%) who agree with the second statement.

For the satisfaction of the simulation for electrolysis, one-third of respondents (6 respondents, 33.3%) agree that they are satisfied with the simulation, while two-thirds of respondents (12 respondents, 66.7%) strongly agree. The fourth question is whether the users felt completely engrossed in the application. Although only one respondent (5.6%) disagree with that and 4 out of 18 respondents (22.2%) are not sure, the majority of respondents do with 7 agree (38.9%) and 6 strongly agree (33.3%). On the other hand, more than half of respondents (11 respondents, 61.1%) strongly agree that they are satisfied with the user interface design of the application and one-third (6 respondents, 33.3%) agree, even though one of the respondents is unsure.

The users enjoyed doing the quiz as a revision is the following question asked in the survey. The above claim is agreed upon by one-third, which is 6 respondents (33.3%) and strongly agreed upon by almost half, which is 10 respondents (55.6%). However, the remaining 11.1% or 2 respondents are unsure of the claim. The last question asks about whether the users will use the application frequently. Out of 18 respondents, half (9 respondents, 50%) strongly agree, one-third (6 respondents, 33.3%) agree and one-sixth (3 respondents, 16.7%) are not sure with the last question. In short, all of the respondents were satisfied with the Electrolysis AR application's usability and functionality.

The mean and standard deviation values for the satisfaction are presented in the following table.

Table 6.17: Mean and SD of Satisfaction from User's Perspective

Satisfaction			
No.	**Statement**	**Mean**	**Standard Deviation**
After using this Electrolysis AR application, I ...			
1.	Felt excited when using this application.	4.44	0.70
2.	Enjoyed exploring this application.	4.50	0.71

3.	Satisfied with the simulation of electrolysis.	4.67	0.49
4.	Felt immersed in this application.	4.00	0.91
5.	Satisfied with the user interface design.	4.56	0.62
6.	Enjoyed doing the quiz as a revision.	4.44	0.70
7.	Would like to use this application frequently.	4.33	0.77

Total respondents: 18

Based on Table 6.17, there are a total of seven statements, and the mean value for each of the statements is equal or more than 4. This suggests that the users were satisfied and agreed with the usability of the Electrolysis AR application. The mean value of 4 in statement 4 indicates that the users are relatively agreed. This implies that due to certain shortcomings, the users may not feel immersed in the application. However, the mean value, on the other hand, is not far off from the 4 mean value. Based on the analysis, we can say that the user is quite satisfied with this application because all mean values are higher or equal to 4, which is agree. The Electrolysis AR application can be said as an application that is effective in delivering abstract concepts as a learning platform through 3D simulation. This is because statement 3 has the highest mean value, 4.67, which is quite near to 5 (strongly agree). The bulk of questions, however, have a standard deviation greater than 0.6. This demonstrates the wide range of opinions held by users.

Table 6.18: Mean and Standard Deviation for Usability of User

Section	Mean	Standard Deviation
Effectiveness	4.56	0.63
Satisfaction	4.42	0.72

Total respondents: 18

All of the sections for evaluating the usability of the Electrolysis AR application have mean values greater than 4, according to Table 6.18. The effectiveness section's mean value (4.56) is higher than the satisfaction section's (4.42). Nevertheless, these two mean values are nearly identical. Overall, this application gets a high grade for user effectiveness and satisfaction, with a low

standard deviation variability. Users appear to believe that the Electrolysis AR application can be considered effective and satisfied.

Aside from the quantitative data received from the questionnaire, the qualitative data is acquired from 18 respondents by interviewing the same respondents. The qualitative feedback was obtained by providing open-ended questions in the Electrolysis AR application evaluation questionnaire from the user's perspective. The majority of the respondents have responded positively. They did, however, propose a recommendation for improving the application. The three of the users' comment and feedback are represented in Table 6.19.

Table 6.19: Comments and Feedbacks from User

User	Comment and Feedback
1	"*Lebih baik jika application ini adalah dalam bahasa Melayu*."
2	"Can add electrochemistry topic in this app."
3	"The content is useful for revision."

6.5.3 Effectiveness of Electrolysis AR Application Content

The evaluation of the Electrolysis AR application's effectiveness was carried out by gathering data from the pre-post testing. The pre-test and post-test were given to 18 users from the same group with the evaluation of Electrolysis AR application from the user's perspective. The comparison of the tests performed was used to statistically analyze the data using SPSS. The independent samples t-test was applied for this evaluation as the hypothesis testing method. This testing can be described as two experimental conditions, with the same respondents participating in each. Two different questionnaires were used to do the pre-post testing. Each of the pre-test and post-test consist of 10 questions. The two tests were given to the same group of respondents at two distinct times. The number of correct answers gained by each of the respondent for the pre-test and post-test is represented in the following figure.

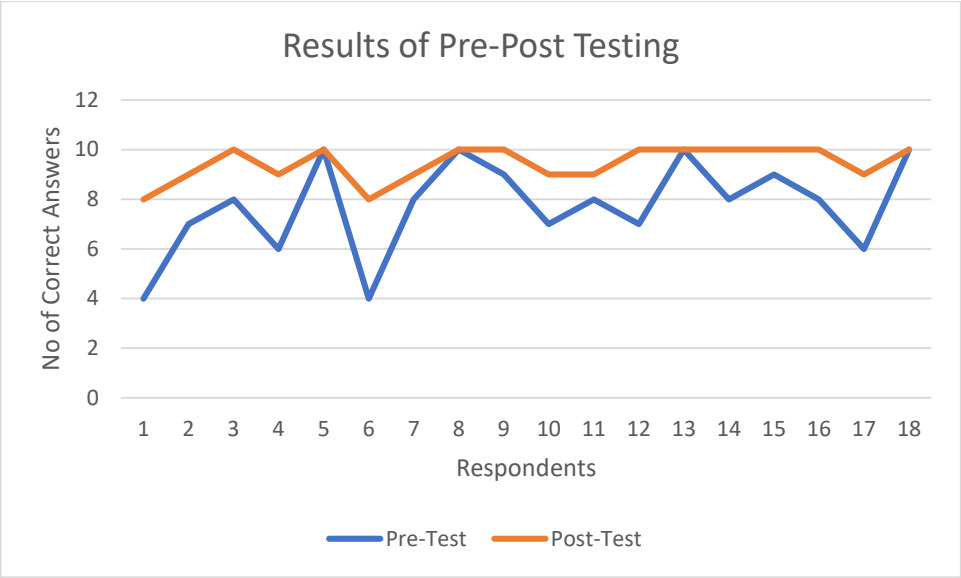


Figure 6.13: Analysis of Pre-Post Testing

The number of correct answers that respondents get for the pre-test and post-test is shown in Figure 6.13. As shown in this graph, there are many users who have higher post-test results than pre-test results while four people have the same result. The data represents that a few respondents answer all questions correctly on each of the pre-test and the post-test. However, the lowest number of correct answers for the pre-test is 4 while the lowest number of correct answers for the post-test is 8. By comparing the lowest number of correct answers earned by the respondents for the pre-test and the post-test, the data acquired from the post-test demonstrates that the Electrolysis AR application is capable of improving user's results.

6.6 Analysis Testing

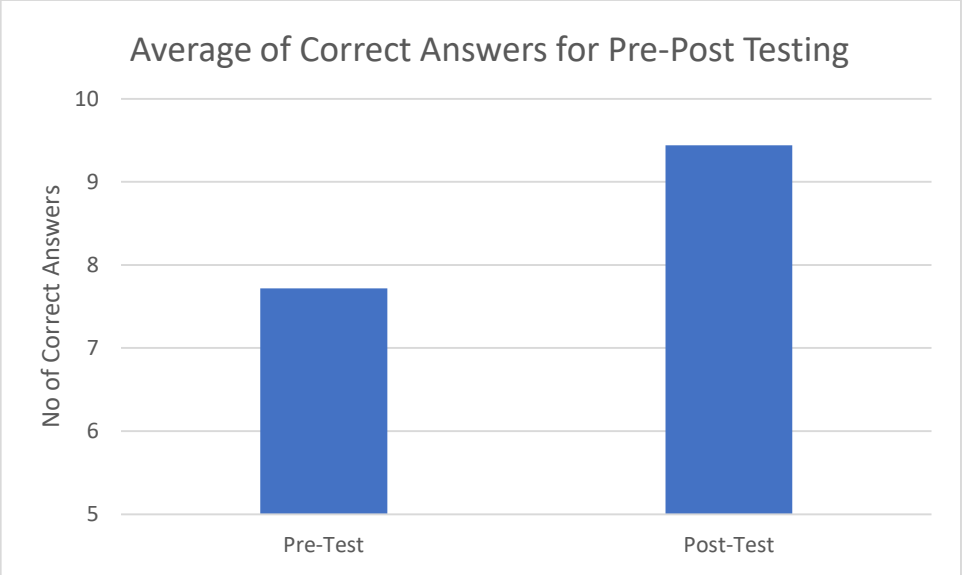


Figure 6.14: Result of Average of Correct Answers for Pre-Post Testing

Table 6.20: Average of Correct Answers for Pre-Post Testing

Test Type	Total Respondent	Average Correct Answers
Pre-Test	18	7.72
Post-Test	18	9.44

The purpose of the comparative test is to examine the effectiveness of the Electrolysis AR application as a learning platform. In the Table 6.19, the test results are gathered and analyzed. Two distinct tests were used to do the pre-post testing. The average of the correct answers for the pre-test and post-test are shown in the Figure 6.14. The average pre-test correct answer is 7.72 whereas the average post-test correct answer is 9.44. The results reveal that the average correct answer of the post-test is higher than the average correct answer of the pre-test. The findings demonstrate that the AR application is able to enhance user's results in chemistry.

Furthermore, an independent t-test analysis was performed on both the pre-test and the post-test to see if there was a significant difference between the two tests. This

is to determine that this application is effective enough to increase the knowledge of users. The analysis of the independent t-test used to determine the effectiveness of the Electrolysis AR application was produced and evaluated with users will be shown in the following table.

Table 6.21: Analysis of Independent t-Test

Test	Mean	SD	*t*-value	*p*-value
Pre-Test	7.72	1.873	9.113	0.005
Post-Test	9.44	0.705		

Total respondents: 18, Note: $p < 0.05$*

The table above showed the results of the independent t-tests conducted to find if differences in scores between pre-test and post-test are significant. This is to determine that this application is effective enough to increase the knowledge of users. As shown in Table 6.22, the results from the independent t-tests showed a significant difference in the score between pre-test and post-test (p=0.005).

The results of the analysis revealed that the mean for the total correct answer of the post-test is higher than the mean for the total correct answer of the pre-test, with the pre-test of 7.72 and the post-test of 9.44. The mean values suggested that the respondents in the post-test (M=9.44, SD=0.705) had a better performance than the pre-test (M=7.72, SD=1.873). The result suggests that the Electrolysis AR application is able to increase the user's knowledge in Chemistry. Furthermore, the standard deviation in the post-test is higher than the standard deviation for the pre-test. This is because the users have achieved better results in the post-test and variability has been lowered by choosing one correct answer.

After conducting an independent t-test using SPSS, a *p*-value lower than 0.05 can be said to be significantly different. Therefore, the *p*-value of 0.005 has shown that this application is effective enough to improve the performance of students in the topic of electrolysis.

6.7 Conclusion

The purpose of the testing is to see how effective an AR application can be in learning electrolysis. The AR application was developed successfully. With 4 experts and 18 users, both the expert and user testing were completed satisfactorily. This chapter had collected and analyzed all of the results and data. In the overall analysis, the AR application was found to be effective for chemistry educational purposes. Besides, the majority of users were satisfied with the Electrolysis AR application.

CHAPTER 7: PROJECT CONCLUSION

7.1 Introduction

The final stage of this project is the conclusion. This chapter will concentrate on determining whether the project's goal has been met. This chapter will also analyze and summarize the observation on the project's weaknesses and strengths. Furthermore, the propositions for improvement for the AR project might be explored in this chapter. Hence, this will help to make the application more relevant and effective for today's demands.

7.2 Observation on Weaknesses and Strengths

When the testing was done, some flaws in this Electrolysis AR application were discovered. The tone of the speaker is rigid. Therefore, this will bore the user. Moreover, the content is limited in terms of language because not everyone learns chemistry with English. There were some of the students who learn chemistry with Malay. The student who learns chemistry in Malay will face problems when using this application. This is because some of the specific terms used are different for different languages. Thus, they will not understand which ions are present during the electrolysis. In addition, there were many iPhone users nowadays and they are unable to use this application. This is because the application is only available for the Android platform.

The attractive 3D animation of the electrolysis in this AR application is one of the strengths of the project. The interesting animation will help to attract user's attention when they use the Electrolysis AR application to learn chemistry. Besides, the explanation cards provided in the Electrolysis AR application enable the user to

read and gain more information about the electrolysis topic. Another strength of this AR application is the attractive color used in the project. The color and font used are not harmed the user's eyes. Furthermore, users can reinforce what they have learned through the interactive quiz. With the interaction between the user and the AR application, the user will be more immerse and enjoy to use the AR application for learning purpose.

7.3 Propositions for Improvement

Many enhancements to this project are still required to produce a better Electrolysis AR application. In order to develop a more effective AR application for learning purposes, several approaches should be investigated further. One of the flaws in making this Electrolysis AR application is a lack of skill and experience. The language used in the Electrolysis AR application needs to be enhanced. It will be preferable if several languages are prepared. Hence, users are able to choose the language they prefer to. Furthermore, this Electrolysis AR application also needs to be developed for IOS platform devices. Thus, not only Android smartphone users can use this AR application, but this application will also be available for IOS smartphone users. Besides, the improvement can be done by referring to the comments and feedbacks that are collected from the experts and users. The quiz in the application also need to be improved is one of the comments from the experts. The quiz can be more interactive and the mark that users get should be shown at the end. In addition, the expert also suggested that the improvement can be made on the explanation part since the explanation content seemed to be repeated.

7.4 Project Contribution

The development of 3D electrolysis using augmented reality can be contributed to particularly secondary school students who learn chemistry subject and also to people who are interested in learning about electrolysis. With the Electrolysis AR application, students can easily learn chemistry with their smartphones anywhere anytime. Furthermore, the Electrolysis AR application can promote enjoyment for the users during learning process. In addition, users can view the abstract concept of the electrolysis topic through the 3D electrolysis simulation using AR.

7.5 Conclusion

In a nutshell, this project was produced successfully. The project's objectives have been achieved. The Development of 3D Electrolysis using Augmented Reality is an application that can help students who learn chemistry subjects in secondary school to learn chemistry interestingly. Users can observe electrolysis simulation and can use the button provided to interact with AR content. With this, the development of 3D electrolysis using AR can help students to better understand the topic of electrolysis. Following the project's plan, the Electrolysis AR application has been developed and evaluated. However, this application still has many aspects that can be improved for better performance. Further improvement on the Electrolysis AR application can be carried out in order to enhance the application. Thus, a better Electrolysis AR application can be produced and help more students in their studies. Finally, the project was developed successfully. Besides, all of the objectives listed have been achieved by showing that this application is effective enough to improve the performance of students on the electrolysis topic.

REFERENCES

Anyflip.com. (2020, December 17). Electrolysis-flip eBook pages 1 - 15| AnyFlip | AnyFlip. Free Flip Book Maker; PDF to HTML5 Page Flipping Book & Digital Publishing | AnyFlip. https://anyflip.com/jfmkf/pjib/basic

Camelia, M., Adrian, I., & Daniela, G. (2020). Learn chemistry with augmented reality. ScienceDirect.com | Science, health and medical journals, full text articles and books. https://www.sciencedirect.com/science/article/pii/S1877050920321542

Finsa Nurpandi, & Agung Gumelar. (2018). Augmented Reality Chemical Reaction with User-Centered Design. MATEC Web of Conferences. https://www.matec-conferences.org/articles/matecconf/pdf/2018/77/matecconf_iciee2018_04012.pdf

Hsin Kai, W., Wen Yu, L. S., Hsin Yi, C., & Jyh Chong, L. (2013, March). Current status, opportunities and challenges of augmented reality in education. ScienceDirect.com | Science, health and medical journals, full text articles and books. https://www.sciencedirect.com/science/article/abs/pii/S0360131512002527

Jegede, S. A. (2007, July). Students' anxiety towards the learning of Chemistry in some Nigerian secondary schools. CiteSeerX. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1053.808&rep=rep1&type=pdf

Josh, H. (2014, March 6). FuseSchool's YouTube channel. RSC Education. https://edu.rsc.org/review/fuseschools-youtube-channel/2000464.article

Kamisah Osman, & Tien Tien, L. (2012, March). (PDF) Interactive multimedia module with pedagogical agent in electrochemistry. ResearchGate. https://www.researchgate.net/publication/221927447_Interactive_Multimedia_Module_with_Pedagogical_Agent_in_Electrochemistry

Kwee. (2020, August 13). Kimia SPM Tingkatan 4 (KBSM) Bab 6 - Elektrokimia - Kimia SPM. Kimia SPM. https://spmkimia.blog.onlinetuition.com.my/elektrokimia-spm-tingkatan-4-bab-6/

Mahzan Bakar. (2005). Curriculum Specifications: Chemistry Form 4, Ministry of Education Malaysia, Putrajaya, Malaysia.

Mehmet, K., & Yasin, O. (2012). Augmented reality in education: Current technologies and the potential for education. ScienceDirect.com | Science, health and medical journals, full text articles and books. https://www.sciencedirect.com/science/article/pii/S1877042812023907

Mohd H. A. Kalana, Syahrul N. Junaini, & Ahmad H. Fauz. (2020, May 13). Mobile Augmented Reality for Biology Learning: Review and Design Recommendations. Journal of Critical Reviews. https://ir.unimas.my/id/eprint/30035/1/197-1592494873.pdf

Muzammila Akram, Johari Surif, & Murad Ali. (2014, September 29). (PDF) Conceptual difficulties of secondary school students in electrochemistry. ResearchGate. https://www.researchgate.net/publication/287265351_Conceptual_Difficulties_of_Secondary_School_Students_in_Electrochemistry

Nor Farhah Saidin, Noor Dayana Abd Halim, & Noraffandy Yahaya. (2015, June 25). (PDF) A review of research on augmented reality in education: Advantages and applications. ResearchGate. https://www.researchgate.net/publication/281336331_A_Review_of_Research_on_Augmented_Reality_in_Education_Advantages_and_Applications

Roslinda Ramli. (2018, August 2). (PDF) A methodology design of mobile augmented reality (AR) education application on learning Jawi: "Belajar Jawi dengan AR". ResearchGate. https://www.researchgate.net/publication/326767876_A_METHODOLOGY_DESIGN_OF_MOBILE_AUGMENTED_REALITY_AR_EDUCATION_APPLICATION_ON_LEARNING_JAWI_BELAJAR_JAWI_DENGAN_AR

Septi Irwansyah, F., Yusof, Y. M., Ida Farida, & Muhammad Ali Ramdhani. (2017). (PDF) Augmented reality (AR) technology on the Android operating system in chemistry learning. ResearchGate. https://www.researchgate.net/publication/322705473_Augmented_Reality_AR_Technology_on_The_Android_Operating_System_in_Chemistry_Learning

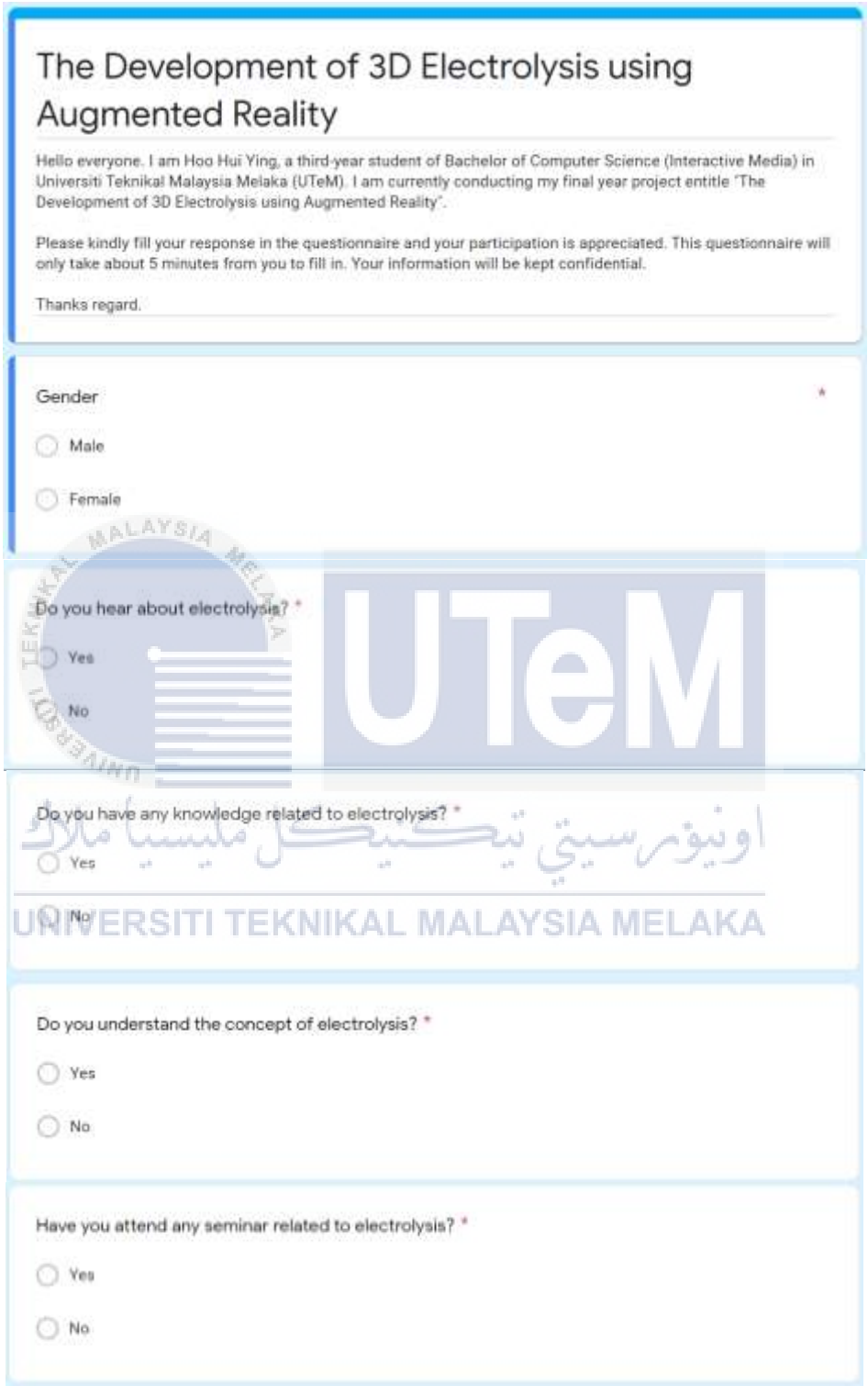
Singaravelu, G., & Sivakumar, A. (2020, April 25). (PDF) Augmented reality in teaching and learning process. ResearchGate.

https://www.researchgate.net/publication/340925293_AUGMENTED_REALITY_IN_TEACHING_AND_LEARNING_PROCESS

Su, C., Xu, W., & Kuang Chiang, F. (2014, August). A case study of augmented reality simulation system application in a chemistry course. ScienceDirect.com | Science, health and medical journals, full text articles and books. https://www.sciencedirect.com/science/article/pii/S07475632140022

Wernhuar, T. & Kuo-Liang, O. (2015). A study of campus butterfly ecology learning system based on augmented reality and mobile learning. https://klou.ilst.nthu.edu.tw/wp-content/uploads/2018/04/Conference-5.pdf

Appendix A: Requirement Gathering Questionnaire



The Development of 3D Electrolysis using Augmented Reality

Hello everyone. I am Hoo Hui Ying, a third-year student of Bachelor of Computer Science (Interactive Media) in Universiti Teknikal Malaysia Melaka (UTeM). I am currently conducting my final year project entitle "The Development of 3D Electrolysis using Augmented Reality".

Please kindly fill your response in the questionnaire and your participation is appreciated. This questionnaire will only take about 5 minutes from you to fill in. Your information will be kept confidential.

Thanks regard.

Gender *

- Male
- Female

Do you hear about electrolysis? *

- Yes
- No

Do you have any knowledge related to electrolysis? *

- Yes
- No

Do you understand the concept of electrolysis? *

- Yes
- No

Have you attend any seminar related to electrolysis? *

- Yes
- No

How do you find electrolysis related knowledge? *

- [ ] Book
- [ ] Internet
- [ ] Television

Do you know about augmented reality (AR)? *

- ( ) Yes
- ( ) No

Have you seen any AR application for learning before? *

- ( ) Yes
- ( ) No

Do you interested in learning electrolysis through AR? *

- ( ) Yes
- ( ) No

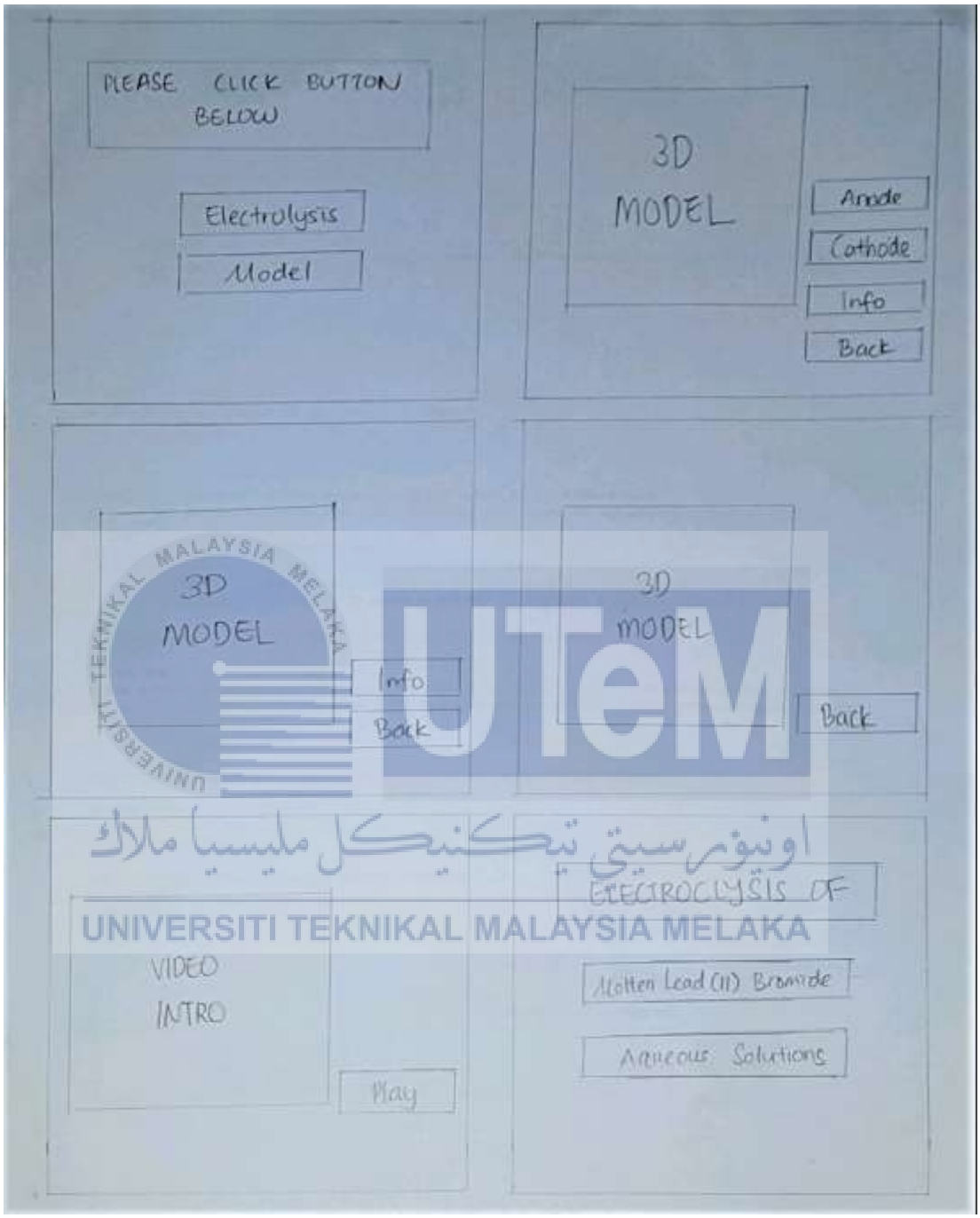
What is the reason that will affect you to learn electrolysis through AR? *

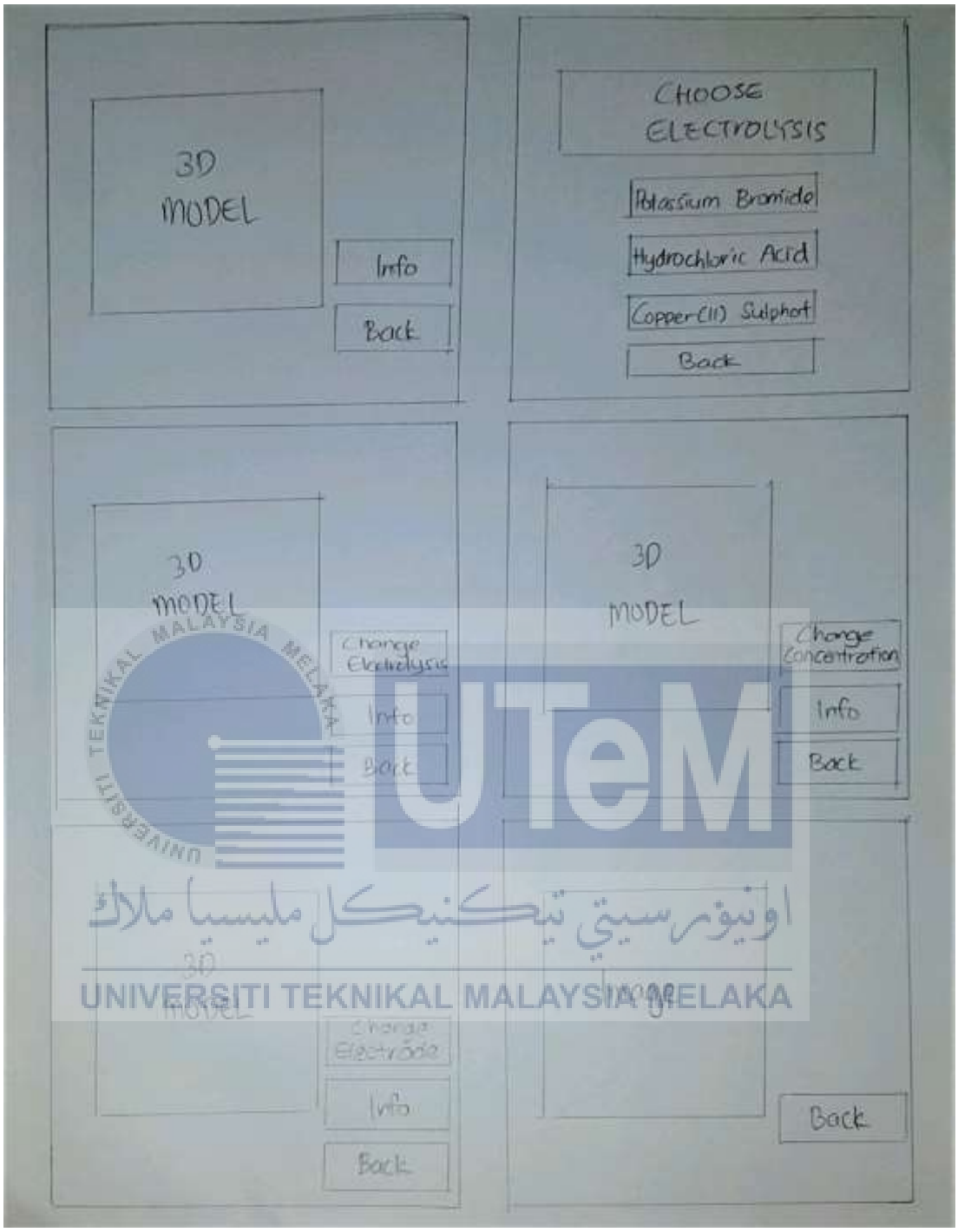
- [ ] Easier to understand the abstract concept
- [ ] Allow user to experiment in a safer environment
- [ ] More attractive compare to other sources

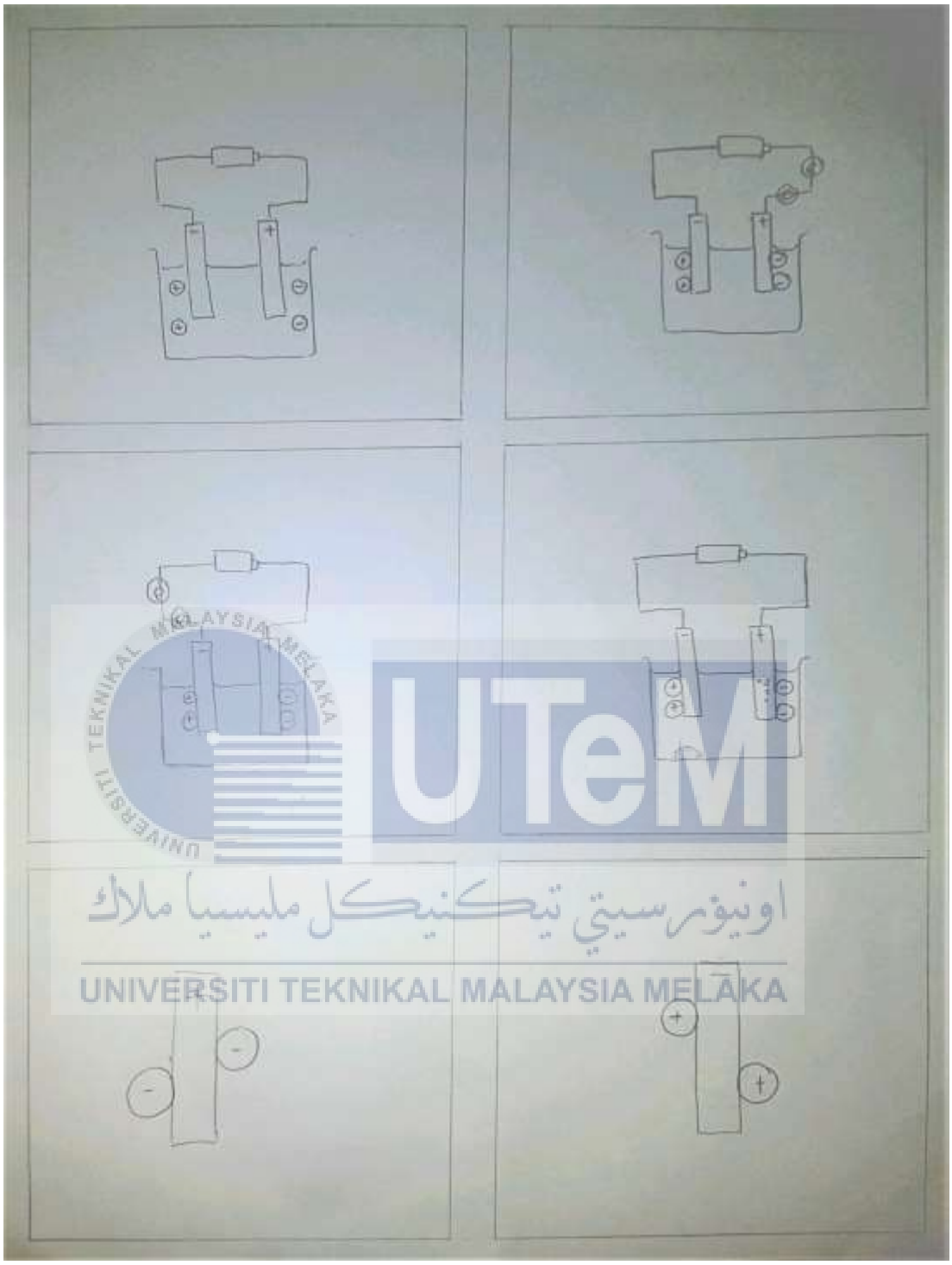
Do you think AR can help you in understanding electrolysis? *

- ( ) Yes
- ( ) No

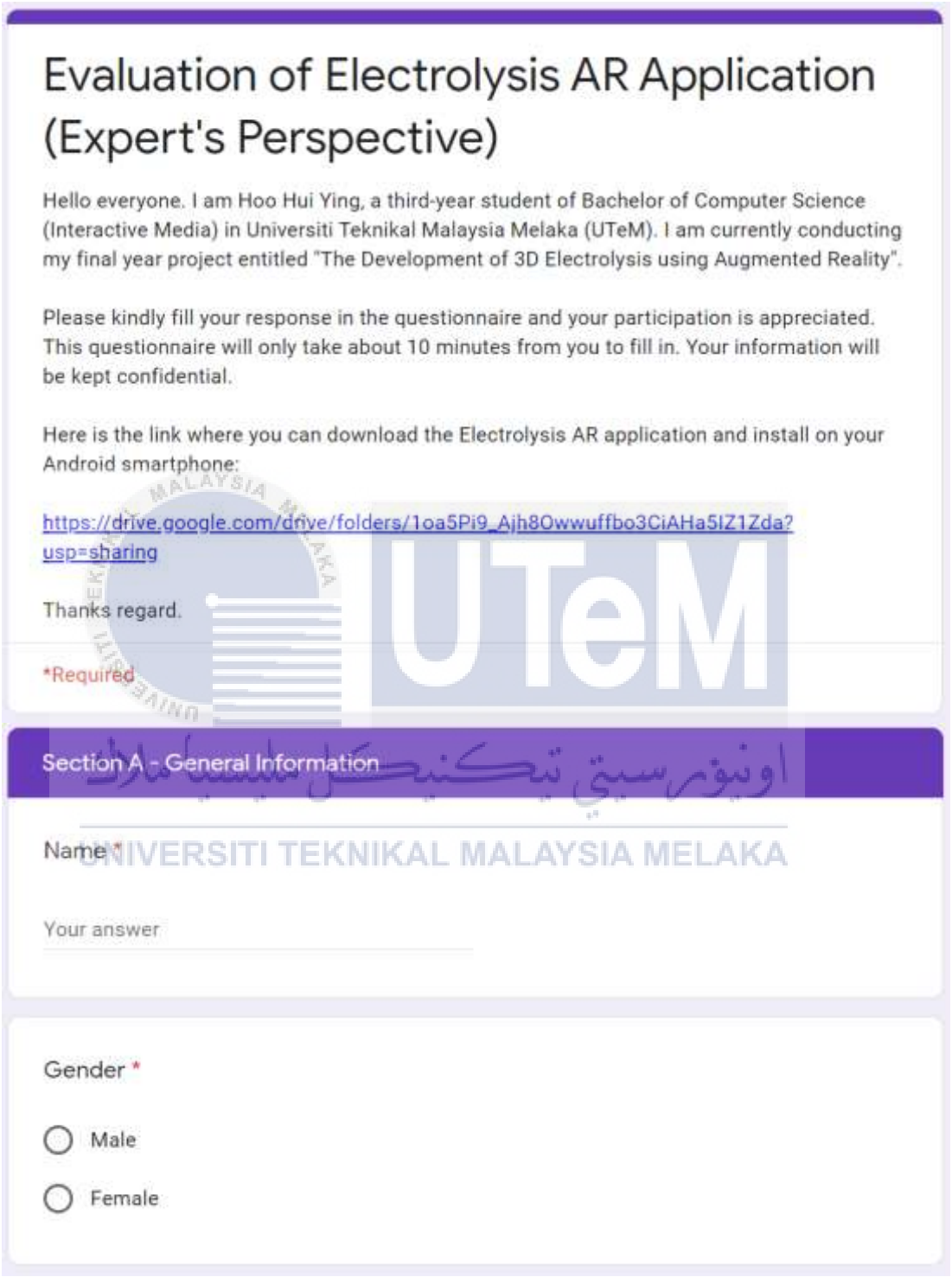
Appendix B: Storyboard







Appendix C: Evaluation of Electrolysis AR Application (Expert's Perspective) Questionnaire



Evaluation of Electrolysis AR Application (Expert's Perspective)

Hello everyone. I am Hoo Hui Ying, a third-year student of Bachelor of Computer Science (Interactive Media) in Universiti Teknikal Malaysia Melaka (UTeM). I am currently conducting my final year project entitled "The Development of 3D Electrolysis using Augmented Reality".

Please kindly fill your response in the questionnaire and your participation is appreciated. This questionnaire will only take about 10 minutes from you to fill in. Your information will be kept confidential.

Here is the link where you can download the Electrolysis AR application and install on your Android smartphone:

https://drive.google.com/drive/folders/1oa5Pi9_Ajh8Owwuffbo3CiAHa5IZ1Zda?usp=sharing

Thanks regard.

*Required

Section A - General Information

Name *

Your answer

Gender *

Male

Female

Age *

Your answer

Race *

- Malay
- Chinese
- Indian
- Other:

Occupation *

Your answer

Working Institution *

Your answer

Number of Years Worked in Related Area *

Your answer

Have you ever heard about Augmented Reality (AR) before? *

- ◯ Yes
- ◯ No

Have you ever used any AR application before? *

- ◯ Yes
- ◯ No

Do you think Augmented Reality application is effective for educational purposes? *

- ◯ Yes
- ◯ No

Section B – Interaction Design

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree

The AR marker can detect by the camera of the device easily. *

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

The usage of buttons to pause and resume the video is convenient. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The simulations' loop for continuous play is efficient. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Menu buttons provided enable users to control the application easily. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The 3D model's size is appropriate for viewing on the device's screen. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The integration of multimedia elements help receive information more effectively. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The AR application promotes enjoyment for users during the learning process. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section C - Information Design

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree

The content is easy to understand. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The AR application has a good integration of contents with the curriculum. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The AR application has a clear classification of specific focuses. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The AR application enhances the user's attention or concentration in the lesson. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The use of interaction and animation enables to visualize the abstract concept of electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The explanation for the electrolysis is clear and detailed. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The quiz in the AR application helps to reinforce the knowledge. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section D - Interface Design

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree

The interface design of the booklet and AR marker is suitable and attractive. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The use of color is attractive. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The font used are suitable and recognizable. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The animation of 3D models are clear and interesting. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The position of the buttons are appropriate and recognizable. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The content arrangement is appropriate and delivers the information effectively. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The user interface is attractive and user-friendly. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section E - Effectiveness

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree

After using this Electrolysis AR application, I found that ...

This application was easy to use. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

This application was function well. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

This application was suitable to learn electrolysis as a learning platform. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I can interact with this application easily. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I understood the abstract concept of electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

This application can consolidate user's memory of electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

This application can motivate users to learn electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section F - Satisfaction

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree.

After using this Electrolysis AR application, I...

Felt excited when using this application. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Enjoyed exploring this application. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Satisfied with the simulation of electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Felt immersed in this application. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Satisfied with the user interface design. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Enjoyed doing the quiz as a revision. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Would like to use this application for educational purpose. *

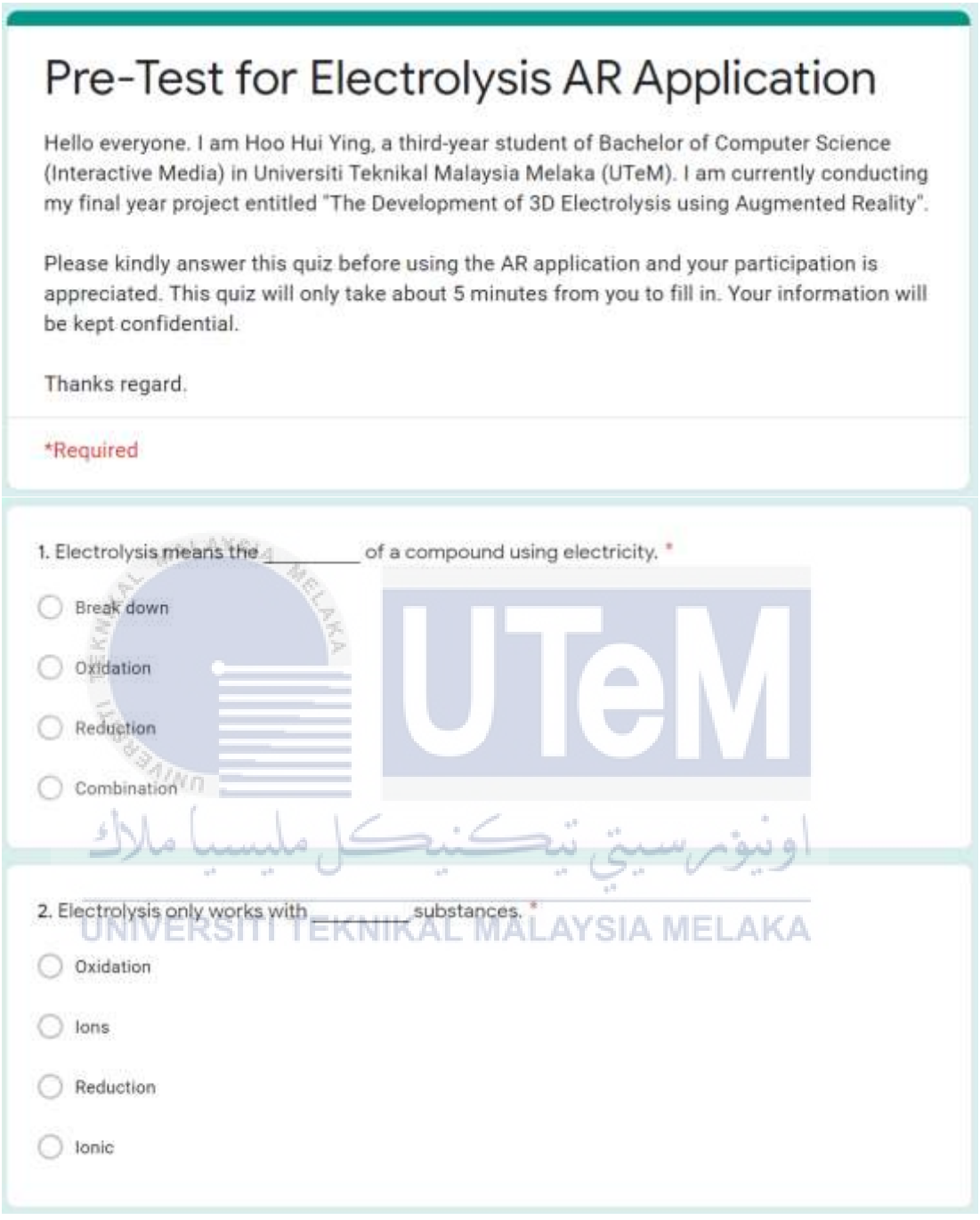
	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section G - Comment and Feedback

Do you have any comment or feedback to the Electrolysis AR application for the future improvement? *

Your answer

Appendix D: Pre-Test Questionnaire



Pre-Test for Electrolysis AR Application

Hello everyone. I am Hoo Hui Ying, a third-year student of Bachelor of Computer Science (Interactive Media) in Universiti Teknikal Malaysia Melaka (UTeM). I am currently conducting my final year project entitled "The Development of 3D Electrolysis using Augmented Reality".

Please kindly answer this quiz before using the AR application and your participation is appreciated. This quiz will only take about 5 minutes from you to fill in. Your information will be kept confidential.

Thanks regard.

*Required

1. Electrolysis means the _____ of a compound using electricity. *

- Break down
- Oxidation
- Reduction
- Combination

2. Electrolysis only works with _____ substances. *

- Oxidation
- Ions
- Reduction
- Ionic

3. For the electrolysis to work the ions must be _____. *

- Positive electrode
- Zinc and chlorine
- Free to move
- Oxidation

4. Which statement correctly describes the 2 electrodes? *

- The anode is negative and the cathode is positive
- The anode and cathode are both positive
- The anode is positive and the cathode is negative
- The anode and cathode are both negative

5. During electrolysis, cations move to the _____ electrode. *

- Copper
- Positive
- Negative
- Chlorine

6. At the cathode, cations _____ electrons. *

- Charge
- Lose
- Discharge
- Gain

7. The lose of electrons is called _____. *

- Melt
- Oxidation
- Free to move
- Reduction

8. In the electrolysis of potassium bromide, what would be formed at the cathode? *

- Hydrogen gas
- Potassium
- Oxygen gas
- Bromine gas

9. In the electrolysis of copper(II) sulphate, what would you see at the anode? *

- Grey solid
- Brown solid
- Colorless bubbles of gas
- Yellow bubbles of gas

10. During the electrolysis of copper(II) sulfate by using carbon electrode, why the solution will become less bluish as time continues? *

- Because less copper is deposited
- Because less copper ions are available
- Because the concentration of sulfate ions goes on decreasing
- Because less sulfate ions are available

Appendix E: Post-Test Questionnaire

Post-Test for Electrolysis AR Application

Hello everyone. I am Hoo Hui Ying, a third-year student of Bachelor of Computer Science (Interactive Media) in Universiti Teknikal Malaysia Melaka (UTeM). I am currently conducting my final year project entitled "The Development of 3D Electrolysis using Augmented Reality".

Please kindly answer this quiz after using the AR application and your participation is appreciated. This quiz will only take about 5 minutes from you to fill in. Your information will be kept confidential.

Here is the link where you can download the Electrolysis AR application and install on your Android smartphone:

https://drive.google.com/drive/folders/1oa5Pi9_Ajh8Owwuffbo3CiAHa5IZ1Zda?usp=sharing

Thanks regard.

*Required

1. The substance that is broken down is called the _____. *

- Ion
- Electron
- Electrolyte
- Electrode

2. Why ionic compounds can not conduct electricity when they are solid? *

- Their electrons are not free to move
- Their ions are not free to move
- Their ions are free to move
- Their electrons are free to move

3. An anode is _____ charged. *

- Positively
- Negatively
- Neutrally

4. In the electrolysis of copper(II) sulfate, what would be formed at the anode? *

- Hydrogen gas
- Oxygen gas
- Sulfate gas
- Copper

5. The half equation that occurs at the anode during the electrolysis of molten lead(II) bromide is: *

- $2Br^- \rightarrow Br_2 + 2e$
- $Pb^{2+} + 2e \rightarrow Pb$
- $4OH^- \rightarrow 2H_2O + O_2 + 4e$
- $2H^+ + 2e \rightarrow H_2$

6. Oxidation is loss of electron. Where does oxidation take place during electrolysis? *

- At the anode
- At the circuit
- In the solution
- At the cathode

7. During electrolysis, anions move to the _____ electrode. *

- Copper
- Positive
- Negative
- Chlorine

8. At the anode, anions _____ electrons. *

- Charge
- Lose
- Discharge
- Gain

9. The gain of electrons is called _____. *

- Melt
- Oxidation
- Free to move
- Reduction

10. Why Cl is selected to be discharged during electrolysis of 2 mol dm-3 hydrochloric acid? *

- Because the concentration of chloride is lower than hydroxide
- Because chloride occupies a lower position than hydroxide in the electrochemical series
- Because the concentration of chloride is higher than hydroxide
- Because chloride occupies a higher position than hydroxide in the electrochemical series

Appendix F: Evaluation of Electrolysis AR Application (User's Perspective) Questionnaire

Evaluation of Electrolysis AR Application (User's Perspective)

Hello everyone. I am Hoo Hui Ying, a third-year student of Bachelor of Computer Science (Interactive Media) in Universiti Teknikal Malaysia Melaka (UTeM). I am currently conducting my final year project entitled "The Development of 3D Electrolysis using Augmented Reality".

Please kindly fill your response in the questionnaire and your participation is appreciated. This questionnaire will only take about 10 minutes from you to fill in. Your information will be kept confidential.

Here is the link where you can download the Electrolysis AR application and install on your Android smartphone:

https://drive.google.com/drive/folders/1oa5Pi9_Ajh8Owwuffbo3CiAHa5IZ1Zda?usp=sharing

Thanks regard.

*Required

Section A - General Information

Gender *

- ◯ Male
- ◯ Female

Race *

- ◯ Malay
- ◯ Chinese
- ◯ Indian
- ◯ Other:

Have you ever heard about Augmented Reality(AR) before? *

- ◯ Yes
- ◯ No

Do you have experience in AR-based learning? *

- ◯ Yes
- ◯ No

Do you interested in learning electrolysis through Augmented Reality?

- ◯ Yes
- ◯ No

Section B - Interaction Design

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree

The AR marker can easily detect by the camera of the device. *

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

The size of the 3D model is suitable for viewing on the screen of the device. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

It is convenient to use buttons to pause and resume the video. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The loop of the simulations to play continuously is efficient. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Users can easily view the explanation by clicking the button provided. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The integration of multimedia elements help receive information more effectively. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The AR application promote enjoyment for users in learning process. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section C - Information Design

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree

The content is easy to understand. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The content is suitable for learning electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The content helps to clarify user's misunderstanding of the abstract concept. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The explanation for the electrolysis is clear and detailed. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The use of interaction and animation enables to visualize the abstract concept of electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Quizzes in AR application is effective to reinforce the acquired knowledge. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The simulation of the electrolysis is clear and easy to understand. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section D - Interface Design

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree

The interface design of the booklet and AR marker is attractive. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The use of color is attractive. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The font used are suitable and recognizable. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The animation of 3D models are clear and interesting. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The design of the buttons are appropriate and recognizable. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The arrangement of the content is appropriate and being deliver more effectively. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The navigation design is clear and easy to understand. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section E - Effectiveness

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree

After using this Electrolysis AR application, I found that ...

This application was easy to use. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

This application was function well. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

This application was suitable to learn electrolysis as a learning platform. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I can interact with this application easily. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I understood the abstract concept of electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

My memory of electrolysis is consolidated. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I have the motivation to learn electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section F - Satisfaction

This section consists of 7 questions. Please rate all the questions.

1 - Strongly Disagree
2 - Disagree
3 - Not Sure
4 - Agree
5 - Strongly Agree

After using this Electrolysis AR application, I...

Felt excited when using this application. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Enjoyed exploring this application. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Satisfied with the simulation of electrolysis. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Felt immersed in this application. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Satisfied with the user interface design. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Enjoyed doing the quiz as a revision. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Would like to use this application frequently. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section G - Comment and Feedback

Do you have any comment or feedback to the Electrolysis AR application for the future improvement?

Your answer

Appendix G: Sample Source Code

Video Introduction

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using UnityEngine.Video;

public class StreamVideo : MonoBehaviour
{
    public RawImage image;
    public GameObject playIcon;
    public GameObject pauseIcon;

    public VideoClip videoToPlay;

    private VideoPlayer videoPlayer;
    private VideoSource videoSource;

    private AudioSource audioSource;

    private bool isPaused = false;
    private bool firstRun = true;

    IEnumerator playVideo()
    {
        playIcon.SetActive(false);
        pauseIcon.SetActive(true);
        firstRun = false;

        //Add VideoPlayer to the GameObject
        videoPlayer = gameObject.AddComponent<VideoPlayer>();

        //Add AudioSource
        audioSource = gameObject.AddComponent<AudioSource>();

        //Disable Play on Awake for both Video and Audio
        videoPlayer.playOnAwake = false;
        audioSource.playOnAwake = false;
        audioSource.Pause();

        //We want to play from video clip not from url

        videoPlayer.source = VideoSource.VideoClip;

        //Set Audio Output to AudioSource
        videoPlayer.audioOutputMode = VideoAudioOutputMode.AudioSource;

        //Assign the Audio from Video to AudioSource to be played
        videoPlayer.EnableAudioTrack(0, true);
        videoPlayer.SetTargetAudioSource(0, audioSource);

        //Set video To Play then prepare Audio to prevent Buffering
        videoPlayer.clip = videoToPlay;
        videoPlayer.Prepare();
```

```
        //Wait until video is prepared
        while (!videoPlayer.isPrepared)
        {
            yield return null;
        }

        //Assign the Texture from Video to RawImage to be displayed
        image.texture = videoPlayer.texture;

        //Play Video
        videoPlayer.Play();

        //Play Sound
        audioSource.Play();

        // Restart from beginning when done
        videoPlayer.isLooping = true;
    }

    public void PlayPause()
    {
        if(!firstRun && !isPaused)
        {
            videoPlayer.Pause();
            audioSource.Pause();
            playIcon.SetActive(true);
            pauseIcon.SetActive(false);
            isPaused = true;
        }
        else if (!firstRun && isPaused)
        {
            videoPlayer.Play();
            audioSource.Play();
            playIcon.SetActive(false);
            pauseIcon.SetActive(true);
            isPaused = false;
        }
        else
        {
            StartCoroutine(playVideo());
        }
    }
}
```


Menu

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class HideShow : MonoBehaviour
{
    public GameObject hideBtn;
    public GameObject showBtn;
    public GameObject expBtn;
    public GameObject closeBtn;
    public GameObject img;

    public GameObject anode;
    public GameObject cathode;
```

```
public GameObject btnAnode;
public GameObject btnCathode;
public GameObject btnExit;
public GameObject btnExpA;
public GameObject btnExpC;
public GameObject btnCloseA;
public GameObject btnCloseC;
public GameObject cathodeExp;
public GameObject anodeExp;
public GameObject electrolysis;
public GameObject imgElectrode;
public GameObject btnMenu;
public GameObject btnCloseD;
public GameObject btnAnode2;

public GameObject model;
public GameObject ion;
public GameObject electrode;
public GameObject electrolyte;
public GameObject backMainBtn;

public AudioSource ionAu;
public AudioSource electrodeAu;
public AudioSource electrolyteAu;
public AudioSource cathodeAu;
public AudioSource anodeAu;
public AudioSource electrolysisAu;

void Start()
{
    electrolysis.SetActive(false);
    img.SetActive(false);
    anode.SetActive(false);
    cathode.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(false);
    btnExpA.SetActive(false);
    btnExpC.SetActive(false);
    btnCloseA.SetActive(false);
    btnCloseC.SetActive(false);
    btnExit.SetActive(false);
    cathodeExp.SetActive(false);
    anodeExp.SetActive(false);
    closeBtn.SetActive(false);
    expBtn.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    imgElectrode.SetActive(true);
    btnMenu.SetActive(true);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(false);

    model.SetActive(false);
    ion.SetActive(false);
    electrode.SetActive(false);
    electrolyte.SetActive(false);
    backMainBtn.SetActive(false);
}
```

```
public void show(GameObject obj)
{
    obj.SetActive(true);
    hideBtn.SetActive(true);
    showBtn.SetActive(false);
}

public void hide(GameObject obj)
{
    obj.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(true);
}

public void exp()
{
    closeBtn.SetActive(false);
    expBtn.SetActive(false);
    img.SetActive(true);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(false);
    imgElectrode.SetActive(false);
    btnMenu.SetActive(false);
    btnExit.SetActive(false);
    btnCloseD.SetActive(true);
    btnAnode2.SetActive(false);
    model.SetActive(false);
    ion.SetActive(false);
    electrode.SetActive(false);
    electrolyte.SetActive(false);
    backMainBtn.SetActive(false);
}

public void demo()
{
    closeBtn.SetActive(false);
    img.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    expBtn.SetActive(true);
    electrolysis.SetActive(true);
    btnMenu.SetActive(false);
    anode.SetActive(false);
    cathode.SetActive(false);
    btnAnode.SetActive(true);
    btnCathode.SetActive(true);
    btnExit.SetActive(true);
    btnExpA.SetActive(false);
    btnExpC.SetActive(false);
    btnCloseA.SetActive(false);
    btnCloseC.SetActive(false);
    cathodeExp.SetActive(false);
    anodeExp.SetActive(false);
    imgElectrode.SetActive(false);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(false);
    model.SetActive(false);
    ion.SetActive(false);
    electrode.SetActive(false);
    electrolyte.SetActive(false);
```

```
    backMainBtn.SetActive(false);
    electrolysisAu.Play();
}

public void introF()
{
    closeBtn.SetActive(false);
    img.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    expBtn.SetActive(false);
    electrolysis.SetActive(false);
    btnMenu.SetActive(false);
    anode.SetActive(false);
    cathode.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(false);
    btnExit.SetActive(false);
    btnExpA.SetActive(false);
    btnExpC.SetActive(false);
    btnCloseA.SetActive(false);
    btnCloseC.SetActive(false);
    cathodeExp.SetActive(false);
    anodeExp.SetActive(false);
    imgElectrode.SetActive(false);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(false);
    model.SetActive(true);
    ion.SetActive(false);
    electrode.SetActive(false);
    electrolyte.SetActive(false);
    backMainBtn.SetActive(false);
}

public void ionF()
{
    closeBtn.SetActive(false);
    img.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    expBtn.SetActive(false);
    electrolysis.SetActive(false);
    btnMenu.SetActive(false);
    anode.SetActive(false);
    cathode.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(false);
    btnExit.SetActive(false);
    btnExpA.SetActive(false);
    btnExpC.SetActive(false);
    btnCloseA.SetActive(false);
    btnCloseC.SetActive(false);
    cathodeExp.SetActive(false);
    anodeExp.SetActive(false);
    imgElectrode.SetActive(false);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(false);
    model.SetActive(false);
    ion.SetActive(true);
    electrode.SetActive(false);
    electrolyte.SetActive(false);
    backMainBtn.SetActive(true);
```

```
    ionAu.Play();
}

public void electrodeF()
{
    closeBtn.SetActive(false);
    img.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    expBtn.SetActive(false);
    electrolysis.SetActive(false);
    btnMenu.SetActive(false);
    anode.SetActive(false);
    cathode.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(false);
    btnExit.SetActive(false);
    btnExpA.SetActive(false);
    btnExpC.SetActive(false);
    btnCloseA.SetActive(false);
    btnCloseC.SetActive(false);
    cathodeExp.SetActive(false);
    anodeExp.SetActive(false);
    imgElectrode.SetActive(false);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(false);
    model.SetActive(false);
    ion.SetActive(false);
    electrode.SetActive(true);
    electrolyte.SetActive(false);
    backMainBtn.SetActive(true);
    electrodeAu.Play();
}

public void electrolyteF()
{
    closeBtn.SetActive(false);
    img.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    expBtn.SetActive(false);
    electrolysis.SetActive(false);
    btnMenu.SetActive(false);
    anode.SetActive(false);
    cathode.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(false);
    btnExit.SetActive(false);
    btnExpA.SetActive(false);
    btnExpC.SetActive(false);
    btnCloseA.SetActive(false);
    btnCloseC.SetActive(false);
    cathodeExp.SetActive(false);
    anodeExp.SetActive(false);
    imgElectrode.SetActive(false);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(false);
    model.SetActive(false);
    ion.SetActive(false);
    electrode.SetActive(false);
    electrolyte.SetActive(true);
    backMainBtn.SetActive(true);
```

```
    electrolyteAu.Play();
}

public void close()
{
    Start();
}

public void exit()
{
    demo();
}

public void viewAnode()
{
    anode.SetActive(true);
    cathode.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(true);
    btnExpA.SetActive(true);
    btnExpC.SetActive(false);
    btnCloseA.SetActive(false);
    btnCloseC.SetActive(false);
    btnExit.SetActive(false);
    cathodeExp.SetActive(false);
    anodeExp.SetActive(false);
    electrolysis.SetActive(false);
    closeBtn.SetActive(true);
    expBtn.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    imgElectrode.SetActive(false);
    btnMenu.SetActive(false);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(false);
    model.SetActive(false);
    ion.SetActive(false);
    electrode.SetActive(false);
    electrolyte.SetActive(false);
    backMainBtn.SetActive(false);
    anodeAu.Play();
}

public void viewCathode()
{
    cathode.SetActive(true);
    anode.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(false);
    btnExpA.SetActive(false);
    btnExpC.SetActive(true);
    btnCloseA.SetActive(false);
    btnCloseC.SetActive(false);
    btnExit.SetActive(false);
    cathodeExp.SetActive(false);
    anodeExp.SetActive(false);
    electrolysis.SetActive(false);
    closeBtn.SetActive(true);
    expBtn.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    imgElectrode.SetActive(false);
```

```
    btnMenu.SetActive(false);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(true);
    model.SetActive(false);
    ion.SetActive(false);
    electrode.SetActive(false);
    electrolyte.SetActive(false);
    backMainBtn.SetActive(false);
    cathodeAu.Play();
}

public void expAnode()
{
    cathode.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(false);
    btnExpA.SetActive(false);
    btnExpC.SetActive(false);
    btnCloseA.SetActive(true);
    btnCloseC.SetActive(false);
    btnExit.SetActive(false);
    cathodeExp.SetActive(false);
    anodeExp.SetActive(true);
    electrolysis.SetActive(false);
    closeBtn.SetActive(false);
    expBtn.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    imgElectrode.SetActive(false);
    btnMenu.SetActive(false);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(false);
    model.SetActive(false);
    ion.SetActive(false);
    electrode.SetActive(false);
    electrolyte.SetActive(false);
    backMainBtn.SetActive(false);
}
public void expCathode()
{
    anode.SetActive(false);
    btnAnode.SetActive(false);
    btnCathode.SetActive(false);
    btnExpA.SetActive(false);
    btnExpC.SetActive(false);
    btnCloseA.SetActive(false);
    btnCloseC.SetActive(true);
    btnExit.SetActive(false);
    cathodeExp.SetActive(true);
    anodeExp.SetActive(false);
    electrolysis.SetActive(false);
    closeBtn.SetActive(false);
    expBtn.SetActive(false);
    hideBtn.SetActive(false);
    showBtn.SetActive(false);
    imgElectrode.SetActive(false);
    btnMenu.SetActive(false);
    btnCloseD.SetActive(false);
    btnAnode2.SetActive(false);
    model.SetActive(false);
    ion.SetActive(false);
```

```
        electrode.SetActive(false);
        electrolyte.SetActive(false);
        backMainBtn.SetActive(false);
    }

    public void backModel()
    {
        introF();
    }

    public void closeAnode()
    {
        viewAnode();
    }

    public void closeCathode()
    {
        viewCathode();
    }
}
```

Quiz

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class quiz : MonoBehaviour
{
    public GameObject tick;
    public GameObject cross;
    public GameObject q1;
    public GameObject q2;
    public GameObject q3;
    public GameObject q4;
    public GameObject q5;
    public GameObject q6;
    public GameObject q7;
    public GameObject menu;
    public GameObject end;
    public AudioSource right;
    public AudioSource wrong;

    void Start()
    {
        tick.SetActive(false);
        cross.SetActive(false);
        q1.SetActive(false);
        q2.SetActive(false);
        q3.SetActive(false);
        q4.SetActive(false);
        q5.SetActive(false);
        q6.SetActive(false);
        q7.SetActive(false);
        menu.SetActive(true);
        end.SetActive(false);
    }
```

```
public void correct()
{
    tick.SetActive(true);
    cross.SetActive(false);
    right.Play();
}

public void incorrect()
{
    cross.SetActive(true);
    tick.SetActive(false);
    wrong.Play();
}

public void qn1()
{
    tick.SetActive(false);
    cross.SetActive(false);
    q1.SetActive(true);
    q2.SetActive(false);
    q3.SetActive(false);
    q4.SetActive(false);
    q5.SetActive(false);
    q6.SetActive(false);
    q7.SetActive(false);
    menu.SetActive(false);
    end.SetActive(false);
}

public void qn2()
{
    tick.SetActive(false);
    cross.SetActive(false);
    q1.SetActive(false);
    q2.SetActive(true);
    q3.SetActive(false);
    q4.SetActive(false);
    q5.SetActive(false);
    q6.SetActive(false);
    q7.SetActive(false);
    menu.SetActive(false);
    end.SetActive(false);
}

public void qn3()
{
    tick.SetActive(false);
    cross.SetActive(false);
    q1.SetActive(false);
    q2.SetActive(false);
    q3.SetActive(true);
    q4.SetActive(false);
    q5.SetActive(false);
    q6.SetActive(false);
    q7.SetActive(false);
    menu.SetActive(false);
    end.SetActive(false);
}
```

```
public void qn4()
{
    tick.SetActive(false);
    cross.SetActive(false);
    q1.SetActive(false);
    q2.SetActive(false);
    q3.SetActive(false);
    q4.SetActive(true);
    q5.SetActive(false);
    q6.SetActive(false);
    q7.SetActive(false);
    menu.SetActive(false);
    end.SetActive(false);
}

public void qn5()
{
    tick.SetActive(false);
    cross.SetActive(false);
    q1.SetActive(false);
    q2.SetActive(false);
    q3.SetActive(false);
    q4.SetActive(false);
    q5.SetActive(true);
    q6.SetActive(false);
    q7.SetActive(false);
    menu.SetActive(false);
    end.SetActive(false);
}

public void qn6()
{
    tick.SetActive(false);
    cross.SetActive(false);
    q1.SetActive(false);
    q2.SetActive(false);
    q3.SetActive(false);
    q4.SetActive(false);
    q5.SetActive(false);
    q6.SetActive(true);
    q7.SetActive(false);
    menu.SetActive(false);
    end.SetActive(false);
}

public void qn7()
{
    tick.SetActive(false);
    cross.SetActive(false);
    q1.SetActive(false);
    q2.SetActive(false);
    q3.SetActive(false);
    q4.SetActive(false);
    q5.SetActive(false);
    q6.SetActive(false);
    q7.SetActive(true);
    menu.SetActive(false);
    end.SetActive(false);
}
```

```
    public void finish()
    {
        tick.SetActive(false);
        cross.SetActive(false);
        q1.SetActive(false);
        q2.SetActive(false);
        q3.SetActive(false);
        q4.SetActive(false);
        q5.SetActive(false);
        q6.SetActive(false);
        q7.SetActive(false);
        menu.SetActive(false);
        end.SetActive(true);
    }
}
```