THE DEVELOPMENT OF VIRTUAL ELECTROLYSIS EXPERIMENT BY USING AUGMENTED REALITY

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

FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I hereby declare that this project report entitled

THE DEVELOPMENT OF VIRTUAL ELECTROLYSIS EXPERIMENT BY USING AUGMENTED REALITY

is written by me and is my own effort and that no part has been plagiarized without citations.

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(LUA CHEONG FENG)

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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 (Media Interactive) with Honours.

SUPERVISOR : _____ Date : 12/9/2021
(TS.NORAZLIN BINTI MOHAMMED)

DEDICATION

To my beloved parents, supervisor and friends who always give the support during the development of project

UTeM
اونيۏرسيتي تيکنيکل مليسيا ملاك
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Finally, I also like to thank to my friends who helped me in solving the problems when I face the problem of development of Augmented Reality.

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ABSTRACT

ARCHEM is a marker-less based Augmented Reality application about the development of virtual electrolysis experiment by using augmented reality. It allows the user to view the 3D apparatus and the 3D animation of procedures that related to the electrolysis experiments. This project aims to study marker-less based AR application and requirements in implementing the electrolysis experiment, develop a marker-less based augmented reality application in learning the electrolysis experiment procedure and evaluate the user acceptance of augmented reality in learning electrolysis experiment compared to studying on textbook. This project will giving the knowledge about the rules of laboratory, the apparatus used, the procedure steps and the result from the experiment of electrolysis. The apparatus and the procedure steps explained is using the 3D models. Therefore, the user can able to rotate and scale the 3D model by their fingers. They can use interact the application by using the button provided. This project will bring the benefit to Form 5 students who will learn the electrolysis experiment but the school does not provide the opportunities to conduct this experiment. The mobile application ARCHEM will be the final product of project.

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ABSTRAK

ARCHEM merupakan satu aplikasi yang mempunyai AR marker-less berkaitan pembangunan eksperimen elektrolisis maya dengan menggunakan augmented reality. Aplikasi ini membenarkan pengguna untuk melihat 3D radas and 3D langkah prosedur yang berkaitan dengan eksperimen elektrolisis. Projek tersebut bertujuan untuk mengkaji keperluan AR marker-less dalam pembangunan eksperimen elektrolisis, mengembangkan aplikasi augmented reality marker-less dalam mempelajari prosedur eksperimen elektrolisis dan menilai UAT bagi augmented reality dalam pembelajaran eksperimen elektrolisis berbanding dengan belajar dalam buku teks. Projek ini akan memberi ilmu pengetahuan tentang peraturan makmal, alat yang digunakan, langkah prosedur dan kesimpulan dari eksperimen eletrolisis. Radas dan langkah prosedur akan diterangkan dengan menggunakan model 3D. Oleh itu, pengguna dapat memutar dan menskala model 3D dengan menggunakan jari mereka. Pengguna juga boleh menggunakan butang untuk berinteraksi dengan aplikasi. Projek ini memberi kebaikan kepada pelajar Tingkatan 5 yang akan mempelajari eksperimen elektrolisis tetapi sekolah tidak memberi peluang untuk menjalankan eksperimen tersebut. Aplikasi telefon ARCHEM merupakan produk akhir untuk projek tersebut.

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LIST OF ABBREVIATIONS

FYP	**-**	**Final Year Project**
FTMK		**Fakulti Teknologi Maklumat dan Komunikasi**
UTeM		**Universiti Teknikal Malaysia Melaka**
PSM		**Projek Sarjana Muda**
AR		**Augmented Reality**
MCO		**Movement Control Order**
3D		**Three Dimensional**

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Chemistry is the study of the composition of substances, basic form of matter, interaction between matter and the chemical reactions between substances. Chemistry can explain to the people about the innumerable phenomena in the world. For example, the scientists can use the chemistry knowledge to explain the concept about the rusting of iron. Chemicals can occur naturally everywhere, but also some are man made. In the study of chemistry, the most important area is the understanding of elements and what determines how they react. Dmitri Mendeleev was a Russian chemist who developed the first Periodic Table of the Elements in 1834. He listed the 63 known elements in ascending order of atomic mass. When he arranged the elements, he can also group the elements with the similar chemical properties. Thus, the periodic table can be used to explain the relationships between the different element.

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For chemistry, there are many different types of experiments that will be carried out in order to understand a part of chemistry knowledge. An experiment is a procedure designed to test whether the hypothesis is true or not. The experiment also is the foundation of the scientific method that help the people to explore the world around them. The experiment mostly conducted in the school laboratory or private laboratory. In order to carry out an experiment, the people needs to remember the rules of laboratory to avoid the accident that easily caused in laboratory. There are five components of a well-designed scientific experiment which are observations, questions, hypothesis, methods and the results. The experimenters need to observe the changes in experiment. The question is the aspect being tested to understand what

the experiment is trying to answer. Every experiments has the different hypothesis to predict the outcome. Methods is the procedures of the experiment that list all the materials and apparatus used in the experiment in specific detail along with the exact procedures. Then, the experimenter must record the result of the experiment to make a conclusion to decide whether the hypothesis is accepted or rejected.

Nowadays, the augmented reality (AR) is one of the biggest technology trends right now. The use of augmented reality in education is being popularity in schools worldwide. Augmented reality can improve the learning outcomes through interactivity compared to the traditional teaching methods. As a result, EON-XR provides a hands on virtual lab for chemistry students that applied in the safe space for experiments which are AR and VR. They can just experience the experiments by using their smart phones or computers. Therefore, this project is to develop a marker-less based augmented reality application in learning the electrolysis experiment procedure.

1.2 Problem Statement

For the science students, there are many types of experiment that they need to conduct in the school laboratory, but some of the school face the problems about the lack of the material or apparatus needed. Thus, the science students from these schools do not have the chance to conduct some experiments. Although they have the procedure of the experiment, but they will be more harder to understand the outcome of that experiments. The experiment in the laboratory is important for them to understand and improve their learning on the concept of certain chapter.

The second problem is the factor of covid-19 pandemic. In 18 March 2020, Malaysia had implemented Movement Control Order(MCO). During this MCO, the students are not allowed to study in school. They are forced to study on online meeting with their teachers. In case, the science students need to conduct an experiment to understand a certain concept of science, especially for chemistry. Therefore, the use of augmented reality on conducting an experiment will give them benefits because they can learn how to carry out an experiment and conclude the reaction of the chemical by using augmented reality at home. For example, AR Lab mobile app is a teaching tool and replacement of traditional class in laboratory.

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1.3 Objective

This project embarks on the following objectives:

1. To study marker-less based AR application and requirement in implementing the electrolysis experiment.

2. To develop a marker-less based augmented reality application in learning the electrolysis experiment procedure.

3. To evaluate the user acceptance of augmented reality in learning electrolysis experiment compared to studying on textbook.

1.4 Scope

The target user of this project is focused on Form 5 science students and anyone who is interested in electrolysis experiment. Users can learn the rules of the laboratory to avoid the accidents that can easily occur when working in the lab. This project will also have the feature that the users can learn the different augmented reality apparatus and materials. Users also can view the experiment procedures about electrolysis according to the steps through augmented reality.

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1.5 Project Significant

This project will be a marker-less based augmented reality application, which will help the user to understand the procedure of the experiment that related to the electrolysis. Users able to learn the rules of the laboratory. In addition, this project also help users to remember the name of each apparatus easily through augmented reality. As a result, this project will give the significance to user because they able to learn electrolysis through augmented reality and not only in textbook.

1.6 Conclusion

As a conclusion, this chapter describes the objectives of this project that will be carried out to achieve the goal. The next chapter will explain the literature review and methodology of this project.

CHAPTER 2: LITERATURE REVIEW AND PROJECT METHODOLOGY

2.1 Introduction

This chapter will discuss about the literature review and project methodology. The literature review will describe the previous researches about the topic of learning chemistry experiment procedures by using AR or others technologies. Moreover, this chapter will also discuss about the methodology used to develop this project.

2.2 Domain

In domain, there are some elements will be discussed such as the augmented reality and the types of the augmented reality.

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2.2.1 Augmented reality

Augmented reality is a technology that lets people to superimpose the digital content such as images, sounds or text over real-life scenes. In 2016, AR become more and more popular after the game Pokemon Go made it possible to interact with Pokemon through the smart phone. Augmented reality is not a fully immersive experience like virtual reality but augmented reality let the people still interact with the real world.

2.2.2 Type of augmented reality

There are 5 main types of augmented reality, which are marker-based augmented reality, marker-less augmented reality, location-based augmented reality, superimposition based augmented reality, and projection-based augmented reality.

2.2.2.1 Marker-Based Augmented Reality

Marker-Based AR is the augmented reality that uses the markers such as QR code, images or other unique designs to trigger an augmented experience. The digital content will be placed on top of the marker when it is recognized by an augmented reality application.

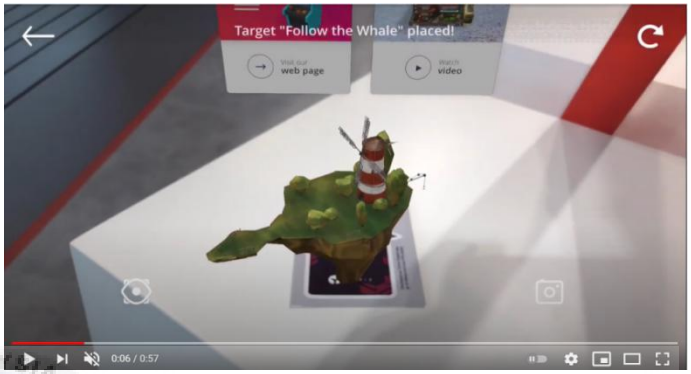

Figure 2.1 Marker-Based AR

2.2.2.2 Marker-less Augmented Reality

Marker-less AR is a software application that does not require prior knowledge of user's environment to overlay virtual 3D content into a scene. It is based on scanning the environment for placing digital objects (Rafat Pucitowski, 2020). Besides, it allows the user to put the virtual object anywhere by themself. Marker-less AR relies on the device's hardware such as the camera, digital compass, GPS, and accelerometer to allow the AR software function.

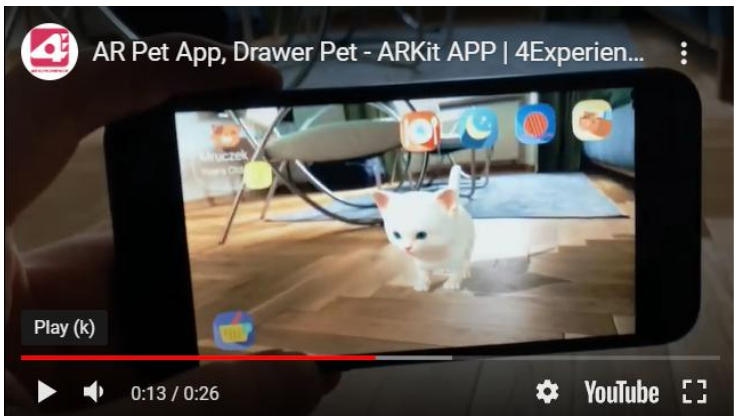

Figure 2.2 Marker-less AR

2.2.2.3 Location-Based Augmented Reality

Location-Based AR stands for a marker-less, position-based and geometric-based augmented reality. This technology uses a device's location and sensors to unite the object to a point of interest (Sonia Schechter, 2020). It more depend on GPS, accelerometer, digital compass and others to identify a device's location and position with high accuracy. For example, Pokemon-Go is one of the location-based augmented reality game. The users can experience the virtual Pokemon in our real world through their smartphones.

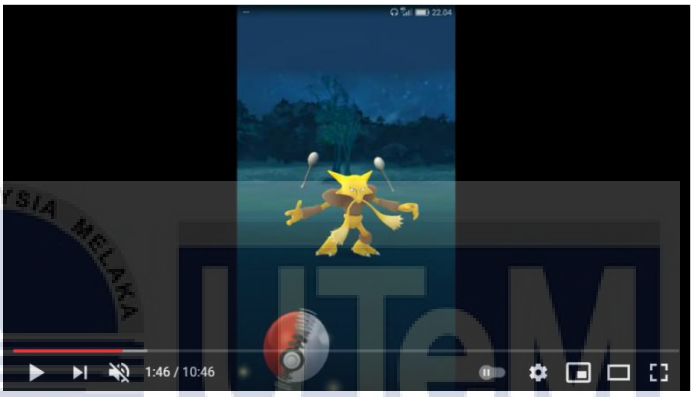

Figure 2.3 Location-based AR

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2.2.2.4 Superimposition Augmented Reality

Superimposition AR recognizes an object in the physical world and enhances it to provide an alternative view. It replaces the real vision of an object fully or partially to show the user an augmented version of it (KC Karnes, 2019). For instance, IKEA used the superimposition augmented reality given that they can replace the original view of the object with an augmented view of that same object.

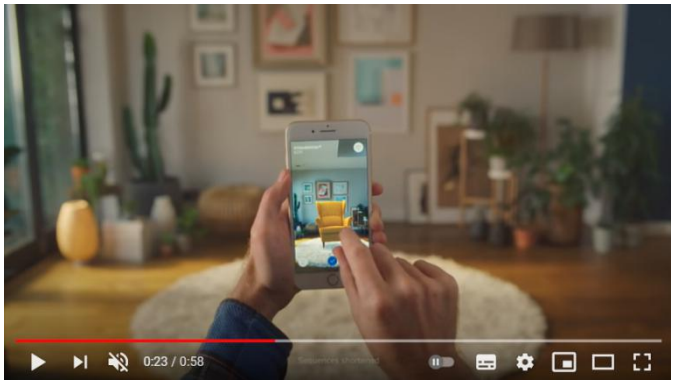

Figure 2.4 Superimposition AR

2.2.2.5 Projection-Based Augmented Reality

For projection-based AR, it uses the light effect to project the digital graphics onto an object or surface to create an interactive experience for the user. The technology projects the virtual image onto physical set to create an augmented virtual experience (Mindsight, 2017). This AR is also used to create 3D objects that can be interacted with the user.

Figure 2.5 Projection-based AR

2.3 Existing System

The project "Interactive Augmented Reality with Natural Action for Chemistry Experiment Learning" was written by Meng Chun Lam, Hwei Kei Tee, Siti Soleha Muhammad Nizam, Nurhazarifah Che Hashim, Nur Asylah Suwadi, Siok Yee Tan, Nazatul Aini Abd Majid, Haslina Arshad and Sook Yee Liew (2020). This study is trying to help the student to keep repeating experiment by using augmented reality for learning the concept of the experiment. This project used the marker-based augmented reality by card-based marker in Figure 2.3.1 and box-based marker in Figure 2.3.2 to conduct the experiment as shown in Figure 2.3.3. The experiment involved dilution of concentrated acid solution. When the marker was detected by camera, the virtual apparatus will superimposition on the marker.

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Figure 2.6 Card-based marker with slim handler

Figure 2.7 Box-based marker which has volume feeling

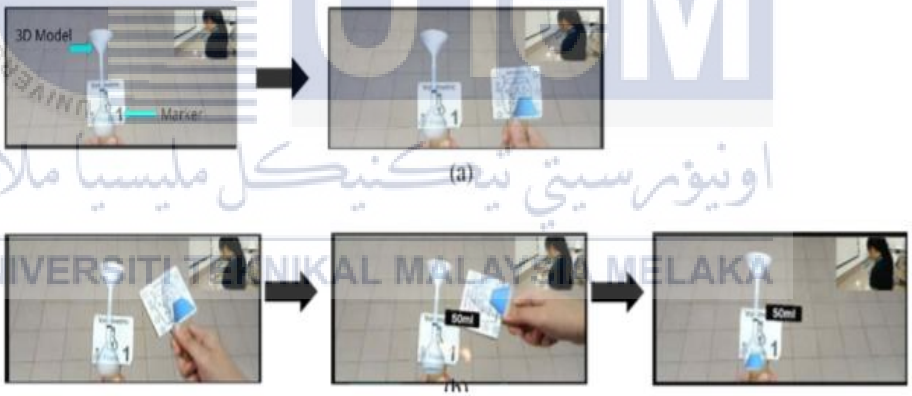

Figure 2.8 AR experiment

The project "A case study of Augmented Reality simulation system application in a chemistry course" by Su Cai, Xu Wang and Feng Kuang Chiang (2014) shows the development of an inquiry-based AR learning tool for the junior high school chemistry courses. By using this project, the students able to use the marker with camera's view. They can observe the AR model of the atoms such as hydrogen, oxygen and the others on the marker. They can also combine the hydrogen model and oxygen model to become the water molecules as shown in Figure 2.3.6.

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Figure 2.9 Marker-based AR hydrogen atom

Figure 2.10 One oxygen model and two hydrogen model

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Figure 2.11 The formation of water molecule AR

Other than that, Finsa Nurpandi and Agung Gumelar (2018) had conducted a project with title "Augmented Reality Chemical Reaction with User-Centered Design". This project allows the user to scan the atoms in periodic table using device especially camera, then the 3D atoms will appear on the marker. User can observe the reaction between atoms by combining multiple markers at once. In Figure 2.3.3.7, the hydrogen model and oxygen model combined to become water H2O.

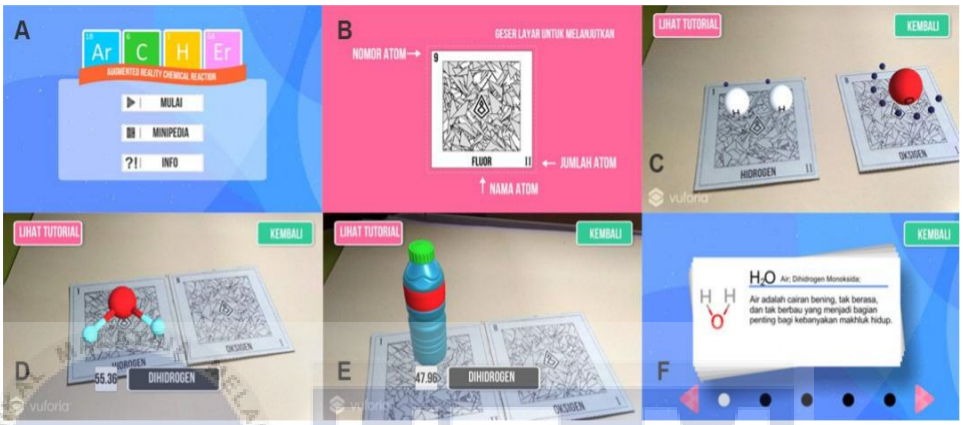

Figure 2.12 Interface of AR Chemical Reaction

2.3.1 Comparison of Existing System

Table 2.1 The comparison between the existing system

Existing system	Interactive Augmented Reality with Natural Action for Chemistry Experiment Learning (ARChemEx)	Augmented Reality simulation system application in a chemistry course	Augmented Reality Chemical Reaction with User-Centered Design.
Goal	-Allows student to keep repeating experiment to help them to understand the concept of the experiment and reduces the cost.	-Develop a set of inquiry-based AR learning tools.	-To help people learn chemical reaction only with the smartphones and cards that serve as markers.
Type of learning materials	Experiment	Theory	Theory

AR model	Apparatus and materials	Atom/Molecule	Atom/Molecule
Type of markers	Card-based and box-based marker	Card-based marker	Card-based QR code marker

2.4 Project Methodology

The methodology used in this project is Multimedia Development Lifecycle (MDL), which consists of five stages. These five stages are define, plan, implement, construct and evaluate.

i.Define

In this stage, the domain of the project is stated to solve the particular problem faced by the target user. After the idea of the project was decided, the following step is to search the research of the topic that related to the project. The importance of phase is to determine the goals of the project.

ii.Plan

This stage is important to analysis the background of the project to determine the scope and the project significant of the project. The objectives and the problem statement also determined. The project methodology is drafted to develop the project.

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iii.Implementation

In implementation stages, the software that will be used to develop the project is installed in the laptop. Then, the ideas of the features and component in the project are also determined before starting to develop the project.

iv.Construction

The 3D model of the project will be created by using Blender in this stages. After that, these model will be added to the unity to develop a complete AR application. The AR application will be tested to make sure there is no any technical

problems. When the application is completed, the demonstration and presentation will be taken.

v.Evaluate

The project will be evaluate by the target user to determine the effectiveness in this stage. The feedback from the target user will be used to improve the application. The report will be completed in this stage.

2.5 Project Requirements

2.5.1 Software Requirement

1. Adobe Photoshop
2. Blender
3. Unity
4. Microsoft word

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2.5.2 Hardware Requirement

1. Laptop
2. Smartphone

2.6 Conclusion

This chapter describes about the definition of augmented reality and type of augmented reality in the domain. Augmented reality can help the teacher to make the lecture become more interactive and improve the learning of the students. Besides, the project methodology and project requirement also discussed about the way to develop this project. The next chapter will discuss about the analysis of the project.

CHAPTER 3: ANALYSIS

3.1 Introduction

This chapter will analysis the study of the existing system that stated in Chapter 2. In this chapter, there will have two parts which are current scenario analysis and the requirement analysis. Besides, the project schedule and milestones will be discussed in this chapter.

3.2 Current Scenario Analysis

Based on the existing system in Chapter 2, these systems have the different scenario for the chemistry learning. Therefore, the systems are Interactive Augmented Reality with Natural Action for Chemistry Experiment Learning, Augmented Reality simulation system application in a chemistry course and Augmented Reality Chemical Reaction with User-Centered Design. The analysis will be explained for each systems.

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3.2.1 Interactive Augmented Reality with Natural Action for Chemistry Experiment Learning

This system is a chemistry experiment learning by AR with natural action. This system will has two different experiment learning type that the user can choose. For example, the user can choose whether they want to view the demonstration video or AR-based chemistry experiment for learning the experiment. For the AR-based chemistry experiment, the user need to scan the marker to present AR apparatus and combine the apparatus in front of camera to conduct the experiment.

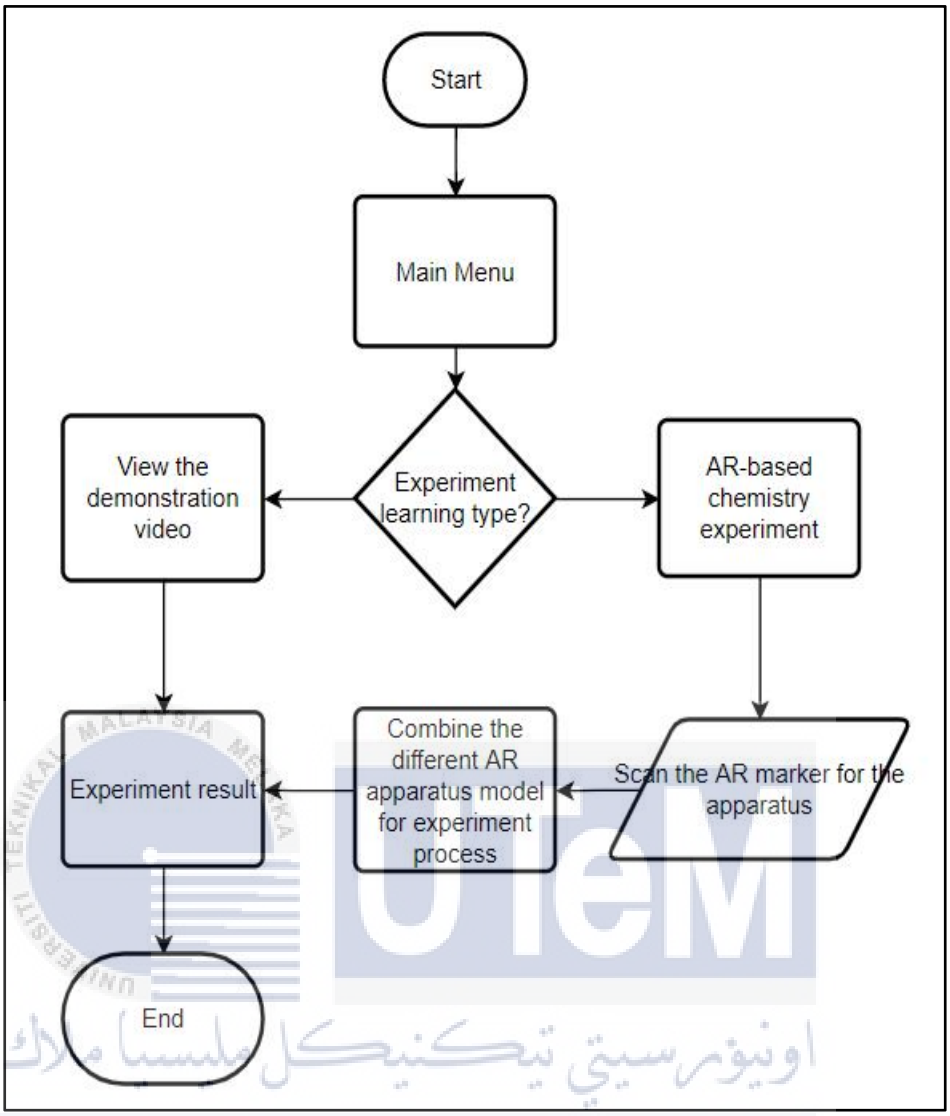

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Figure 3.1 Flowchart for Interactive Augmented Reality with Natural Action for Chemistry Experiment Learning

3.2.2 Augmented Reality simulation system application in a chemistry course

This system is the Augmented Reality simulation system application in a chemistry course. This system will need to use position of markers to present the different type of a structure and various combinations of atoms. For instance, the user can put the two hydrogen marker and one oxygen marker to combine as a water molecule model(H_20).

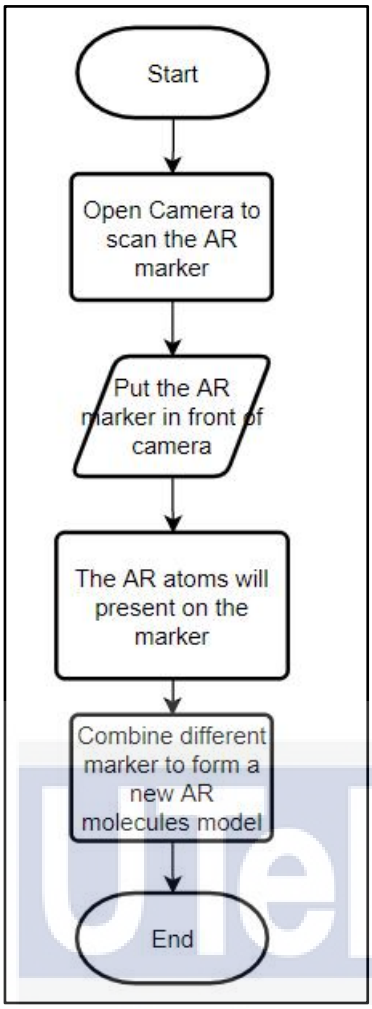

Figure 3.2 Flowchart for Augmented Reality simulation system application in a chemistry course

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3.2.3 Augmented Reality Chemical Reaction with User-Centered Design

This system is used to help the user to observe the reaction between atoms by combining multiple markers at once. First and foremost, this system will give the tutorial to user on how to scan the AR marker. Then, the user will need to open the camera for scanning these marker and also combine the different atom marker to form a molecule.

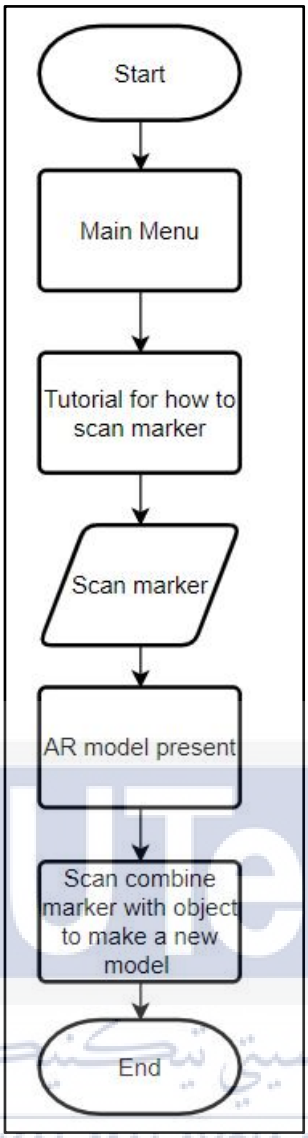

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Figure 3.3 Flowchart for Augmented Reality Chemical Reaction with User-Centered Design

3.3 Requirement Analysis

The requirement analysis is the process of defining the user's expectations for an application that will be modified. In this analysis, the requirements needed will be explained such as project requirement, software requirements and hardware requirements.

3.3.1 Project Requirement

There are different type of requirements had been analyzed in this project requirement. Some requirement gathering used to collect the data from the user with specific techniques.

3.3.1.1 Requirement Gathering

In this project, the techniques used to collect the data is the survey methods. The methods used are qualitative and quantitative methods. The qualitative method is interview. The target of interview is a Form 5 Chemistry teacher. The quantitative method is a set of questionnaire by using Google Form. The respondents for this questionnaire are Form 5 students.

(a) Interview

An interview is conducted with one Form 5 Chemistry teacher who come from SMK Sultan Ibrahim, Kulai, Johor. Some important information collected from this interview. The language used for Form 5 students to learn chemistry is Malay. Teacher stated that the school now have not enough materials and apparatus for each student to conduct the experiment by themselves. The students need to get into a group of 3 person or 4 person to conduct the experiments. Teacher also explained that the school will not give the opportunities for the students to conduct the electrolysis experiment. This is because the electrolysis experiment released the toxic gas. In school, the students do not have enough time to repeat the same experiment in the lab session. Teacher says that she does not used any augmented reality application before. Teacher also agree with virtual experiment by using augmented reality will help students to learn the chemistry experiment easily and able repeat the experiment many times. Since the students in school do not have the chance to do electrolysis, teacher stated that the virtual experiment by augmented reality will give the benefit to student to conduct the electrolysis experiment.

(b) Questionnaire

The questionnaire below distributed to Form 5 students by using Google Form in order to collect the data about their feedback on chemistry experiment and augmented reality. In this questionnaires, there are 3 sections and total of 13 questions will be asked.

For this questionnaire, total amount of 32 respondents filled out the questions. There are 15 of male respondents(46.9%) and 17 of female respondents(53.1%). Most of the respondents are Chinese(59.4%). 31.3% of respondents are Malay and 9.4% of respondents are India. Figure 3.4 below shows the data collection for gender and race of the respondents.

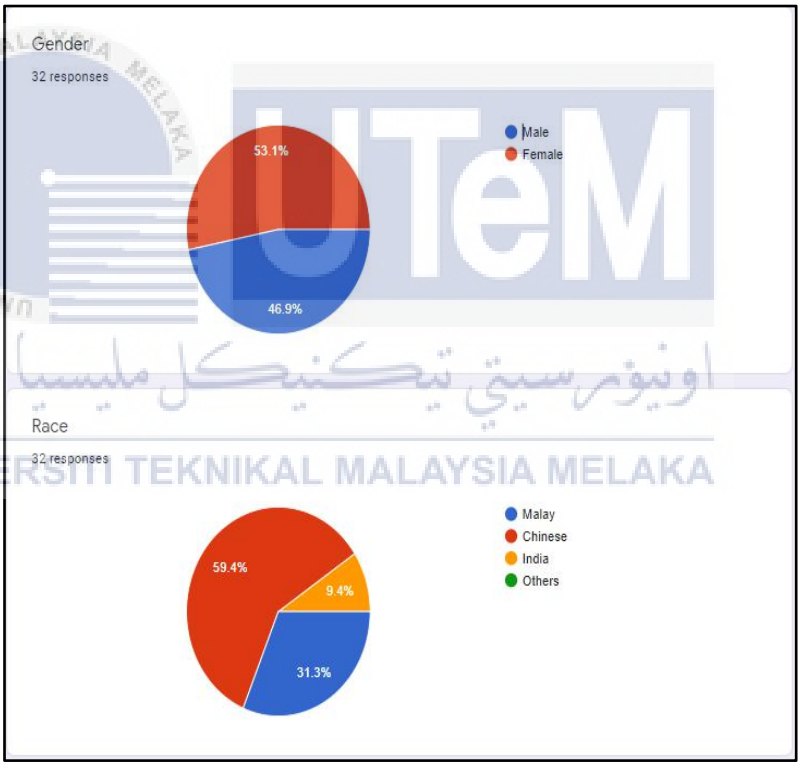

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Figure 3.4 Gender and Race of respondents

In section 2, the questions below are asked to collect the feedback of the respondents on the chemistry experiments in school. There are 25 of respondents(78.1%) always remember the rules of the laboratory. 21.9% of respondents do not remember all the rules of the laboratory during their chemistry

lab. Figure 3.5 shows the data collection for does the respondent remember all the rules of the laboratory.

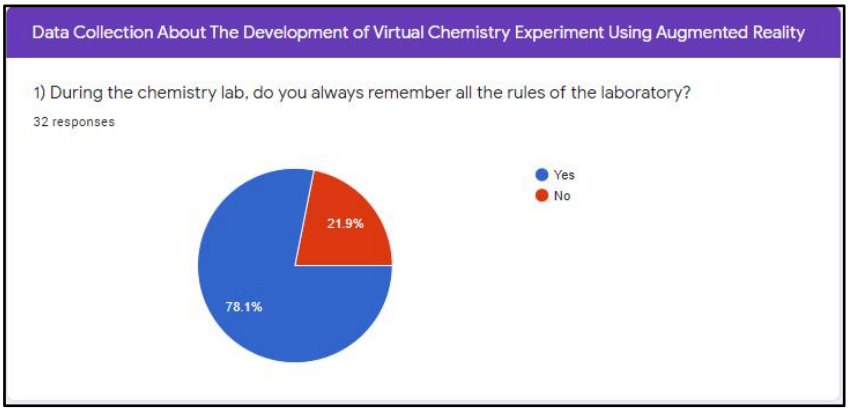

Figure 3.5 During the chemistry lab, does the respondents always remember all the rules of the laboratory?

There are half of the respondents recognize the name and the look of the apparatus for every experiment. The other half of respondents do not remember these apparatus. This can conclude that some of the students does not remember the apparatus after conducting the experiment in school laboratory. Figure 3.6 shows the pie chart for does the respondents recognize or remember all the apparatus with its name and looks for every experiment.

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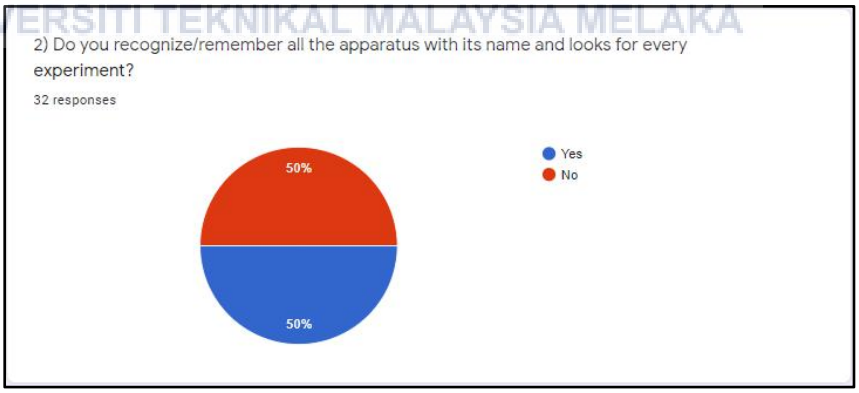

Figure 3.6 Does the respondents recognize or remember all the apparatus with its name and looks for every experiment?

Figure 3.7 shows 62.5% of 20 respondents agree that they do not have enough time to repeat the same experiment during lab session. There are 37.5% of 12 respondents able to repeat the experiment during lab session. This can conclude that

most of the student unable to repeat the same experiment during lab session and this will make them difficult to understand the concept of the experiment. This is because some of the respondents will fail to carry out the output of the experiment and they do not have the chance to repeat that experiment in two hours.

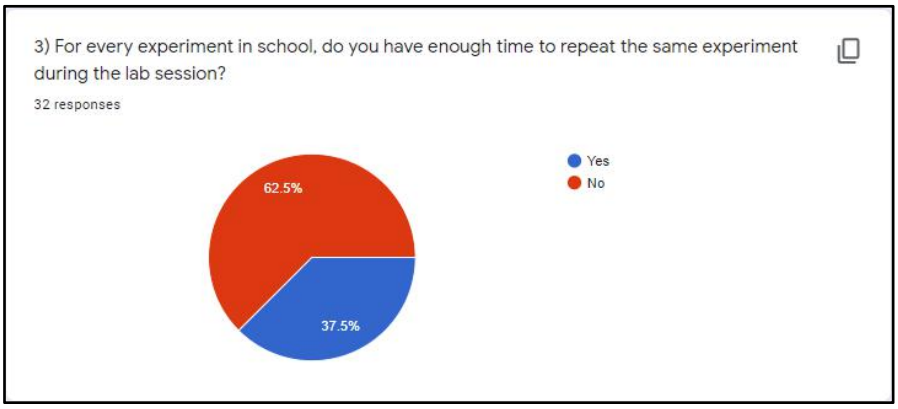

Figure 3.7 For every experiment in school, does the respondent have enough time to repeat the same experiment during the lab session?

There are 65.6% of 21 respondents agree that the school provide them the opportunities to conduct all the experiments in the chemistry syllabus and 34.4% of 11 respondents do not agree. Figure 3.8 is the pie chart for does the school provide the opportunities for students to conduct all the experiment in the syllabus.

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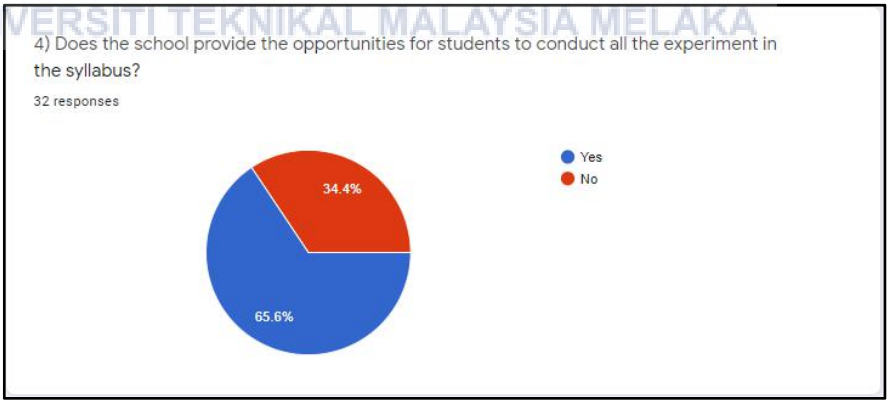

Figure 3.8 Does the school provide the opportunities for students to conduct all the experiment in the syllabus?

Most of the respondents(53.1%) stated that their school have not enough materials and apparatus for each student to conduct the experiment and they need to be in group for every experiment to share these materials and apparatus. This shows that no anyone cannot do the experiment by themselves. If the students do the experiment in group, some of the students will let their group member to conduct most of the part of experiment. In this case, they do not participate in that experiment and just wait the result of the experiment. Figure 3.9 shows the pie chart for does the school have not enough materials and apparatus for each student and the students need to conduct the experiment in group.

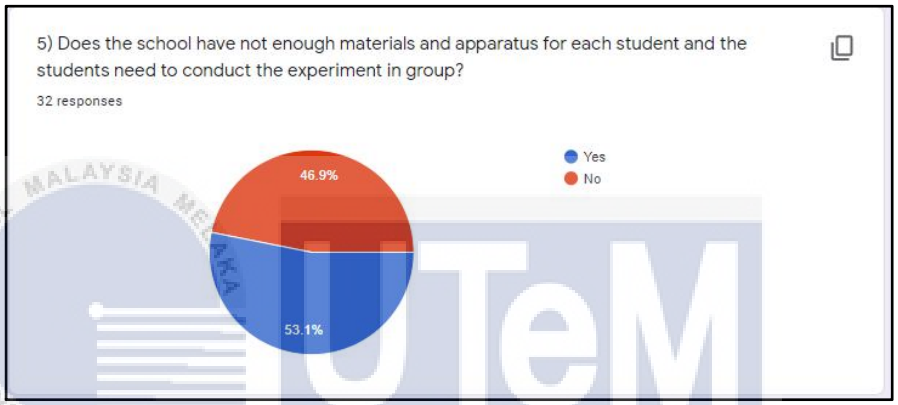

Figure 3.9 Does the school have not enough materials and apparatus for each student and the students need to conduct the experiment in group?

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Section 3 contains the questions about the use of augmented reality in learning of experiment to collect the feedback from the respondents to state whether the virtual chemistry experiment by augmented reality will benefit them or not. There are 53.1% of 17 respondents know about augmented reality and 46.9% of 15 respondents do not know about augmented reality. Figure 3.10 is the pie chart for does the respondents know what is augmented reality(AR)?

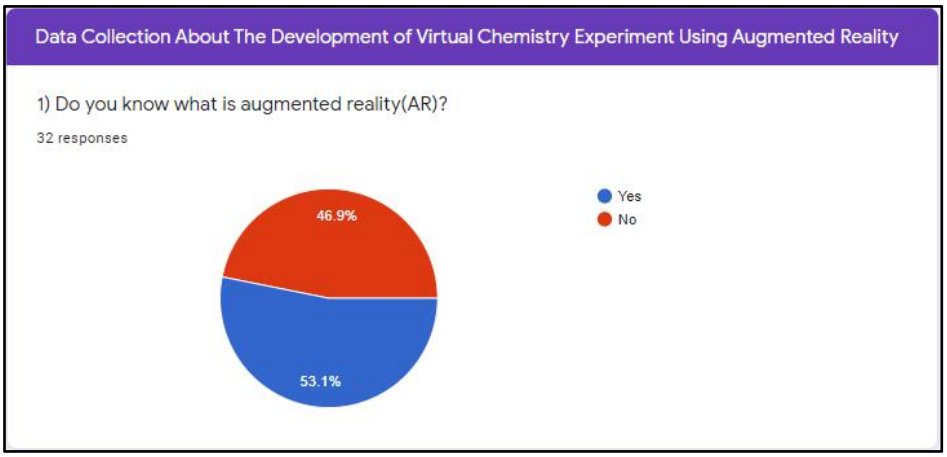

Figure 3.10 Does the respondents know what is augmented reality(AR)?

Most of the respondents(87.5%) do not use the augmented reality to learn the knowledge in past. This can concluded that the school have not start to use augmented reality in teaching and mostly just learning in textbook. Figure 3.11 is the pie chart for has the respondent learned the knowledge by using augmented reality(AR) in past.

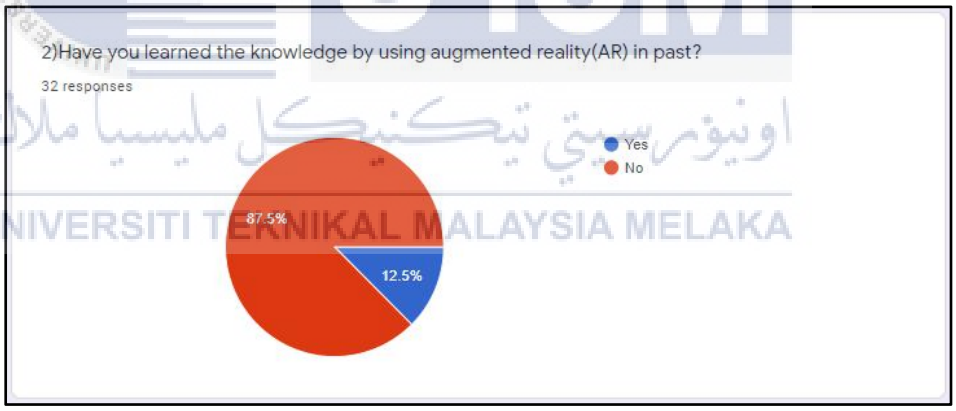

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Figure 3.11 Has the respondent learned the knowledge by using augmented reality(AR) in past?

All of the respondents think that the use of 3D model or augmented reality in learning knowledge is more better than learning on textbook. Figure 3.12 show the pie chart for does the respondent think that learning the knowledge by using the 3D model or AR is more better than learning on textbooks.

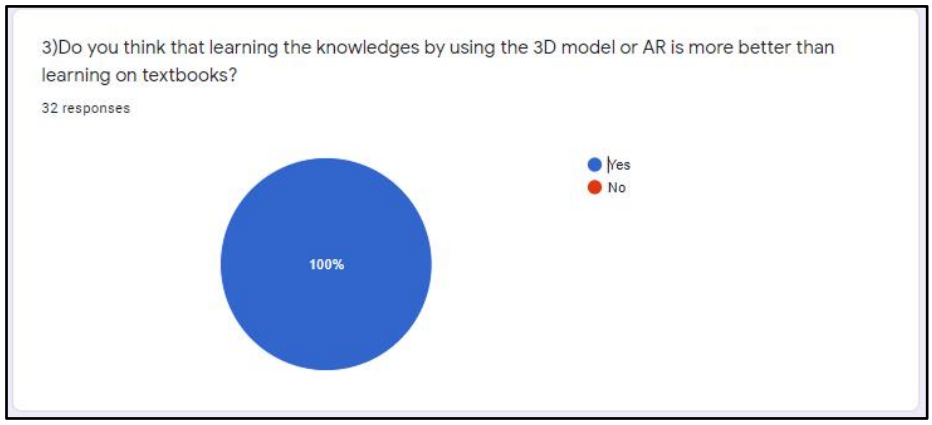

Figure 3.12 Does the respondent think that learning the knowledge by using the 3D model or AR is more better than learning on textbooks?

There are 93.5% of 29 respondents agree that augmented reality application will help them to repeat the experiment for many times. This is because the repeat of experiment will help them more understand about that experiment. Figure 3.13 is the pie chart for AR application will help students to repeat the experiment many times and this can help them more understand about the experiment.

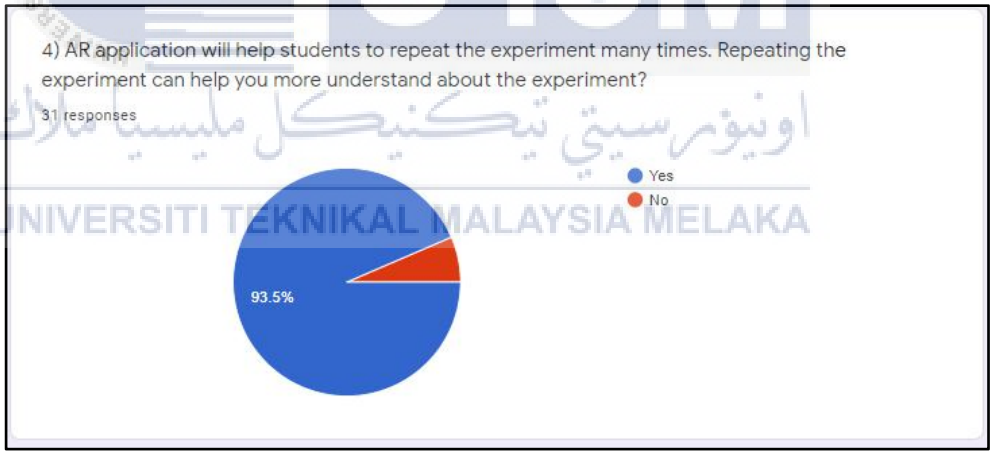

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Figure 3.13 AR application will help students to repeat the experiment many times and this can help them more understand about the experiment?

In question 5, 96.9% of 31 respondents stated that augmented reality application can improve the student's understanding on the experiment by the 3d model. This can conclude that they mostly need the new technology to learn the new thing compared to just read the textbook. Figure 3.14 is the data collection from

respondents for does the respondents think that the augmented reality application can improve the student's understanding on the experiment by the 3d model.

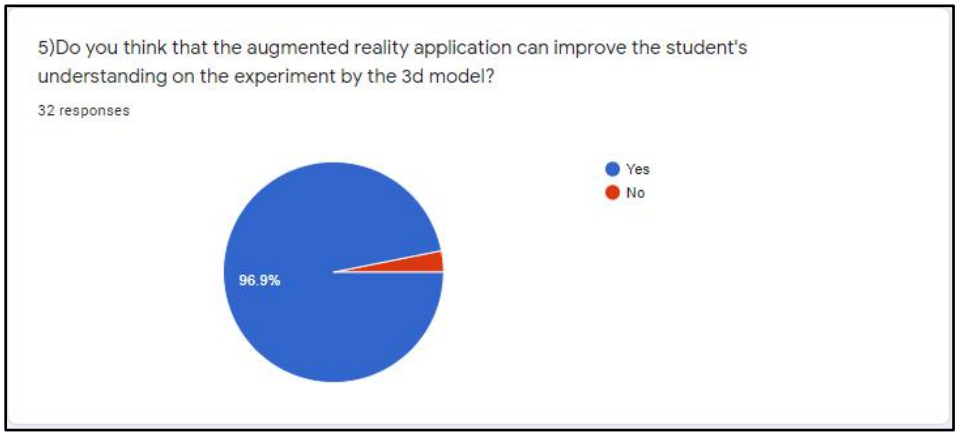

Figure 3.14 Does the respondents think that the augmented reality application can improve the student's understanding on the experiment by the 3d model?

For the last question, there are 78.1% of 25 respondents agree that the virtual chemistry experiment by augmented reality can help them to conduct the experiment that may be dangerous as shown in Figure 3.15.

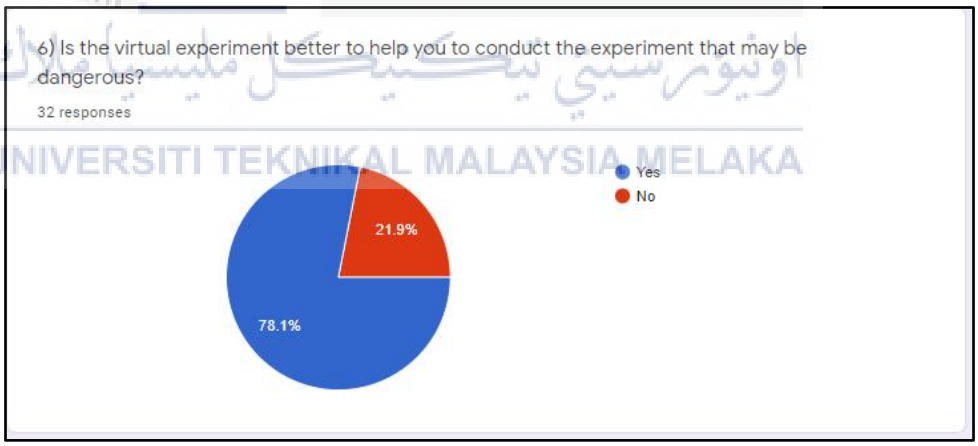

Figure 3.15 Is the virtual experiment better to help you to conduct the experiment that may be dangerous?

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3.3.2 Software Requirement

There are some software used in this project for the development and documentation of the project. In the development of the project, different software that will be used are Unity, Blender, Adobe Photoshop and Android Studio. Microsoft Word and Microsoft PowerPoint will be used in the documentation of the project.

3.3.2.1 Software Development Requirement

i.Unity

Unity used to build the augmented reality application by combining the elements used such as 3D model, images and the others.

ii.Blender

In this project, Blender used to build the 3d model of the apparatus and materials for the experiment. This software also help in making the animation of the apparatus and material model.

iii.Adobe Photoshop

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Adobe Photoshop used to design the interface background images.

3.3.2.2 Software Documentation Requirement

i.Microsoft Word

Microsoft Word used to prepare the elements of the proposal and the final report.

ii.Microsoft PowerPoint

Microsoft PowerPoint used to present the final report by using text, picture, table and chart.

3.3.3 Hardware Requirement

3.3.3.1 Laptop

The minimum requirement for the laptop is 8GB RAM with CPU performance of Intel i5-4 core and also the graphics card of GeForce GTX 16 series to support the development of this application.

3.3.3.2 Mobile Phone

The mobile phone with camera function used in this project to scan and access the AR virtual model. The mobile phone also need to has at least Android 7.0 above.

3.3.4 Other Requirement

i.Google Form

Google Form used to collect the data of questionnaire from the respondents.

3.4 Project Schedule and Milestones

Project schedule and milestone is the element for the project to determine the way of starting the development of the project. It contains the project progress and make sure each phase can be done on time. Figure 3.16 is the Gantt Chart for project.Table 3.1 below is the milestone of the project,

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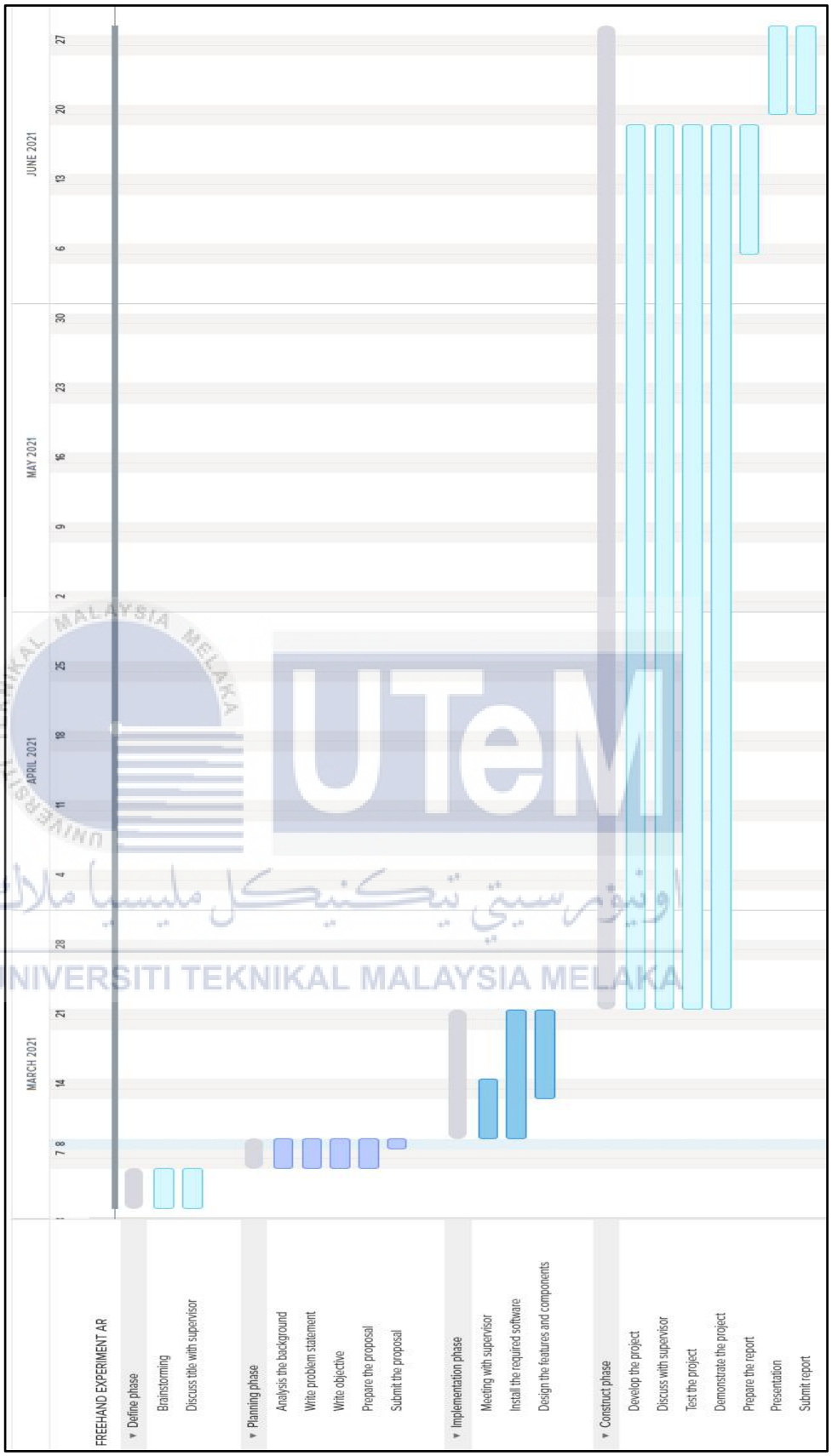

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Figure 3.16 Gantt Chart of the project

Table 3.1 Milestones of the project

Activity	Duration	Start Date	End Date
Define phase			
Brainstoming	4 days	2/3/2021	5/3/2021
Discuss with supervisor	4 days	2/3/2021	5/3/2021
Planning phase			
Analysis the project background	3 days	6/3/2021	8/3/2021
Write problem statement	3 days	6/3/2021	8/3/2021
write objective	3 days	6/3/2021	8/3/2021
prepare the proposal	3 days	6/3/2021	8/3/2021
submit the proposal	1 day	8/3/2021	8/3/2021
Implementation phase			
Meeting with supervisor	6 days	9/3/2021	14/3/2021
Install the required software	12 days	9/3/2021	21/3/2021
Design the features and components	9 days	13/3/2021	21/3/2021
Construct phase			
Develop the project	89 days	22/3/2021	18/6/2021
Discuss with supervisor	89 days	22/3/2021	18/6/2021
Test the project	89 days	22/3/2021	18/6/2021
Demostrate the project	89 days	22/3/2021	18/6/2021
Prepare the report	13 days	6/6/2021	18/6/2021
Presentation	9 days	20/6/2021	28/6/2021
Submit the report	9 days	20/6/2021	28/6/2021

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3.5 Conclusion

As a conclusion, this chapter analyzed the requirements that needed for the development of project. The project schedule and milestone also prepared to make sure every step of the development process can be done on time. In the next chapter, the design of the project will be explained.

CHAPTER 4: DESIGN

4.1 Introduction

This chapter will discussed about the design of the project. The storyboard, logo design and the others will be explained clearly. In this phase, there are three parts which are system architecture, preliminary design and user interface design.

4.2 System Architecture

The system architecture is a conceptual representation of the components and sub-components that show the overall behaviour of a system. As the "ARCHEM" application is the marker-less based augmented reality application, so the user will view the model on the screen of their phones. User can use their phone's camera to detect the AR model.

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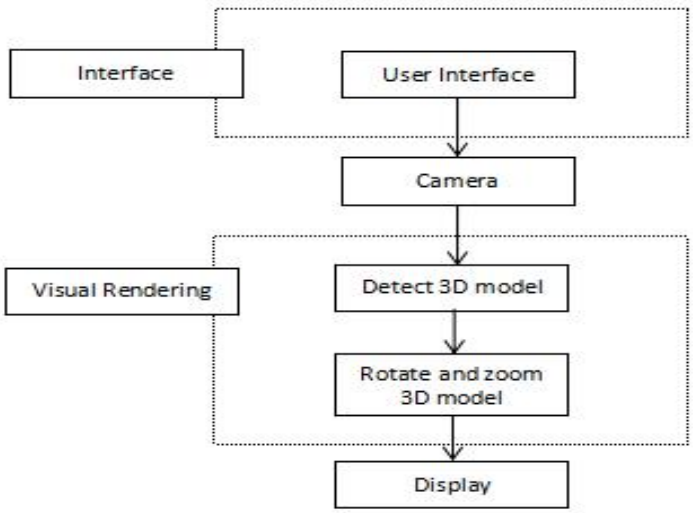

Figure 4.1 The system architecture of mobile application

4.3 Preliminary Design

4.3.1 Interactive Storyboard

Table 4.1 shows the interactive storyboard of the “ARCHEM” application. First and foremost, the user will enter the first interface of “ARCHEM”. The user will able to click the start to next interface. The second interface is the main menu of this application with three buttons which are lab rules, experiment and the instruction button(“How to use”). If the user click “lab rules”, they will go to the rules interface. In this interface, they can read the rules with the image that able to let them understand and remember the rules of the laboratory as shown in image 3. Image 4 shows the “how to use” interface. If the user want to click experiment, they will enter the interface in image 5. There will have three different experiments buttons for the user to choose. After choosing one of the experiment, they will go to the interface with three buttons which are AR apparatus, procedure and report. Image 7 is the interface with the list of apparatus picture and the user can choose any apparatus to show the AR model on the screen. Image 10 is the procedure interface that will have the animation of the apparatus model to show the procedure of the experiment step by step. For the “report” button, there will have all the result from that experiment to let user to do revision easily.

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Table 4.1 Interactive Storyboard of ARCHEM application

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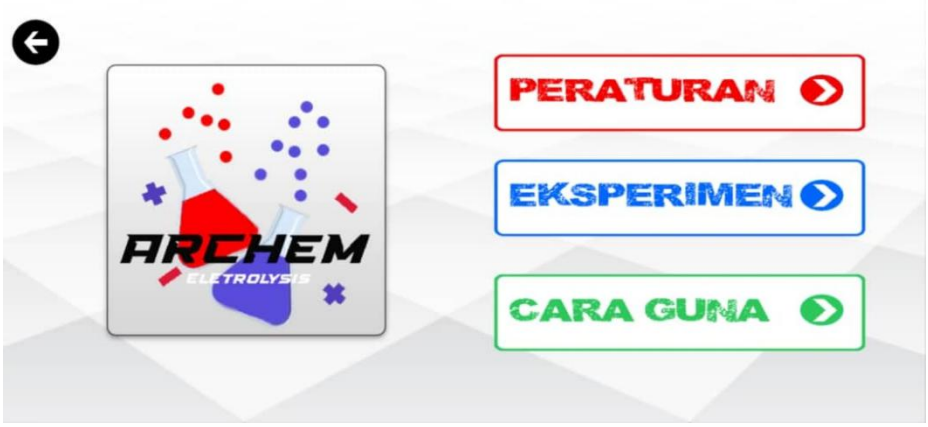
2.



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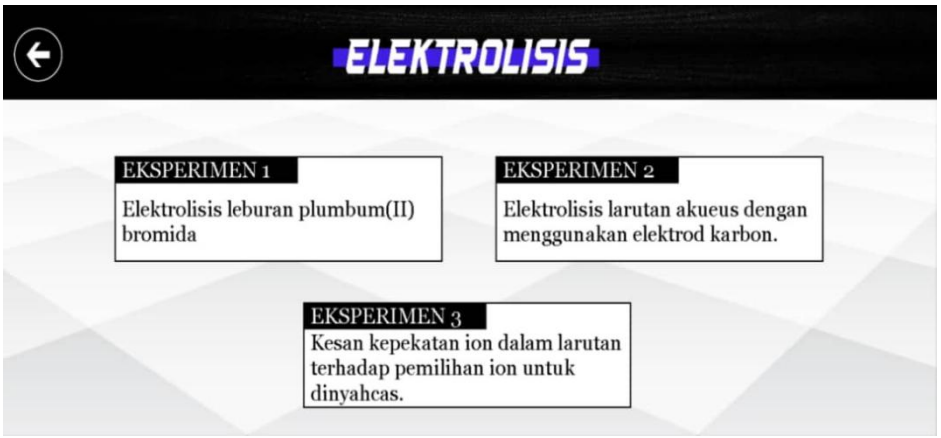

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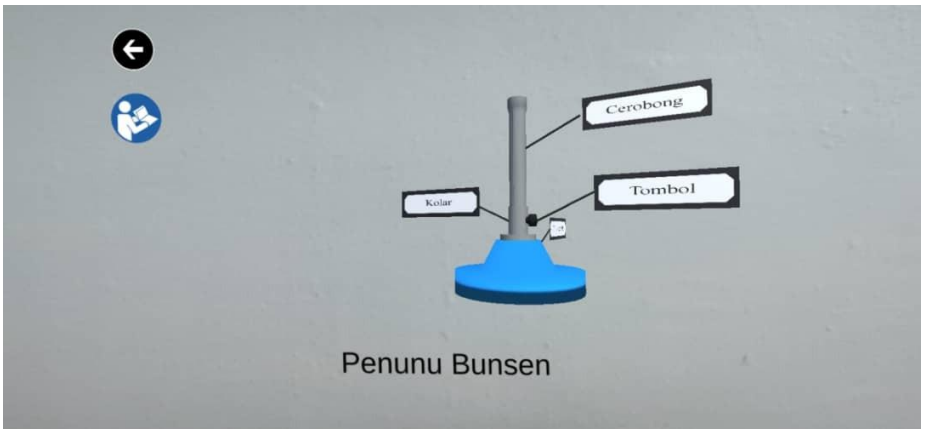

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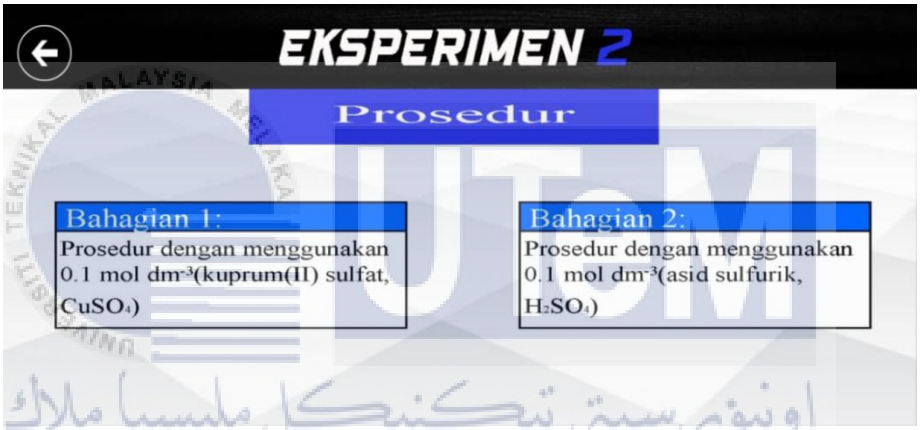

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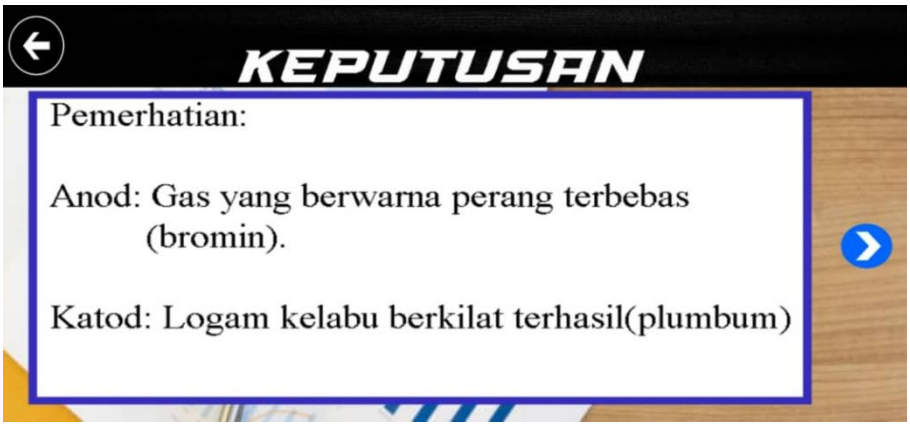
10.

11.



4.4 User Interface Design

4.4.1 Navigation Design

Navigation design is important to navigate the flow of the application in the development of the project. The good navigation design will help user to use the application in the easy way. Figure 4.2 is the flowchart for this application.

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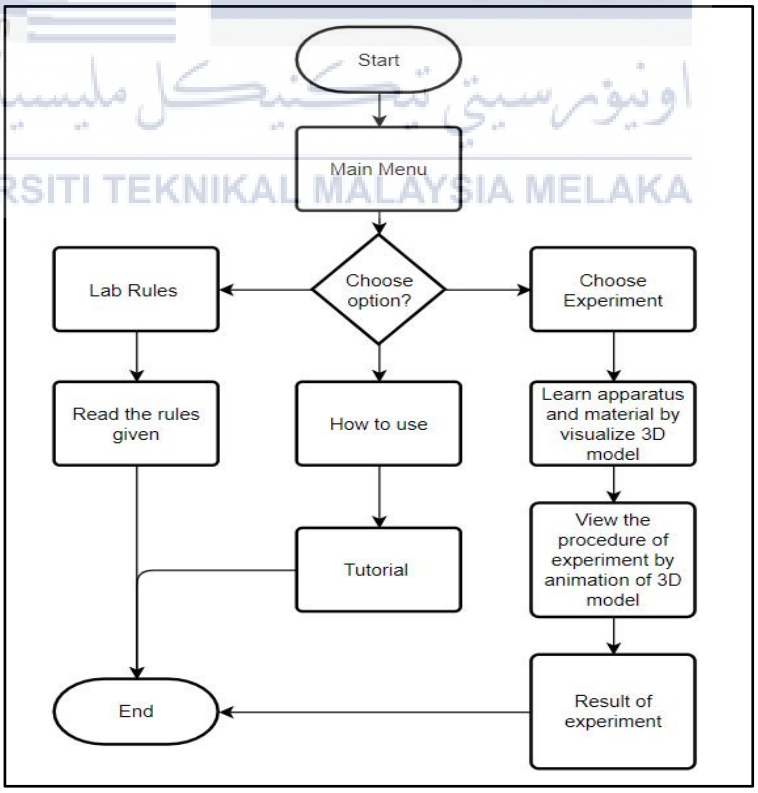

Figure 4.2 Flowchart of the mobile application

4.4.2 Logo Design

The logo of the mobile application was designed with combining the augmented reality and chemistry as "ARCHEM". In the design, the beaker with chemical is aimed to let the user know that the system is an AR chemistry experiment application. The word "Electrolysis" is located at the below of the logo name because this application will only has the experiment about electrolysis.

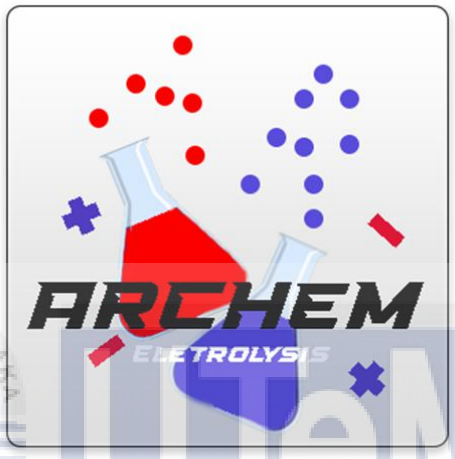

Figure 4.3 Logo of ARCHEM mobile application

4.4.3 Three-Dimensional Model Design

The apparatus and materials were designed in the 3D model to help the user to remember each apparatus and material. Other than that, these apparatus and materials model will be used in the virtual chemistry experiment which is the user can able to view the procedure of the experiment in 3D animation. This will make them easy to learn on how to conduct the experiment. For example, the switch model in Figure 4.4 and beaker model in Figure 4.5.

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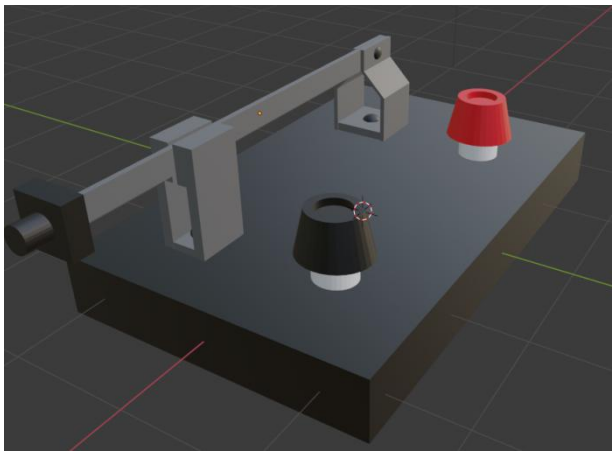

Figure 4.4 3D Switch model

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Figure 4.5 3D beaker model

4.5 Conclusion

In conclusion, all the design phases of the project are discussed in this chapter. A good design of the elements in this project is very important to let the user experience it with a good quality. The next chapter will discuss about the project implementation.

CHAPTER 5: IMPLEMENTATION

5.1 Introduction

In this chapter, implementation phase of the project will be discussed. This phase describe the media creations which are production of texts, graphics, modelling and animation. The media integration will explain the process of combination of all the elements in multimedia. In addition, the product configuration management and implementation status will also be explained in this chapter.

5.2 Media Creation

Media creation contains the various production of media which are production of texts, graphics, modelling and animation.

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5.2.1 Production of Texts

This section will describe the use of texts, font style and the font size that applied in the application. There are some different type of font style used.

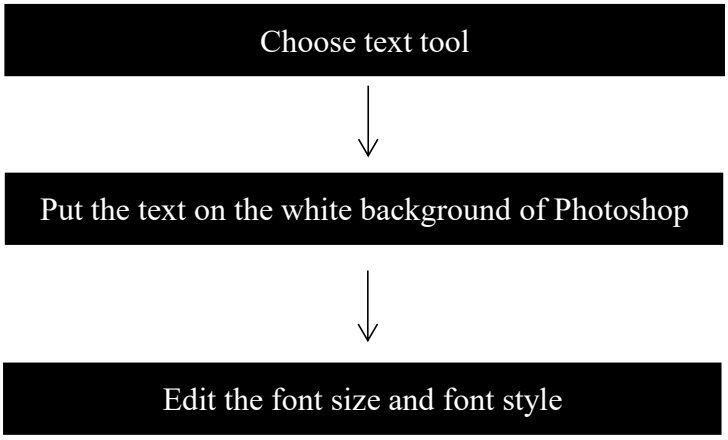

Figure 5.1 Step to create the text in Adobe Photoshop

Table 5.1 Production of tests

No	Font style	Size	Example
1	A Big Deal	60	MULA
2	Terremoto	60pt	PERATURAN
3	Times New Roman	48pt	3) Mengikat rambut panjang.
4	High Speed	48pt	PERATURAN
5	Arial	30pt	Masuk ke halaman peraturan

5.2.2 Production of Graphics

The application used the layout with the interface design such as the background, button, logo, title image and the others. In this project, the graphics design will be created in Adobe Photoshop and then export to Unity to complete the interface design.

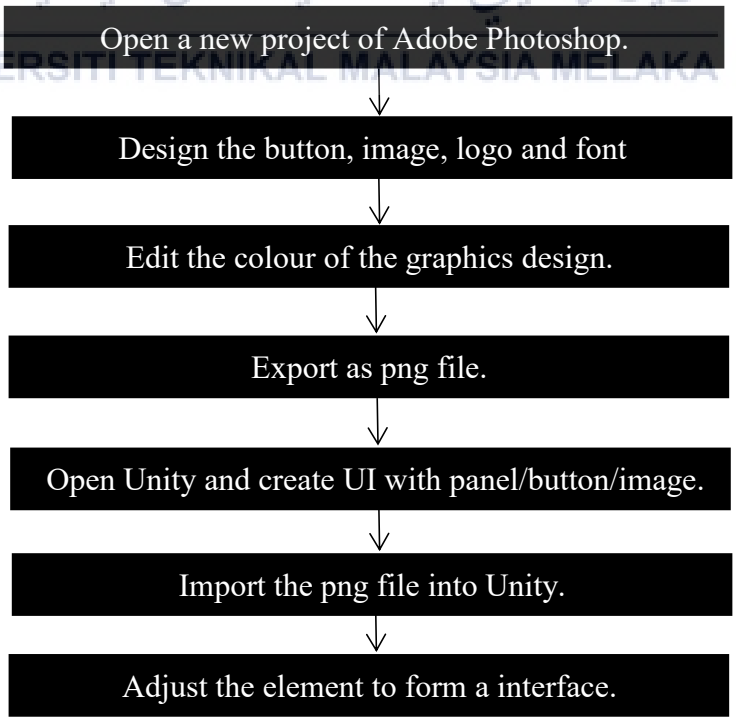

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Figure 5.2 Step to create the graphics from Adobe Photoshop to Unity

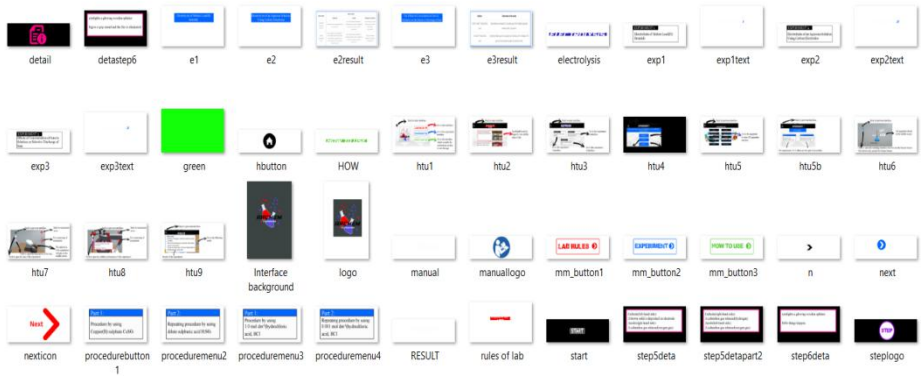

Figure 5.3 The graphics designs created

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Figure 5.4 The interface design by adding the different graphics design in Unity

5.2.3 Production of Modelling

Production of modelling include the modelling and texture of the 3D model. These 3D model will be created by using Blender and exported as fbx files. Then, the fbx will be imported into Unity.

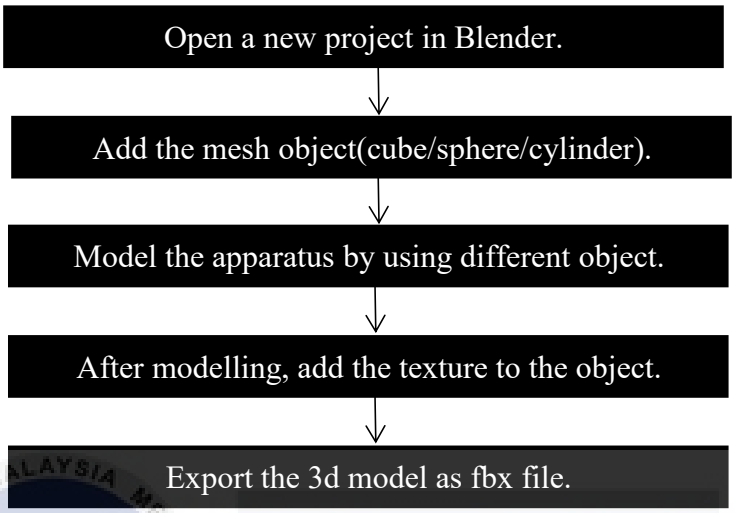

Figure 5.5 Step to create the 3d model in Blender

Figure 5.6 Model the apparatus by different objects

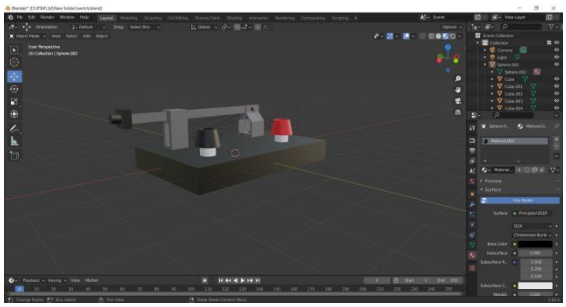

Figure 5.7 Texturing the model

5.2.4 Production of Animation

The most important in this project is the AR experiment which requires the animation of the 3d apparatus to form a complete procedures of the experiment. The animation created in Blender and exported to fbx file. In unity, the animation will be imported.

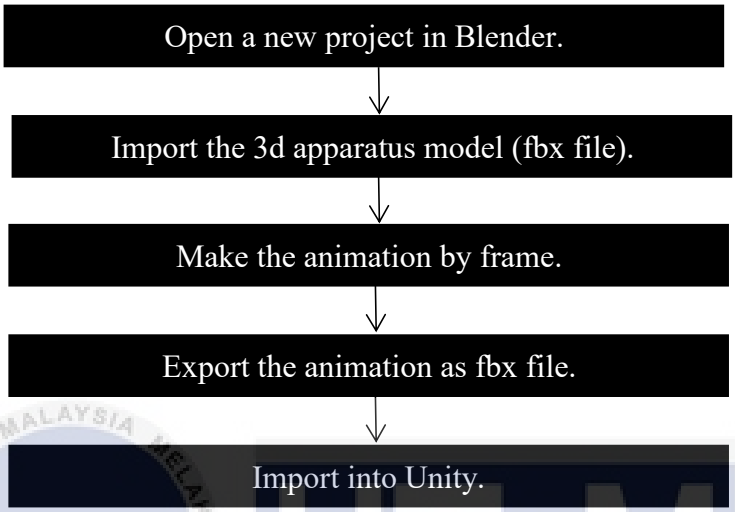

Figure 5.8 Step to make the animation in Blender and export to Unity

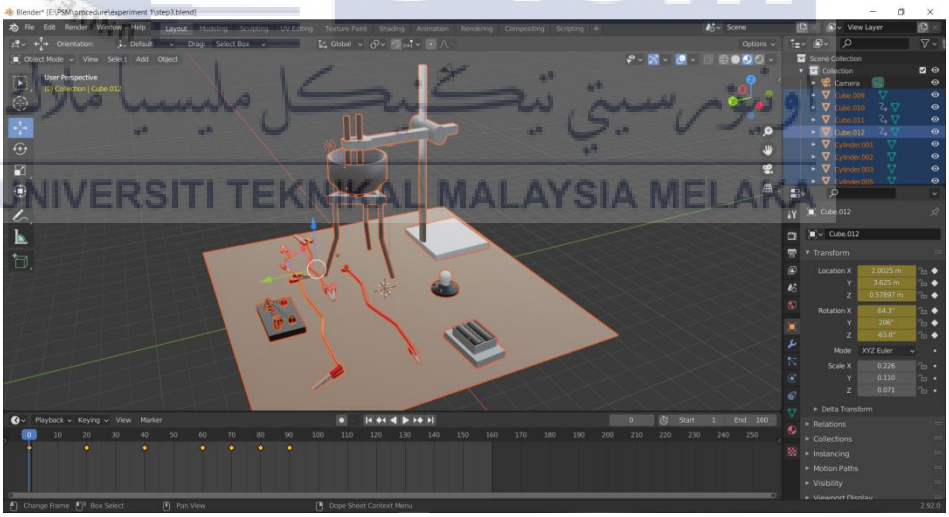

Figure 5.9 Animation created by flame in Blender.

5.3 Media Integration

The text and graphics design created in Adobe Photoshop will be exported as png file and then imported into Unity. The 3d apparatus model and 3d animation will also exported as fbx files from Blender to Unity. After these media imported into Unity, the mobile application will start to build and executed into android phone.

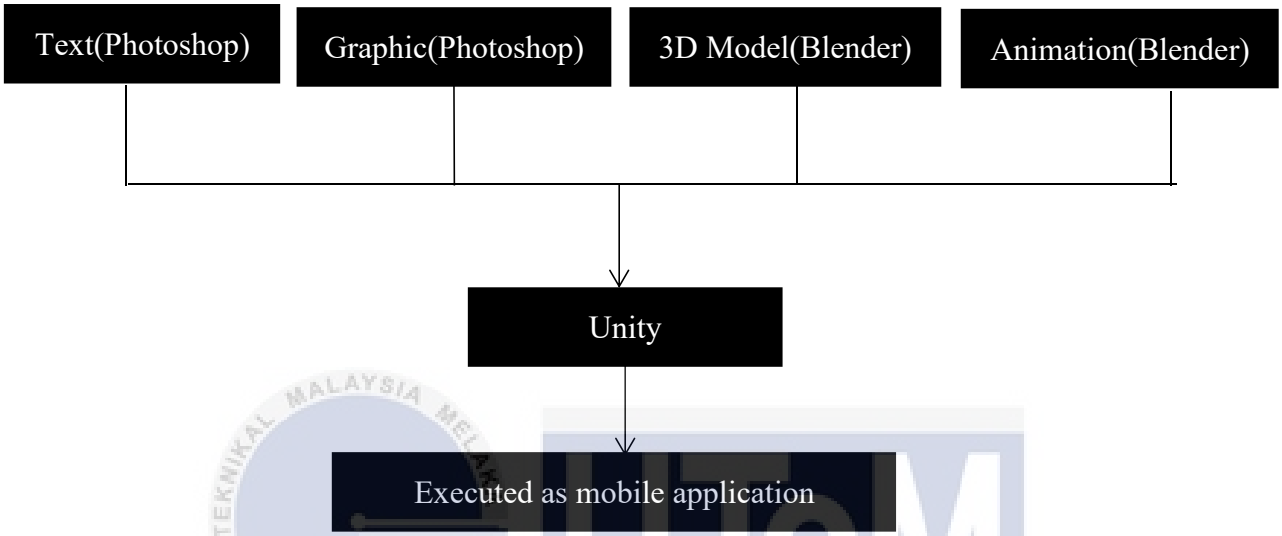

Figure 5.10 Media Integration process

5.4 Product Configuration Management

5.4.1 Configuration Environment Setup

In this section, the configuration environment setup of the mobile application will be explaining. The process to setup in android smartphone is to connect the phone as the running device in the Unity and click “Build and Run” to download the apk file of application on the smartphone. The step below shows the configuration environment setup.

Step 1:

First, change the Huawei P30 into developer mode by going to Setting > About Phone and tapping on the build number 5 times. Then, select “Input MIDI” option in the phone when connect USB to laptop. Go to Setting and select Additional Settings > Developer Options. Allow “USB Debugging” in the phone.

Step2:

Save the progress of the project in Unity and go to File > Build Setting. Add all the scene needed by clicking “Add Open Scene”.

Step3:

In Build Setting, click the lower left corner “Player Settings”. After entering the Player Settings, change the product name to ARCHEM and change the default icon to the logo of ARCHEM. Ensure the minimum API level is at least Android 4.4.

Step 4:

Click “Build and Run” and select the running device to build the application. When the export process is done, the apk file will automatically installed and run in the phone.

5.5 Implementation Status

In this section, the implementation status will list down the development process of the project. The table below show the implementation status to make sure the developer able to finish the project in time.

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Table 5.2 Implementation status of the project

No	Task	Duration (Days)	Date Completed	Status
1.	Define Phase	4	5/3/2021	On-time
2.	Planing Phase	3	8/3/2021	On-time
3.	Project Design			
	Decide the experiment that to develop	27	2/4/2021	On-time
	Flowchart	27	2/4/2021	On-time
	Storyboard	27	2/4/2021	Delayed
4.	Project Implementation and			

	Development			
	Modelling apparatus for first experiment	35	7/5/2021	In-time
	Animation for first experiment	35	7/5/2021	Delayed
	Design the graphics media In Photoshop	7	14/5/2021	On-time
	Create the interface 1 in Unity	7	14/5/2021	On-time
	Modelling apparatus for the second & third experiment	28	11/6/2021	In-time
	Animation for second & third experiment	28	11/6/2021	Delayed
	Completing all the interface	7	18/6/2021	Delayed
5.	Evaluate phase			
	Project testing	-	-	-
	Project Improvement	-	-	-
	Presentation	-	-	-

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5.6 Conclusion

As a conclusion, all the implementation phase of the project discussed. The media creation, media integration, configuration management and the implementation status of the project also explained clearly.

CHAPTER 6: IMPLEMENTATION

6.1 Introduction

This chapter will discuss about the testing phase of this project. There are test user, experts, test environment and test schedule involved in this phase. When the test data collected, analysis of the test will be undergo to identify the results. This testing phase aims to determine whether this application can meet the objectives of the project and show the effectiveness of the project in learning the electrolysis experiment.

6.2 Test Plan

6.2.1 Test user

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In this testing phase, the test users involved are subject matter experts (SME) and end users. SME are the person who will use their professional knowledge in Chemistry to evaluate the content of the application whether it is functionality or not. For example, the SME involved in this testing are the Chemistry teacher from secondary school. For the end users, they are Form 5 science students who will study the electrolysis in their syllabus. As the electrolysis experiment will release harm gas, these end users will only learn this experiment on textbook only. Therefore, they will be tested through two tests with different learning methods which are textbook and ARCHEM application.

6.2.2 Test environment

For the test environment, there will have two different testing conducted separately for SME and end users. The user acceptance testing for SME will be test based on the functionality of the application. In the user acceptance testing, there are four parts which are content, learnability, accessibility and the interface design. The testing will be conducted through online because of the Covid-19 pandemic. SME will download ARCHEM application with the apk file given. After testing ARCHEM, SME will answer the user acceptance testing by using Google form.

For end user, they will be tested by pre-test quiz and post-test quiz to make the comparative test through Google form. Both quizzes contain 10 different questions with the same level. The end-user will be given 30 minutes to read the three different electrolysis procedures in textbook. After 30 minutes, they will start answering the pre-test quiz in 15 minutes. Then, the ARCHEM apk file will be given for the end users to use it in 30 minutes to learn electrolysis experiment. The post-test will be tested through Google form in 15 minutes. When they finished both quizzes, they need to answer the user acceptance testing which is different with the user acceptance testing of SME in 10 minutes.

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6.2.3 Testing Schedule

Test schedule is a schedule that show the flow of all the testing with date and duration.

Table 6.1 Test Schedule

Task	Date	Duration
UAT (SME)	27/8/2020-28/8/2020	10 minutes
Pre-test	24/8/2020-28/8/2020	15 minutes
Post-test		15 minutes
UAT (End user)		10 minutes

6.2.4 Test Script and Design

Test script is a set of instructions that will be performed on a system under test to test the system functions as expected. There are two different test scripts prepared for the experts and end user separately. First and foremost, 3 experts which are the Chemistry teachers from SMK Sultan Ibrahim are needed to test the AR application. The experts will be given the apk file of ARCHEM and download it on the phones. After the experts finished the experience of using ARCHEM, they will need to answer the user acceptance testing(UAT) in 10 minutes.

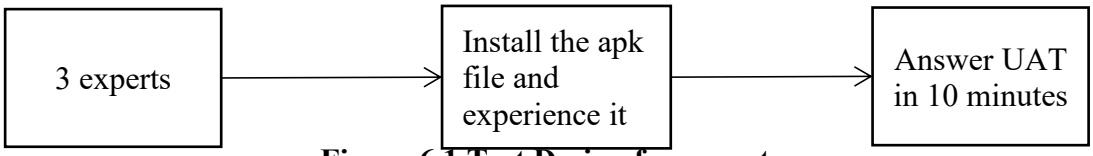

Figure 6.1 Test Design for experts

For the end user testing, there are 30 respondents which are Form 5 students from SMK Sultan Ibrahim will need to test the pre-test, post-test and UAT. The respondents will be given 30 minutes to study the electrolysis experiment on textbook. After that, the respondents need to answer the pre-test quizzes in 15 minutes. Then, the respondents will be given the apk file of ARCHEM to experience it in 30 minutes. The respondents will need to answer post-test in 15 minutes after using ARCHEM. Last, the respondents need to answer the UAT for end user in 10 minutes.

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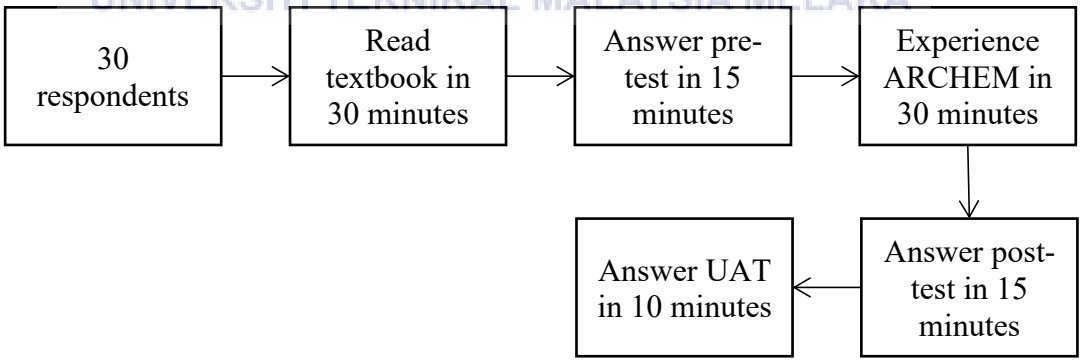

Figure 6.2 Test Design for end user

6.3 Test Strategy

6.3.1 User Acceptance Test (UAT)

The user acceptance test is used to test the ARCHEM application to identify whether marker-less based AR can help in learning the electrolysis experiment. This testing also include four parts of content, learnability, accessibility and interface design. The likert scale for the test is from 1 (Strongly disagree) to 5 (Strongly agree).

User Acceptance Test for SME

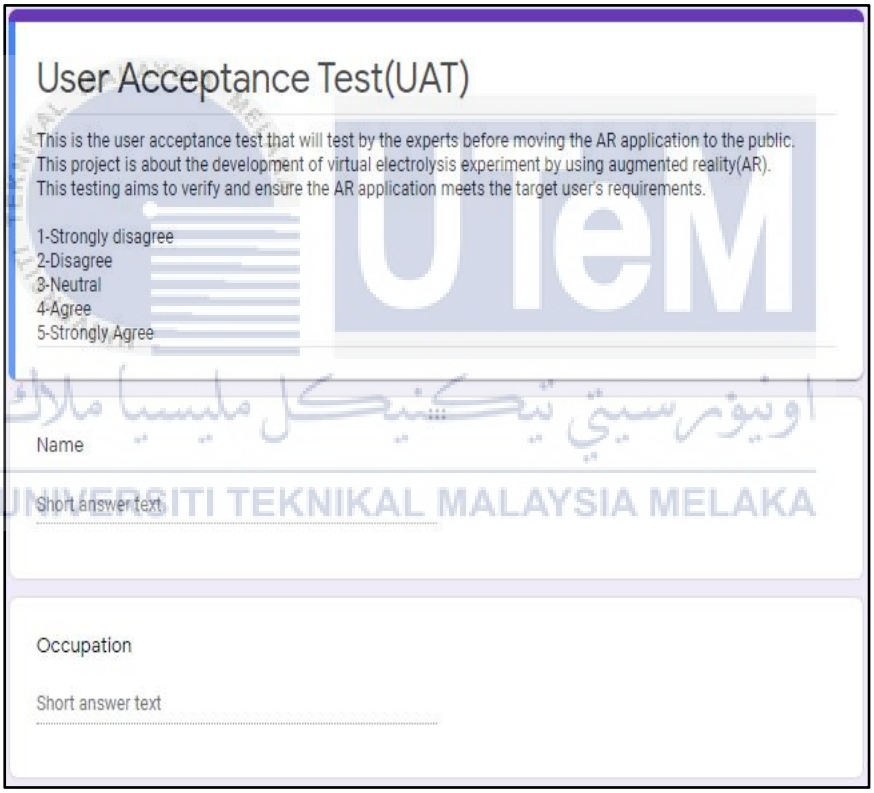

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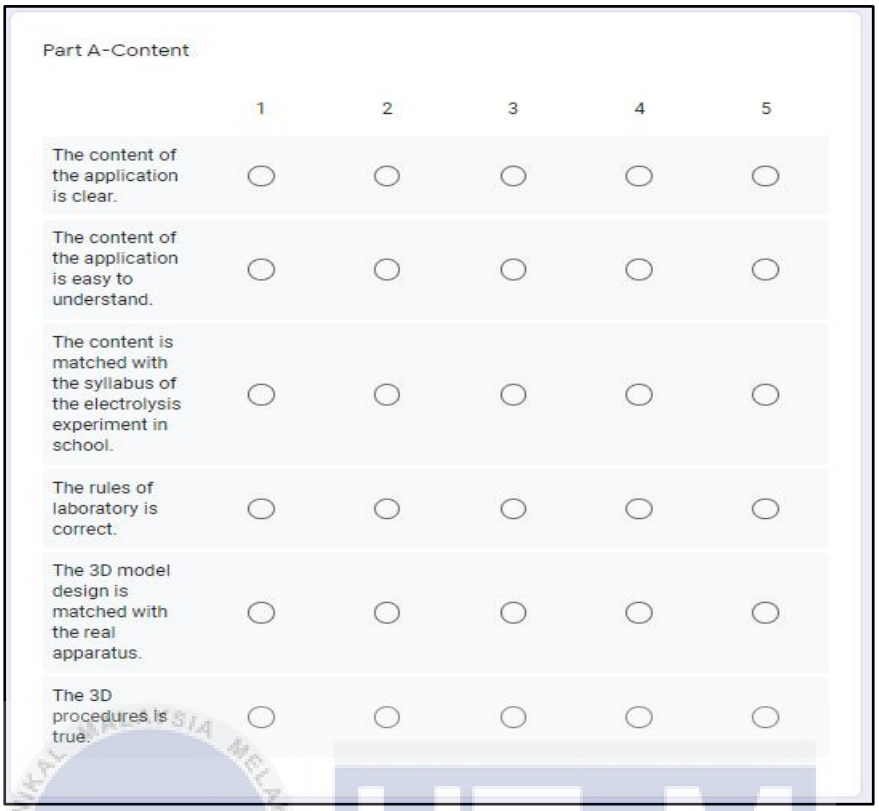
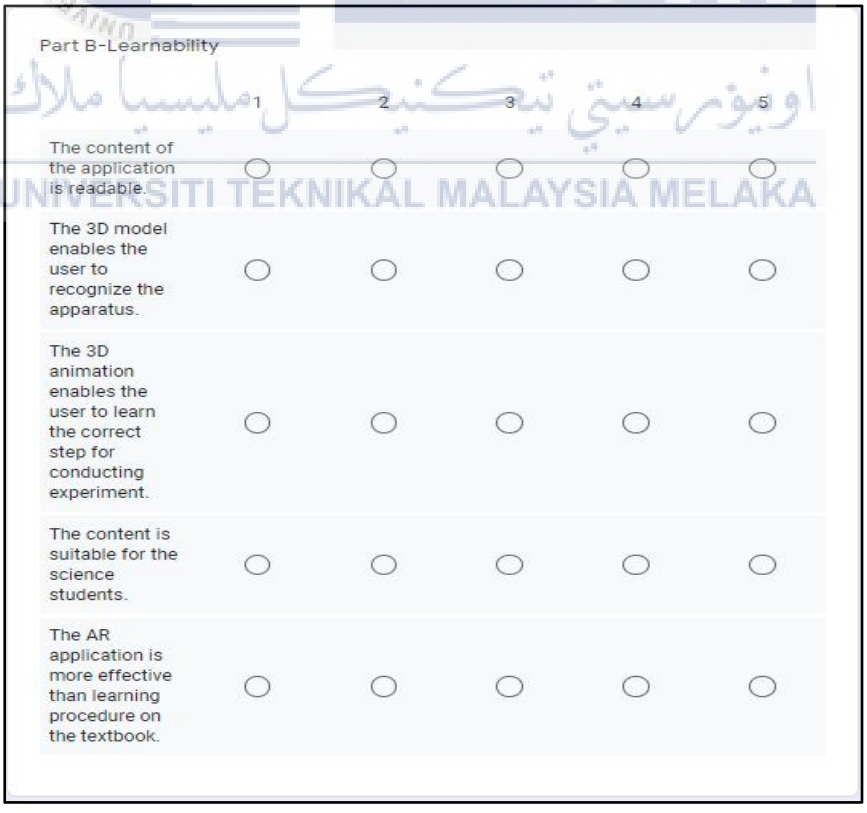
Figure 6.3 UAT for SME with name and occupation



Part A-Content

	1	2	3	4	5
The content of the application is clear.	○	○	○	○	○
The content of the application is easy to understand.	○	○	○	○	○
The content is matched with the syllabus of the electrolysis experiment in school.	○	○	○	○	○
The rules of laboratory is correct.	○	○	○	○	○
The 3D model design is matched with the real apparatus.	○	○	○	○	○
The 3D procedures is true.	○	○	○	○	○

Figure 6.4 UAT for SME about content



Part B-Learnability

	1	2	3	4	5
The content of the application is readable.	○	○	○	○	○
The 3D model enables the user to recognize the apparatus.	○	○	○	○	○
The 3D animation enables the user to learn the correct step for conducting experiment.	○	○	○	○	○
The content is suitable for the science students.	○	○	○	○	○
The AR application is more effective than learning procedure on the textbook.	○	○	○	○	○

Figure 6.5 UAT for SME about learnability

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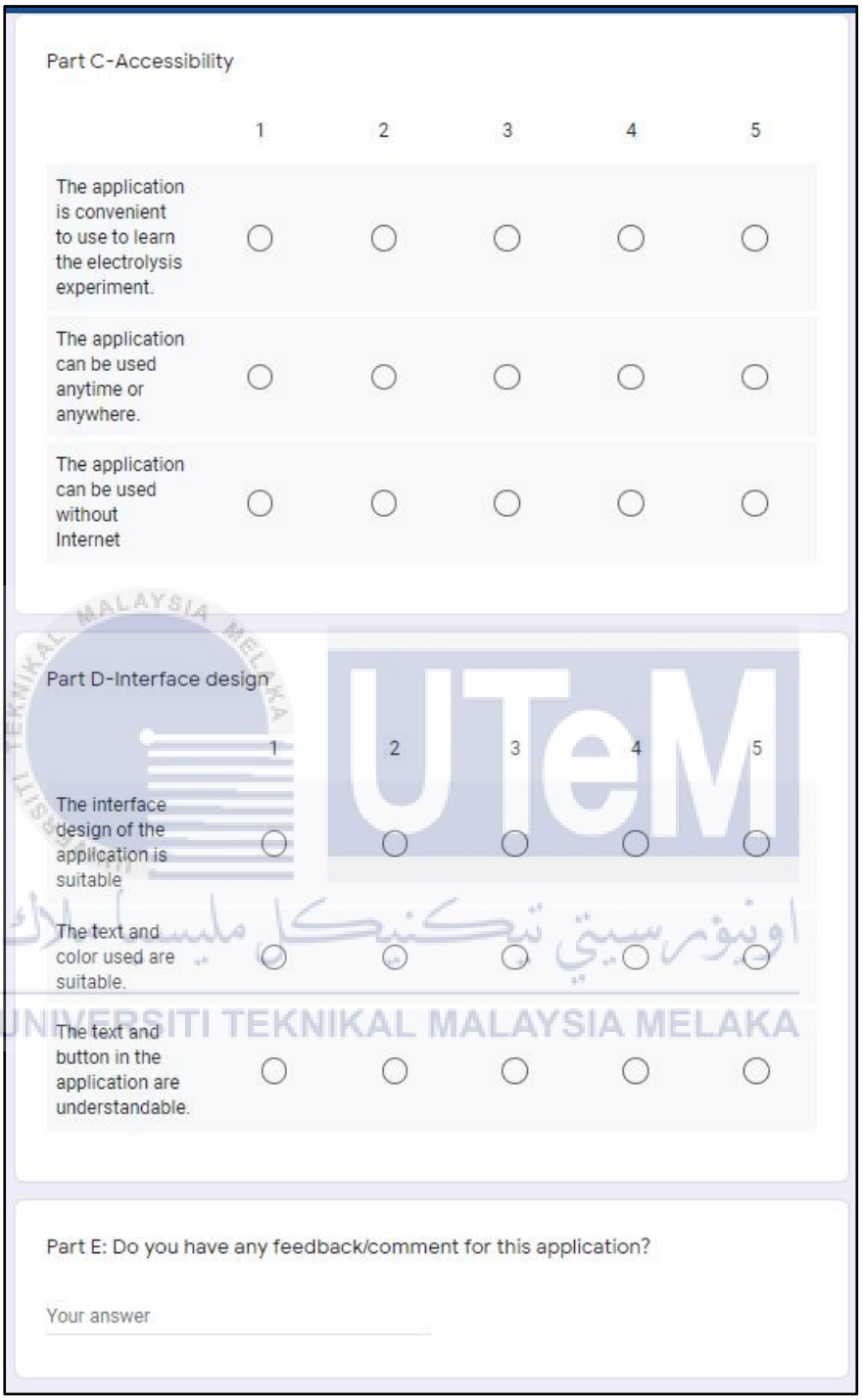

Figure 6.6 UAT for SME about accessibility, interface design and feedback

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User Acceptance Test for end user

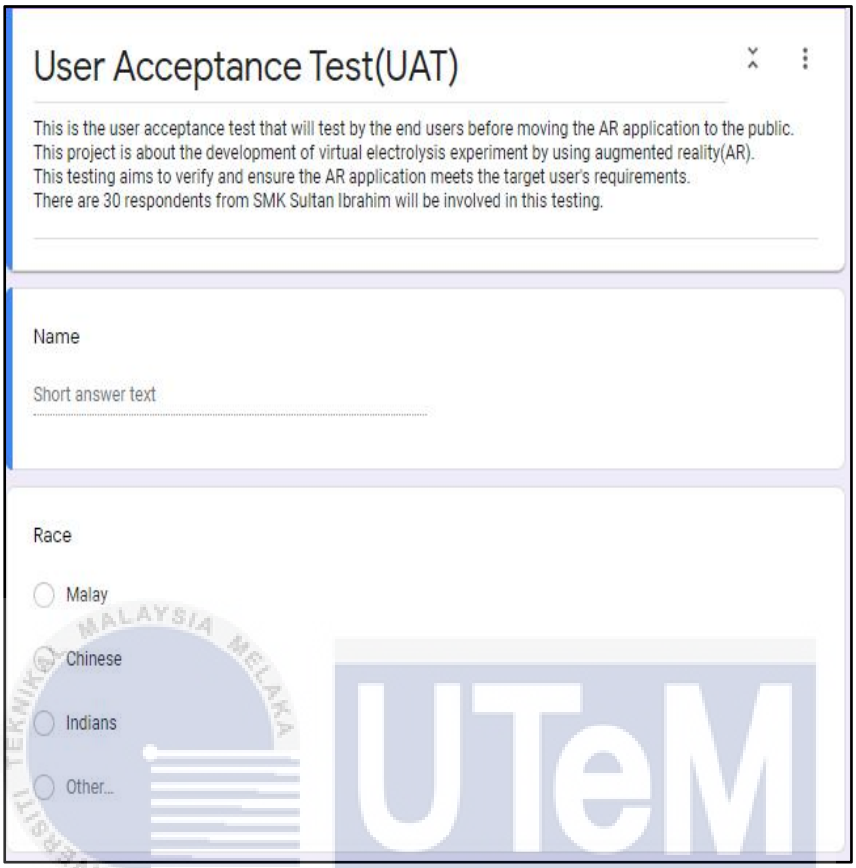

Figure 6.7 UAT for end user about name and race

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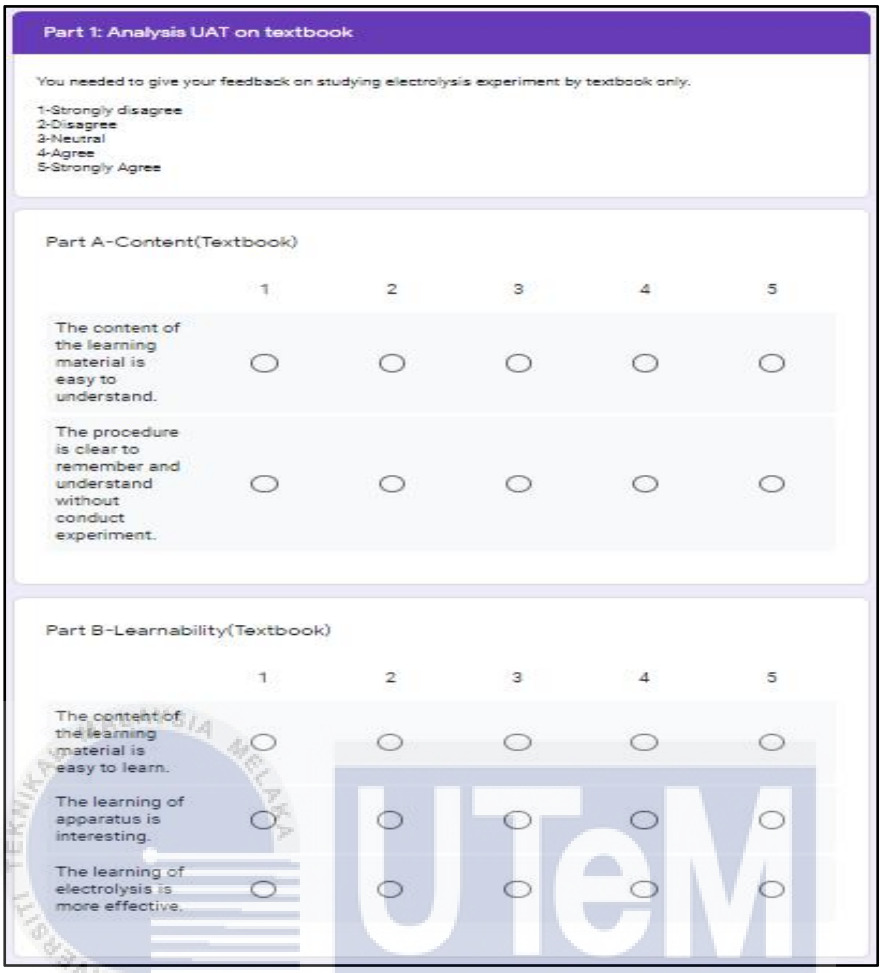


Part 1: Analysis UAT on textbook

You needed to give your feedback on studying electrolysis experiment by textbook only.

1-Strongly disagree
2-Disagree
3-Neutral
4-Agree
5-Strongly Agree

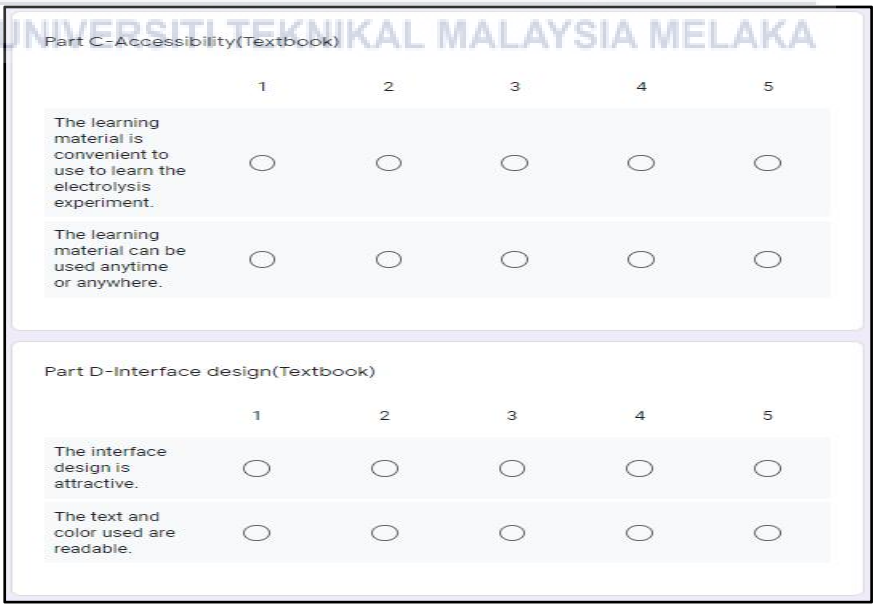
Part A-Content(Textbook)

	1	2	3	4	5
The content of the learning material is easy to understand.	○	○	○	○	○
The procedure is clear to remember and understand without conduct experiment.	○	○	○	○	○

Part B-Learnability(Textbook)

	1	2	3	4	5
The content of the learning material is easy to learn.	○	○	○	○	○
The learning of apparatus is interesting.	○	○	○	○	○
The learning of electrolysis is more effective.	○	○	○	○	○

Figure 6.8 UAT for end user about content and learnability based on textbook



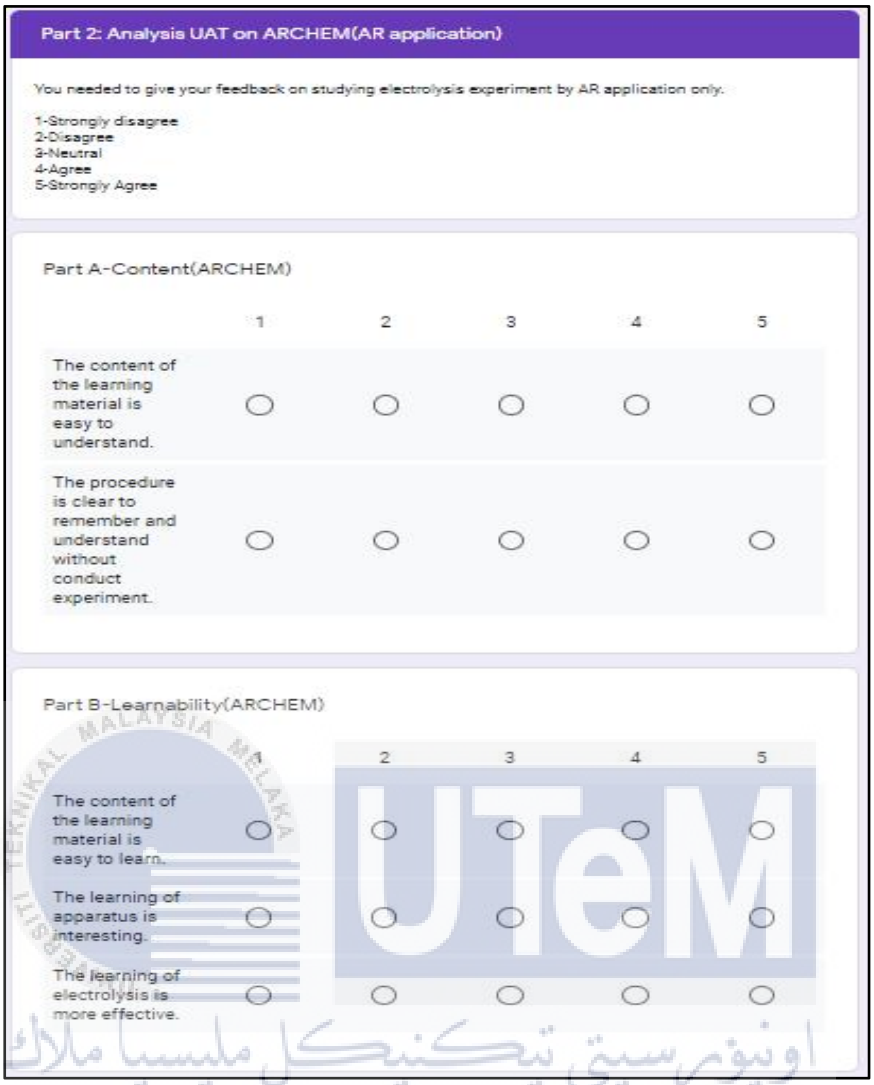
Part C-Accessibility(Textbook)

	1	2	3	4	5
The learning material is convenient to use to learn the electrolysis experiment.	○	○	○	○	○
The learning material can be used anytime or anywhere.	○	○	○	○	○

Part D-Interface design(Textbook)

	1	2	3	4	5
The interface design is attractive.	○	○	○	○	○
The text and color used are readable.	○	○	○	○	○

Figure 6.9 UAT for end user about accessibility and interface design based on textbook



Part 2: Analysis UAT on ARCHEM(AR application)

You needed to give your feedback on studying electrolysis experiment by AR application only.

1-Strongly disagree
2-Disagree
3-Neutral
4-Agree
5-Strongly Agree

Part A-Content(ARCHEM)

	1	2	3	4	5
The content of the learning material is easy to understand.	○	○	○	○	○
The procedure is clear to remember and understand without conduct experiment.	○	○	○	○	○

Part B-Learnability(ARCHEM)

	1	2	3	4	5
The content of the learning material is easy to learn.	○	○	○	○	○
The learning of apparatus is interesting.	○	○	○	○	○
The learning of electrolysis is more effective.	○	○	○	○	○

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Figure 6.10 UAT for end user about content and learnability based on ARCHEM

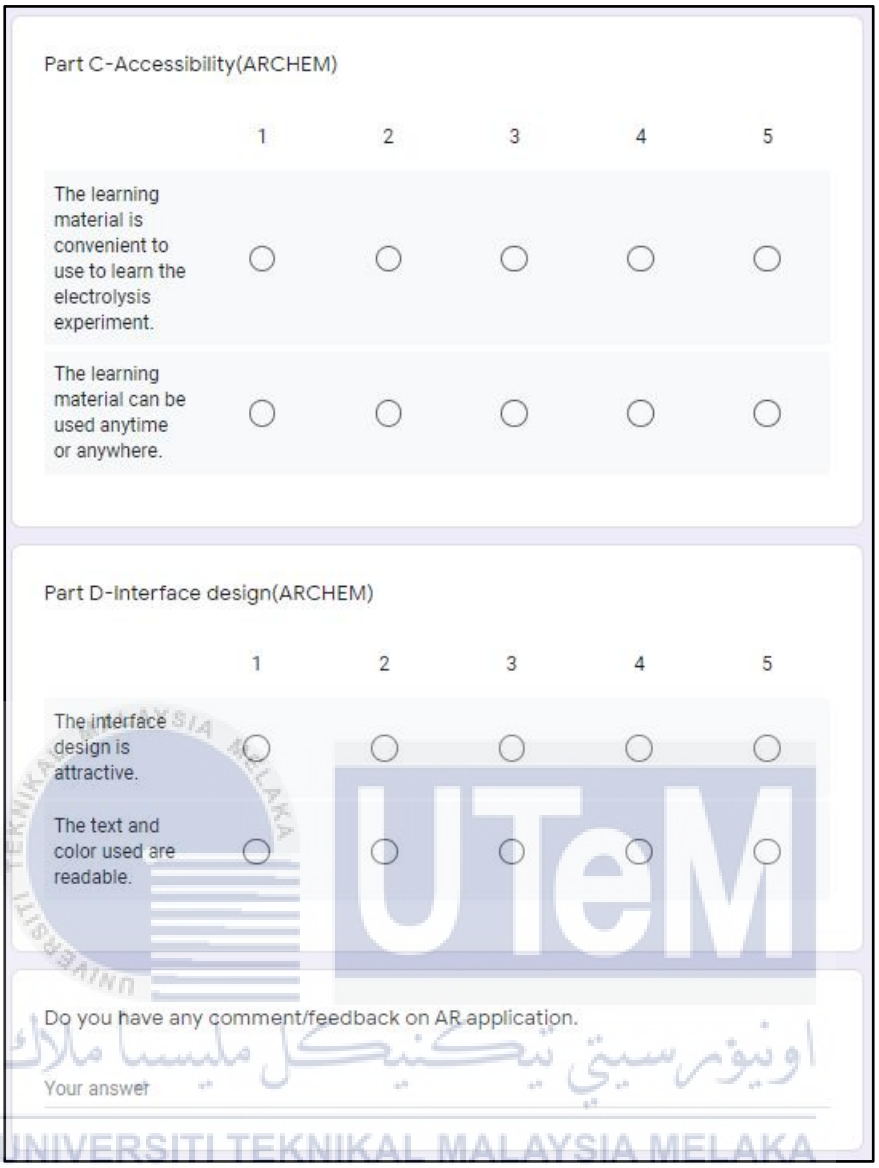

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Figure 6.11 UAT for end user about accessibility, interface design and feedback based on ARCHEM

6.3.2 Pre-post test

The pre-test and post-test are used to test the effectiveness of augmented reality in learning electrolysis experiment compared to studying on textbook. There will be three part of each test which related to three different electrolysis experiments. The first part is the electrolysis of molten lead(II) bromide. The second part is the electrolysis of an aqueous solution using carbon electrodes. The third part is the effects of concentration of ions in solution on the selective discharge of ions. The

pre-test questions are for the procedures on textbook while post-test questions are for ARCHEM application. The questions conducted on both test will be different.

Pre-test Quiz

Figure 6.12 Pre-test Quiz questions

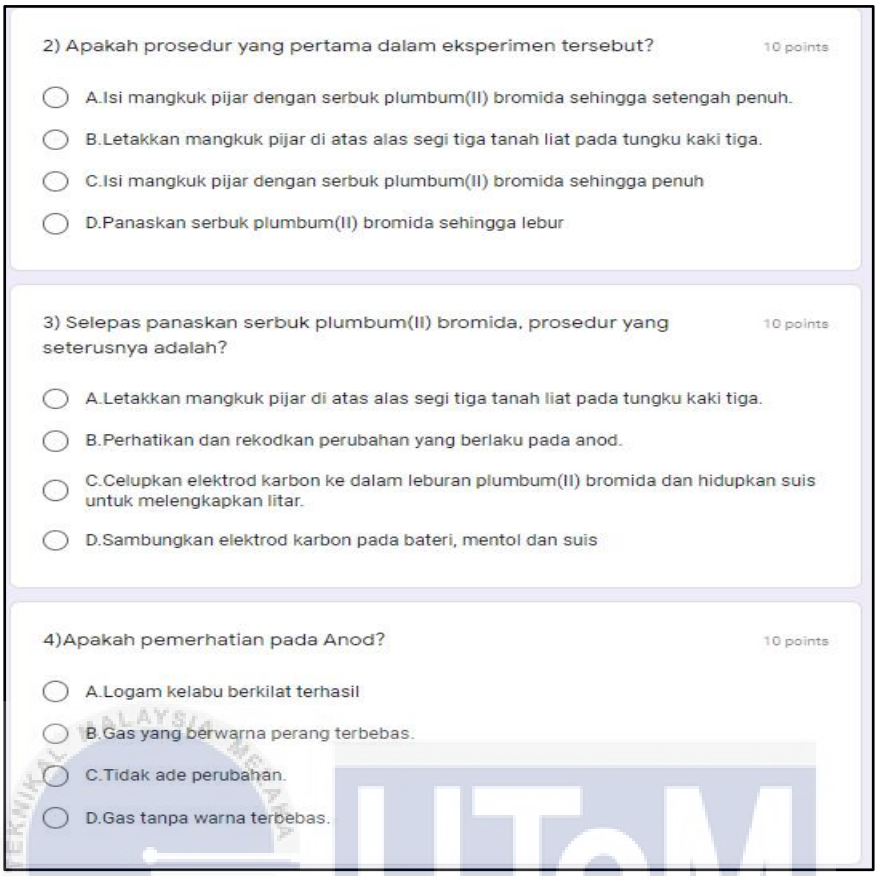

Figure 6.13 Pre-test Quiz questions

Figure 6.14 Pre-test Quiz questions

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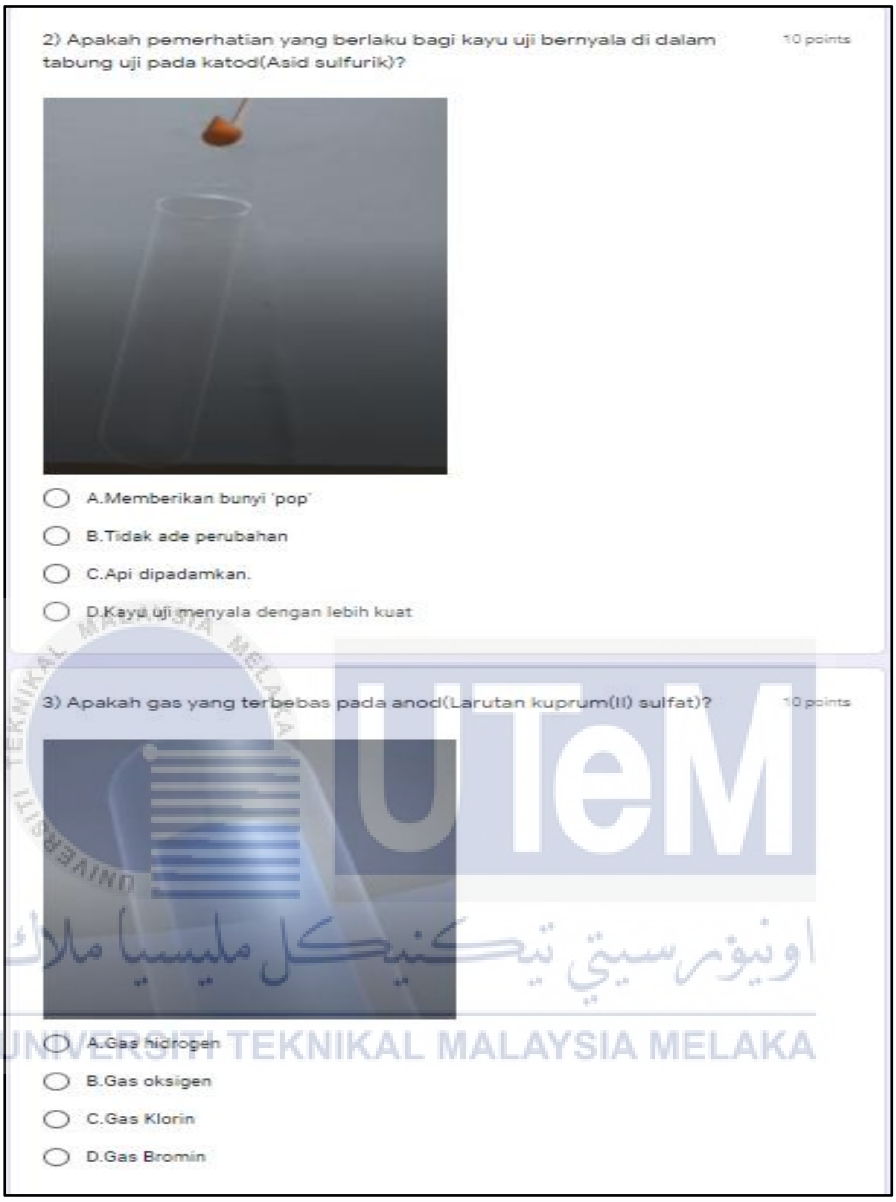

Figure 6.15 Pre-test Quiz questions

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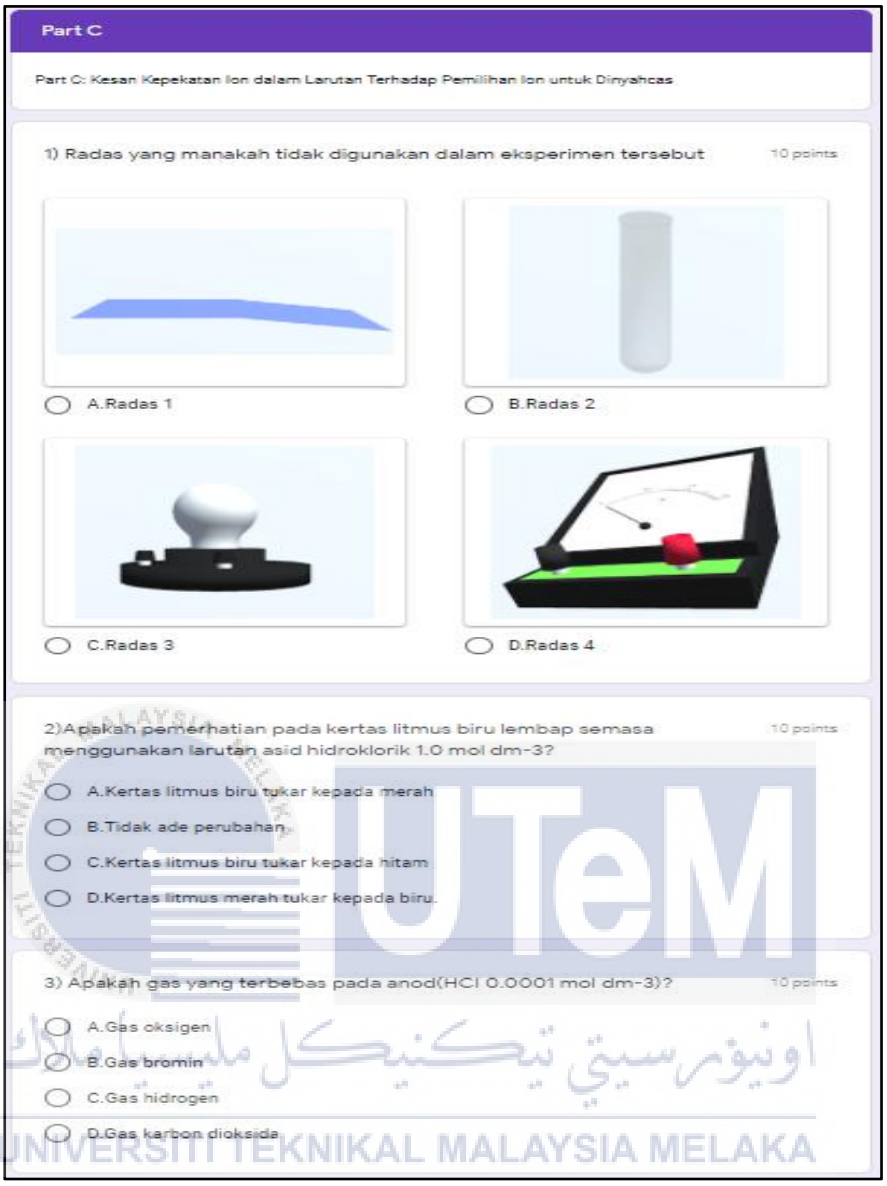

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Figure 6.16 Pre-test Quiz questions

Post-test

Figure 6.17 Post-test Quiz questions

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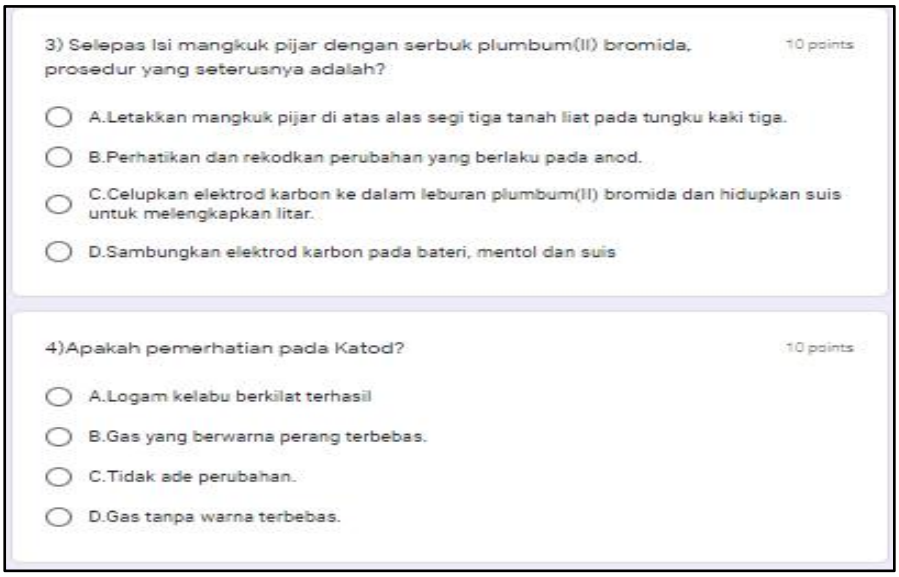

Figure 6.18 Post-test Quiz questions

Figure 6.19 Post-test Quiz questions

Figure 6.20 Post-test Quiz questions

Figure 6.21 Post-test Quiz questions

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6.4 Test Implementation

6.4.1 Test Description

In this project, there are two different people that will be testing. They are SME and end users. The experts are the teachers that are professional in teaching Chemistry course in secondary school which is SMK Sultan Ibrahim Kulai. The ARCHEM apk file will be given to the experts with the instructions to use it. After the experts used the ARCHEM application, the user acceptance testing will be tested by the experts within 2 hours. In user acceptance testing, there are four parts which divided into content, learnability, accessibility and the interface design. The experts will fill their names and occupation first and then answer the questions with the likert scale given from 1 to 5. The digit 1 is strongly disagree; digit 2 is disagree; digit 3 is neutral; digit 4 is agree; digit 5 is strongly agree. After that, the expert will give feedback about the ARCHEM application.

There are 30 Form 5 students as the respondents for the end user testing. First, they will conduct pre-test quiz and post-test quiz with the textbook and ARCHEM separately. They are given 30 minutes to read the procedure on textbook and answer the pre-test quiz with 10 questions in 15 minutes. Next, they will be given 30 minutes to use the ARCHEM application to learn the electrolysis experiment and also answer the post-test quiz with 10 questions in 15 minutes. After pre-test and post-test, respondents also need to answer the user acceptance testing for end users and give the comment to compare the learning on textbook and ARCHEM.

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6.4.2 Test Data

The test data for ARCHEM is collected from three experts which are Chemistry teachers in SMK Sultan Ibrahim. The table 6.2 below shows the expert details.

6.4.2.1 User Acceptance Test for SME

Table 6.2 Details of Experts

No.	Name	Occupation	Working experience
1.	Lim Siew Huang	teacher	2007 - Present (14 years)
2.	Nurun Nadia Masrom	teacher	2011 - Present (10 years)
3.	Siti Nadiah Ibni Hajar	teacher	2016 - Present (5 years)

For the end users, there are 30 respondents from SMK Sultan Ibrahim Kulai involved in the pre-test and post-test. 18 out of 30 respondents are Chinese, 7 out of 30 respondents are Malay and the others(16.7%) are Indians.

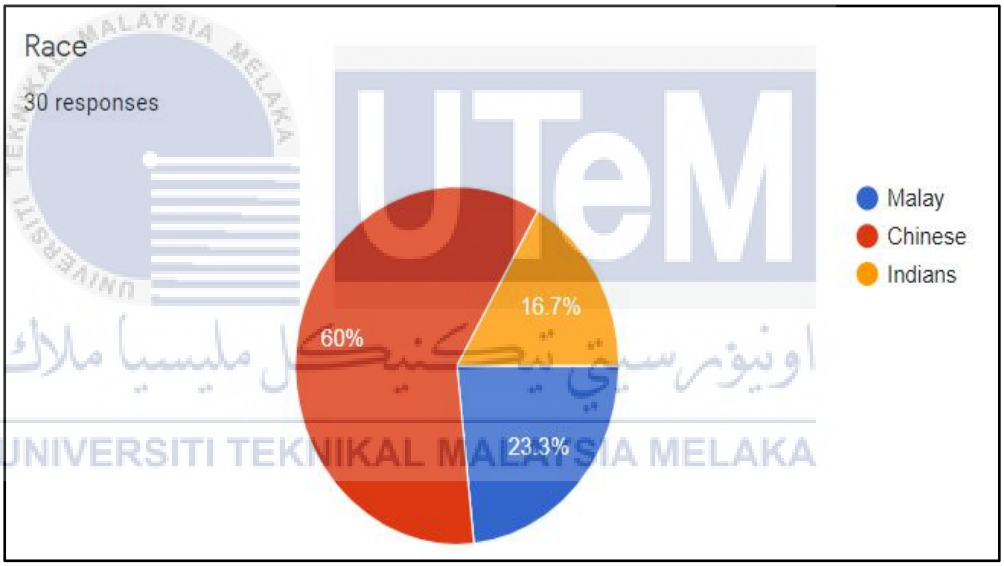

Figure 6.22 Race of the 30 respondents

Table 6.3 shows the data collected from user acceptance testing for SME while Table 6.4 shows the data collected from user acceptance testing for end users. Besides, the pre-test and post-test quizzes result will be in the table 6.5.

Table 6.3 Test Data of UAT for SME

Question	Test Data				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Content					
1	0	0	0	3	0
2	0	0	0	3	0
3	0	0	0	3	0
4	0	0	0	3	0
5	0	0	1	2	0
6	0	0	0	3	0
Learnability					
1	0	0	0	3	0
2	0	0	0	3	0
3	0	0	0	3	0
4	0	0	0	3	0
5	0	0	0	3	0
Accessibility					
1	0	0	0	3	0
2	0	0	0	3	0
3	0	0	1	2	0
Interface design					
1	0	0	0	3	0
2	0	0	0	3	0
3	0	0	0	3	0

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6.4.2.2 User Acceptance Test for End User

Table 6.4 Test Data of UAT for End User

Question	Learning Tools	Test Data				
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Content						
1	Textbook	0	15	12	3	0
	ARCHEM	0	0	0	21	9
2	Textbook	7	18	5	0	0
	ARCHEM	0	0	0	20	10
Learnability						
1	Textbook	0	10	15	5	0
	ARCHEM	0	1	0	18	11
2	Textbook	5	23	2	0	0
	ARCHEM	0	1	0	15	14
3	Textbook	4	17	9	0	0
	ARCHEM	0	1	1	21	7
Accessibility						
1	Textbook	5	15	8	2	0
	ARCHEM	0	0	4	22	4
2	Textbook	16	11	2	0	1
	ARCHEM	0	0	2	20	8
Interface Design						
1	Textbook	4	12	13	1	0
	ARCHEM	0	0	0	17	13
2	Textbook	9	11	10	0	0
	ARCHEM	0	0	4	20	6

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Table 6.5 Pre-test and Post-test for End Users

Respondents	Number of correct answer in both quizzes (each 10 questions)			
	Pre-test (Textbook)	Percentage (%)	Post-test (ARCHEM)	Percentage (%)
1	4	40	10	100
2	6	60	10	100
3	9	90	10	100
4	4	40	6	60
5	8	80	8	80
6	6	60	8	80
7	3	30	9	90
8	7	70	9	90
9	5	50	9	90
10	6	60	6	60
11	7	70	8	80
12	4	40	8	80
13	5	50	7	70
14	8	80	6	60
15	6	60	8	80
16	4	40	8	80
17	6	60	9	90
18	4	40	10	100
19	3	30	8	80
20	7	70	10	100
21	4	40	9	90
22	6	60	9	90
23	6	60	9	90
24	6	60	9	90
25	5	50	7	70
26	6	60	8	80
27	6	60	8	80
28	7	70	8	80

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29	7	70	7	70
30	8	80	7	70
Mean	5.77	57.67	8.27	82.67

6.5 Test Results and Analysis

6.5.1 User Acceptance Test for SME

The test result for the expert was obtained from the user acceptance testing through questionnaires of Google Form. There are 3 experts to give the answer in 4 parts which are content, learnability, accessibility and interface design of ARCHEM application. All the data will be analyse and explained clearly in the form of graph.

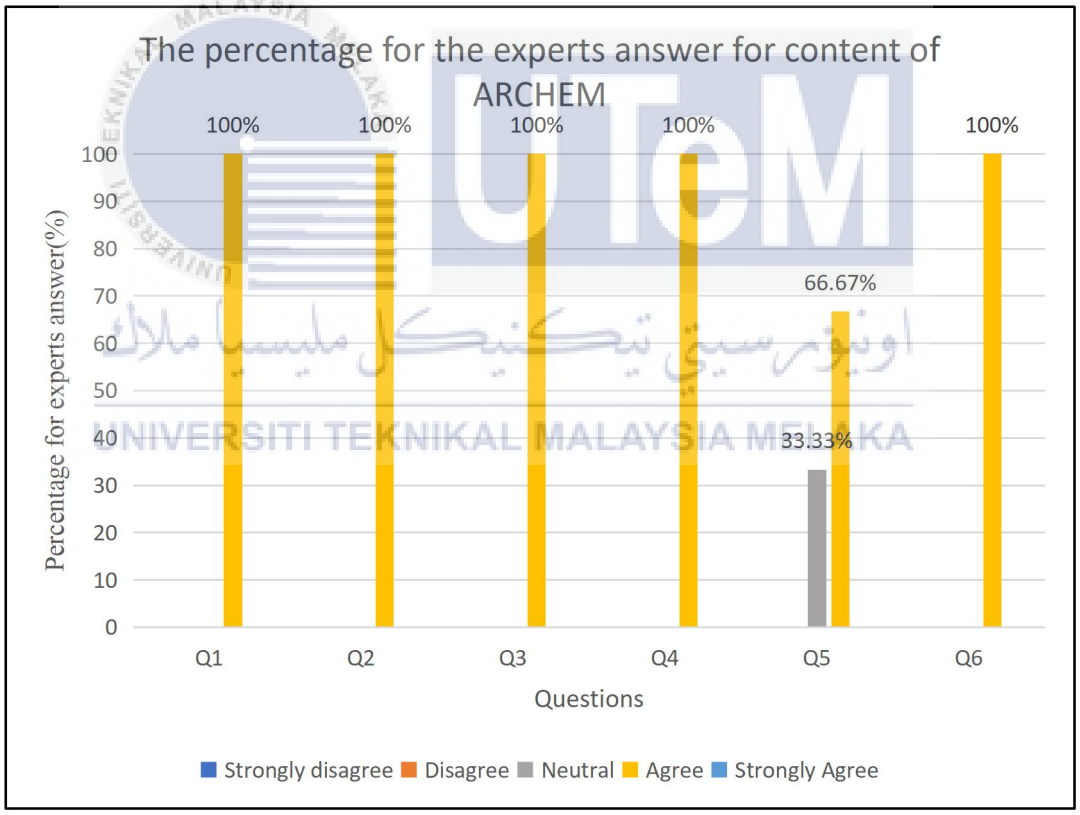

Figure 6.23 Graph of the percentage for the experts answer for content of ARCHEM

Figure 6.23 shows the graph of the percentage for experts answer for content of ARCHEM. There are six questions had been asked for content of ARCHEM application.Question 1 is about the content of the application is clear or not. 100% of

the experts agree that the content of ARCHEM is clear. Question 2 is about the content of the application is easy to understand. 100% of the experts also agree that the content of ARCHEM application is simple to understand. Question 3 is about the content of ARCHEM is matched with the syllabus of the electrolysis experiment in school or not. 100% of the experts agree that the ARCHEM application is similar with the syllabus of the electrolysis experiment on textbook. Question 4 is about the rules of laboratory is correct or not. 100% of experts agree that the rules stated in ARCHEM are true. Question 5 is whether the 3D model design is matched with the real apparatus or not. 66.67% of experts agree that the 3D model design in ARCHEM is similar with the real apparatus while 33.33% of the expert give the neutral answer for this statement. Question 6 is whether the 3D procedures is true or not. 100% of the experts agree that the 3D procedure in ARCHEM is correct as same as the procedures in textbook. Overall, all the experts give the answer with majority agreed to the questions for the content of the ARCHEM.

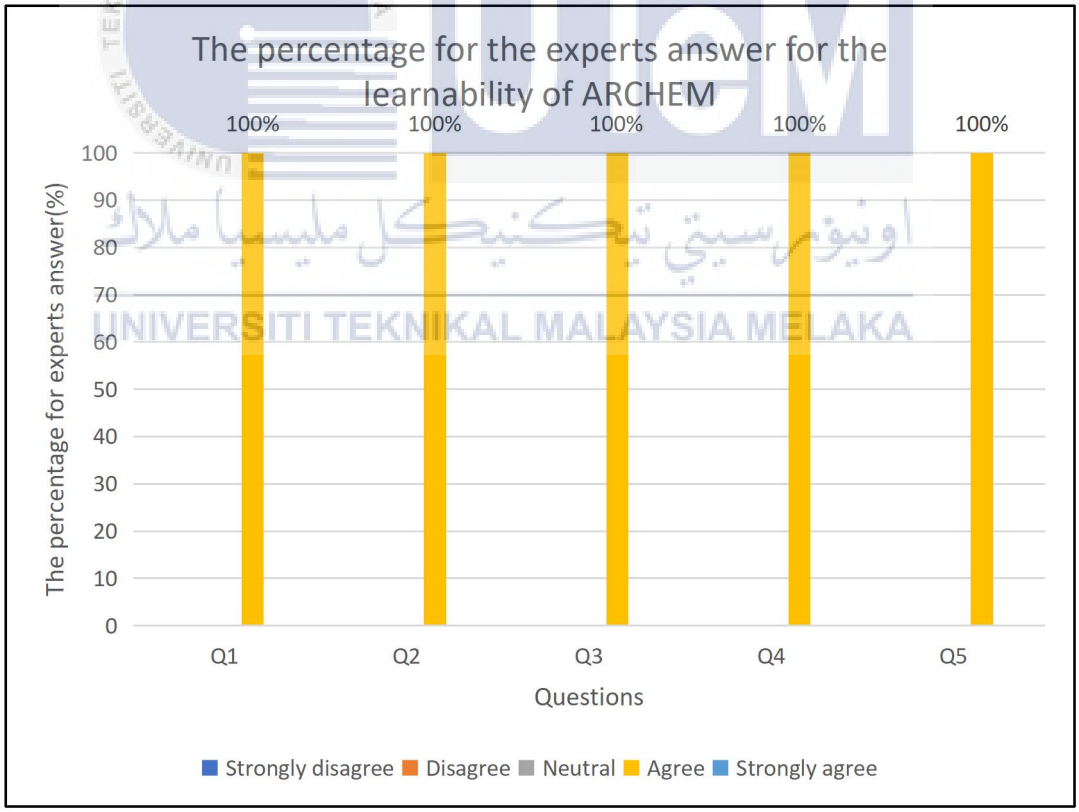

Figure 6.24 Graph of the percentage for the experts answer for learnability of ARCHEM

Figure 6.24 shows the graph of the percentage for experts answer for learnability of ARCHEM application. Question 1 is about the content of the ARCHEM application is readable or not. 100% of the experts agree that the content inside the ARCHEM is able to read. Question 2 is whether the 3D model enables the user to recognize the apparatus or not. 100% of the experts agree that the user can able to recognize the 3D apparatus of ARCHEM application. Question 3 is about the 3D animation enables the user to learn the correct step for conducting experiment. 100% of the experts agree that the user can learn the correct step with the use of ARCHEM application. Question 4 is about the content is suitable for the science students or not. 100% of the experts agree that the ARCHEM provides the content which suitable for the science students. Question 5 is whether AR application is more effective than learning procedures on the textbook. 100% of the experts agree that ARCHEM is more effective to the science students to learn electrolysis compared to the students who just read the procedures on textbook. Overall, all of the experts give the answers with all agree to all the questions for learnability of ARCHEM.

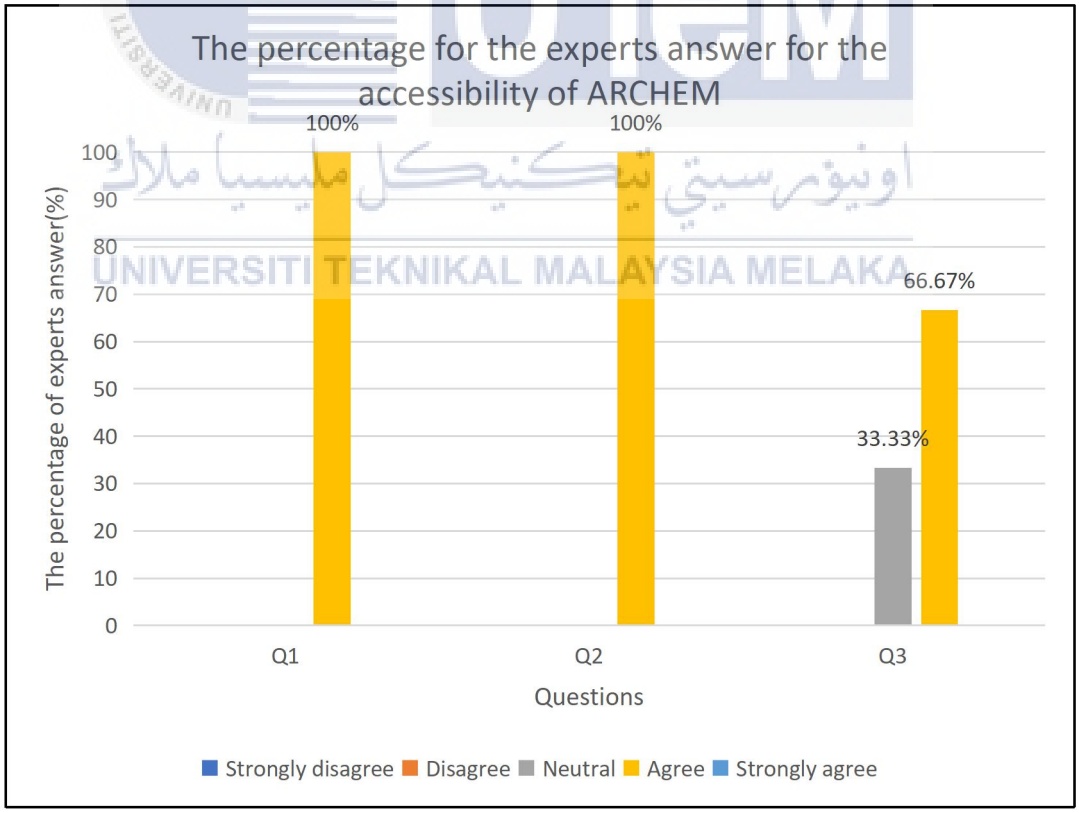

Figure 6.25 Graph of the percentage for experts answer for the accessibility of ARCHEM

Figure 6.25 shows the graph of percentage for experts answer for the accessibility of ARCHEM. Question 1 is about the ARCHEM is convenient to use to learn the electrolysis experiment. 100% of the experts agree that ARCHEM is convenient to use. Question 2 is about the ARCHEM can be used anytime or anywhere. 100% of the experts also agree with this statement because the user can just download ARCHEM in their phone and use it anytime or anywhere. Question 3 is the ARCHEM can be used without Internet. 2 out of 3 experts(66.67%) agree that the ARCHEM application is the offline application while one of the experts(33.33%) give the neutral answer to this statement. Overall, all experts give the good answer with most agree to the questions for accessibility of ARCHEM.

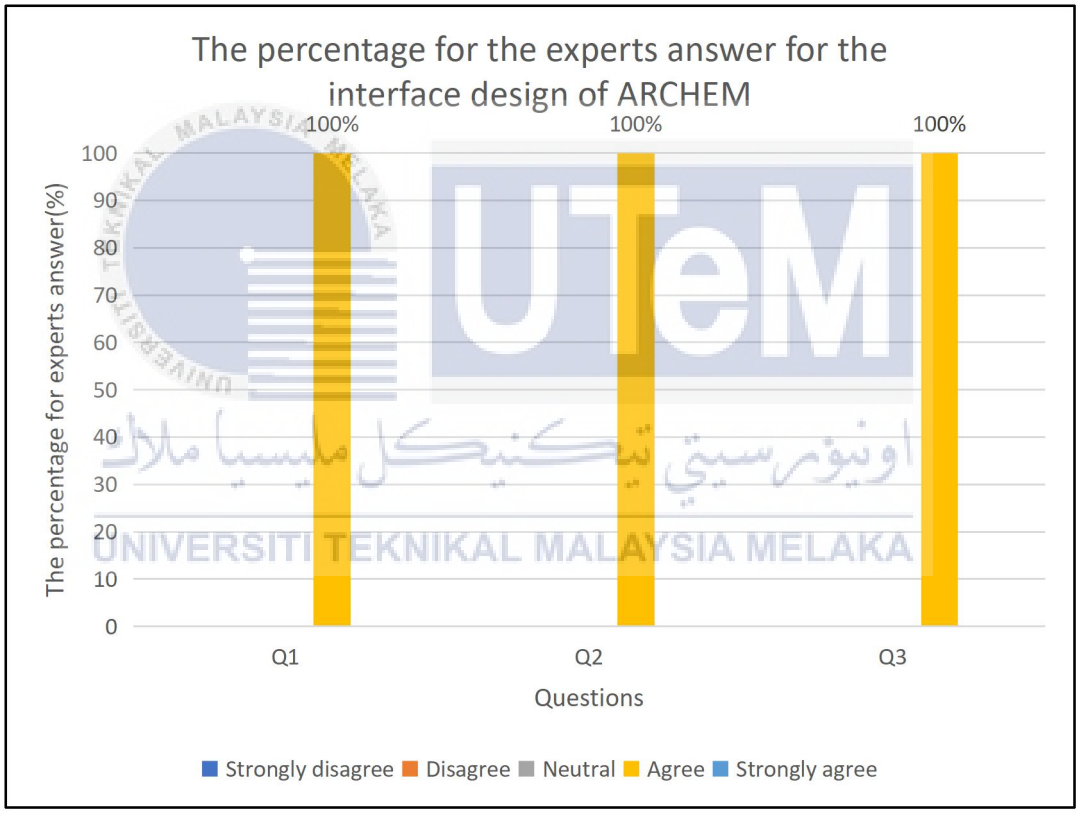

Figure 6.26 Graph of the percentage for the experts answer for the interface design of ARCHEM

Figure 6.26 shows the graph of the percentage for experts answer for the interface design of ARCHEM. Question 1 is the interface design of the application is suitable or not. 100% of the experts agree that interface design of ARCHEM is suitable as the learning material for chemistry experiment. Question 2 is the text and color used in ARCHEM are suitable or not. 100% of the experts agree that the font

and color used in ARCHEM is suitable. Question 3 is about the text and button in the application are understandable. 100% of the experts agree that the text and button in the application are easy to read and understand. Overall of the data stated that all experts agree to all the questions for interface design of ARCHEM.

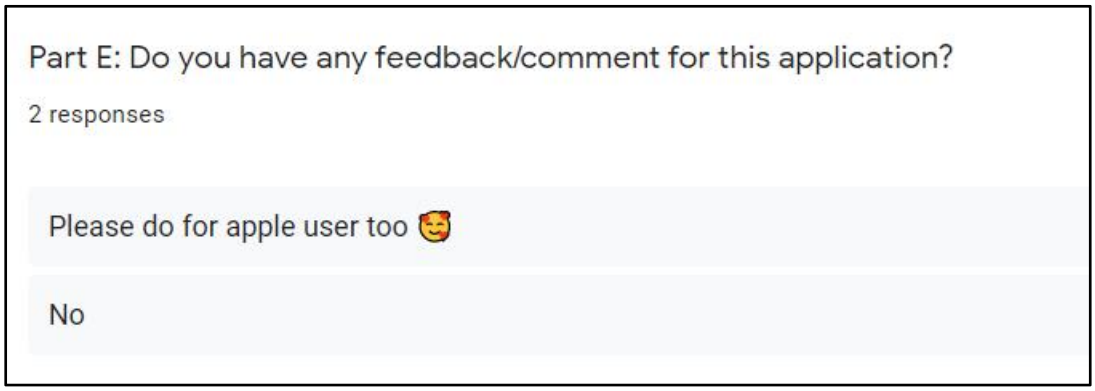

Figure 6.27 The feedback given by the experts

There are the feedback given by 2 out of 3 experts as shown in Figure 6.27. Based on the feedback, only one of the experts suggests that ARCHEM should also provide the IOS version as some of the people use iPhone. Without IOS version, they will not able to use ARCHEM to learn the electrolysis experiment.

As a conclusion, the result from user acceptance testing for experts shows that ARCHEM is suitable for the students to learn the electrolysis experiment. ARCHEM provide the content which is clear, easy to understand and match with the syllabus of electrolysis experiment for Form 5 Chemistry. The user can able to recognize the apparatus and learn the correct step for conducting electrolysis experiment because the content of the ARCHEM application is readable and suitable for science students. In addition, ARCHEM is also convenient to use without considering anytime or anywhere. The interface design for the ARCHEM is suitable.

6.5.2 Pre-test and Post-test

The pre-test and post-test quizzes conducted for the end user. The end user need to answer two set of 10 questions from three different electrolysis experiment after they finished reading the procedure on textbook and ARCHEM separately.

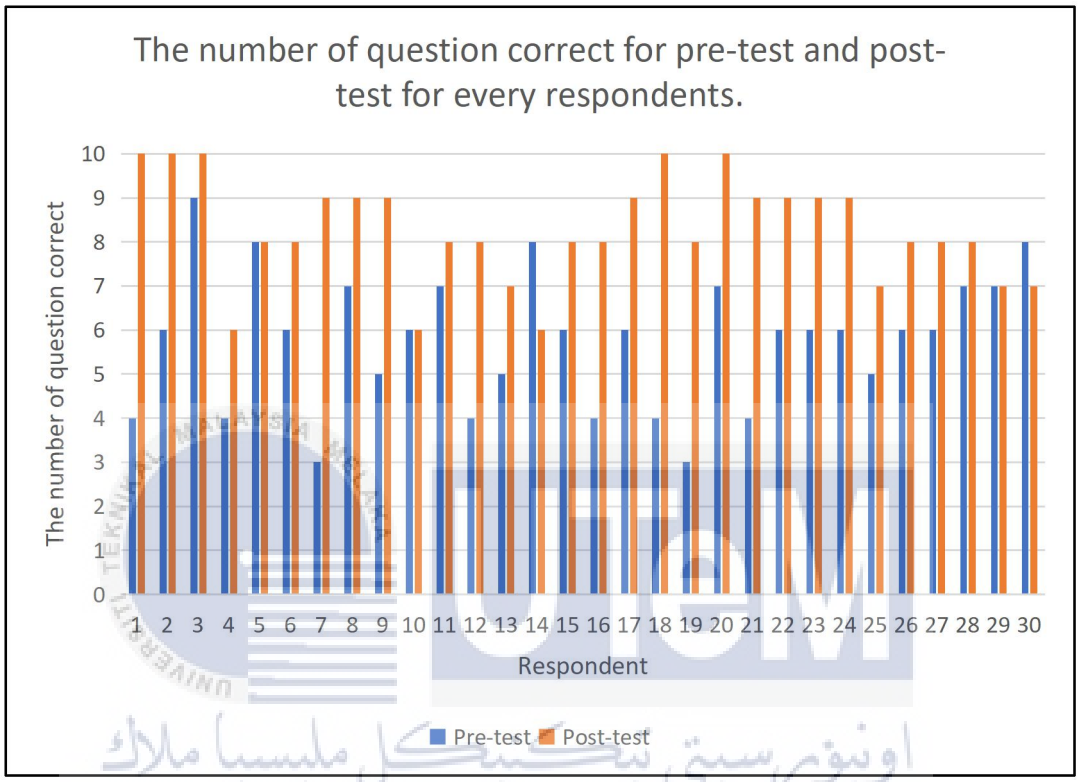

Figure 6.28 Graph for the number of questions correct for pre-test and post-test for every respondents

Figure 6.28 shows the improvement of the result from every respondents between the pre-test and post-test. The graph shows that most of the respondents used ARCHEM achieves better marks compared to textbook.

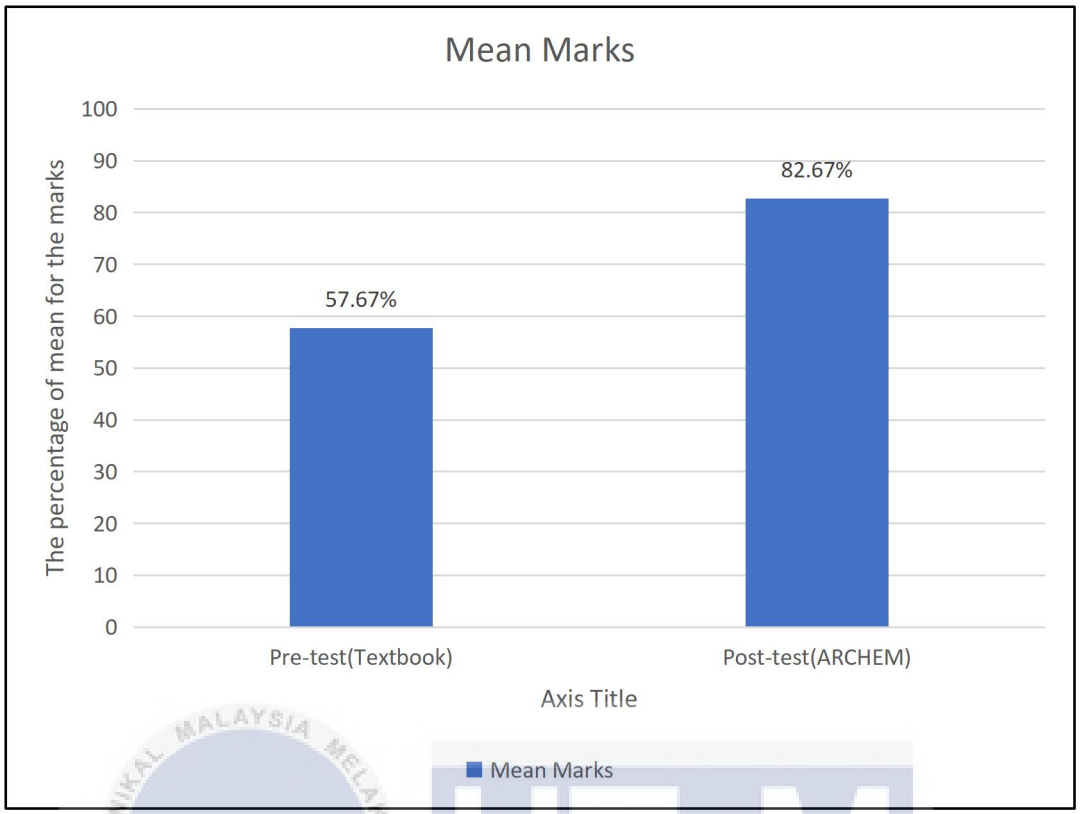

Figure 6.29 Percentage of mean marks for pre-test and post-test

The graph in Figure 6.29 show the result analysis which represent the mean marks for all the respondents for textbook and ARCHEM. The mean mark for pre-test quiz is 57.67 while the mean mark for post-test quiz is 82.67. This graph shows that the marks of respondents after using ARCHEM application is better than the marks after reading textbook. This result show that learning virtual electrolysis experiment by AR is effective compared to the learning electrolysis by textbook.

6.5.3 User Acceptance Test for End User

The test result for the end user was obtained from the user acceptance testing through questionnaires of Google Form. There are 30 respondents to give the answer in 4 parts which are content, learnability, accessibility and interface design for two different learning materials which are textbook and ARCHEM application. All the data will be analyse and explained clearly in the form of graph.

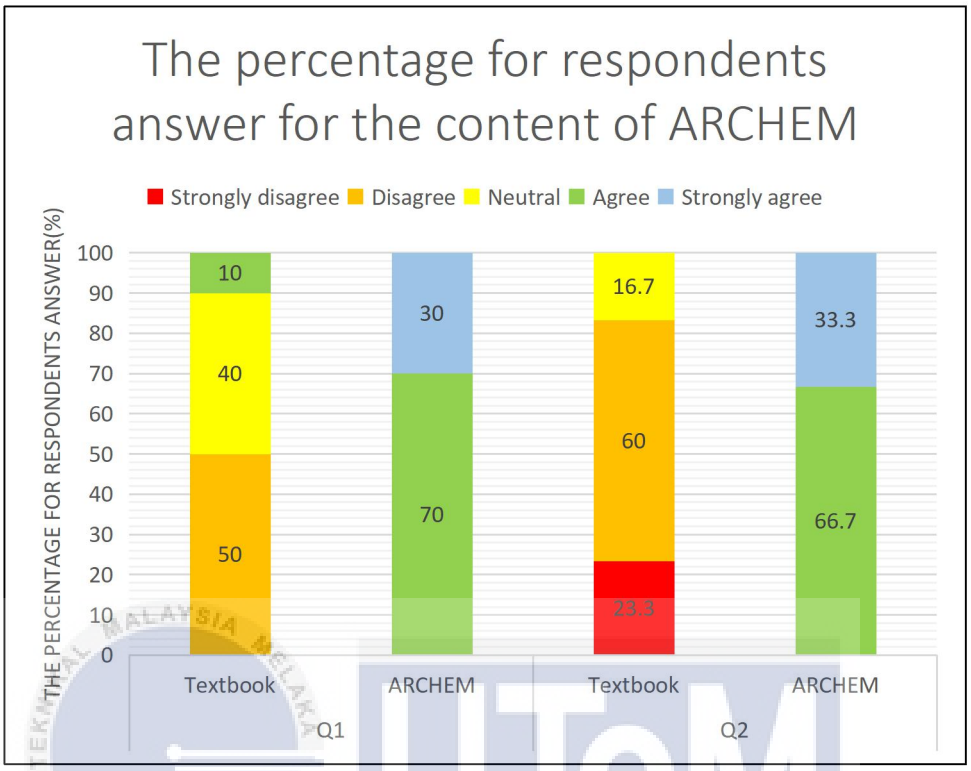

Figure 6.30 Graph of percentage for respondents answer for content of learning material

Figure 6.30 shows the graph of the percentage for the respondents answer for content of learning material. There are two questions in this part. Question 1 is about the content of the learning material is easy to understand. 3 respondents(10%) agree that the content of the textbook is easy to understand, 12 respondents(40%) neutral and 15 respondents disagree(50%). For ARCHEM, there are 9 respondents(30%) strongly agreed and 21 respondents(70%) agreed that it is easy to use. Question 2 is about the procedure is clear to remember and understand without conducting experiment. There are 7 respondents(23.3%) strongly disagree, 18 respondents(60%) disagree and 5 respondents(16.7%) neutral about this statement for textbook. For ARCHEM, there are 10 respondents(33.3%) strongly agreed and 20 respondents(66.7%) agreed to this statement. From all the data collected for content, most of the respondents believe that content of ARCHEM more better than textbook as textbook only show the procedures in text. In the same time, ARCHEM provide the AR apparatus and procedures that enable the user to learn more efficiently.

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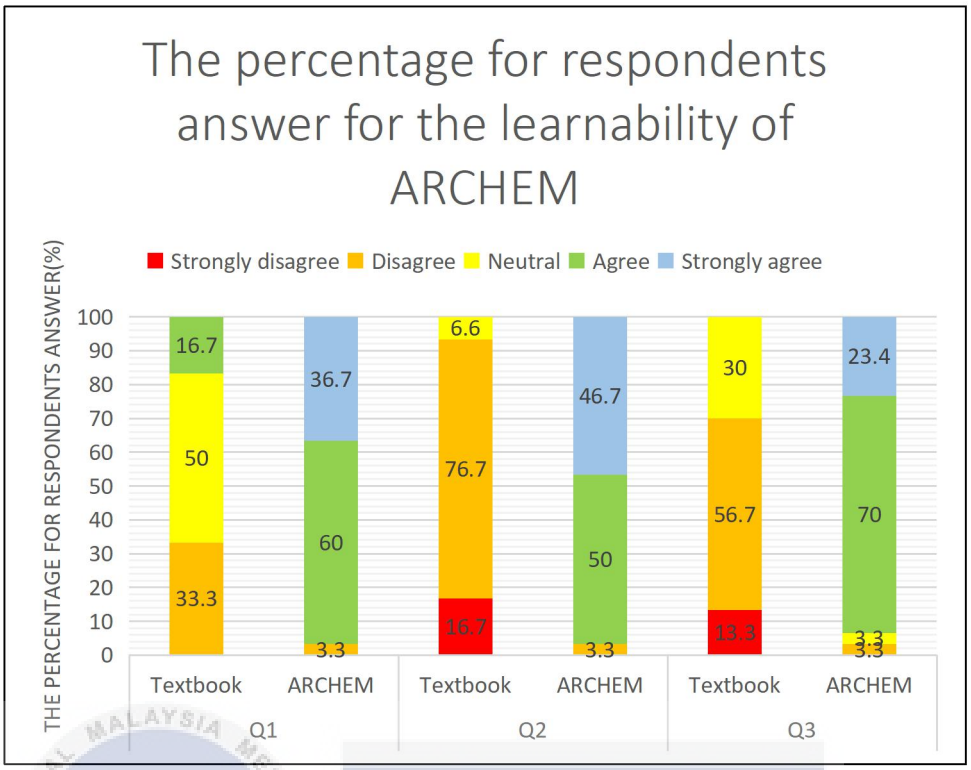

Figure 6.31 Graph of the percentage for respondents answer for learnability of ARCHEM

The graph of the percentage for respondents answer for learnability of learning material is shown in Figure 6.31. There are three questions about the learnability of learning material. Question 1 is about the content of the learning material is easy to learn. 5 respondents(16.7%) agree that the content of electrolysis experiment on textbook is easy to learn, 15 respondents(50%) neutral and 10 respondents(33.3%) disagree. For ARCHEM, there are 11 respondents(36.7%) strongly agree and 18 respondents(60%) agree that the content of ARCHEM is easy to learn while one of the respondents(3.3%) disagrees about this statement. Question 2 is about the learning of apparatus is interesting. There are 23 respondents(76.7%) disagree, 2 respondents(6.6%) neutral and 5 respondents(16.7%) strongly disagree that this statement. On the other hand, there are 15 respondents(50%) agree and 14 respondents(46.7%) strongly agree about the learning apparatus in ARCHEM is interesting while only one respondent(3.3%) disagrees about it. ARCHEM provides virtual AR apparatus that become the reasons for most respondents choose it as the learning material. Question 3 is about the learning of electrolysis is more effective. 4 respondents(13.3%) strongly disagree, 9 respondents(30%) give neutral and 17

respondents(56.7%) disagree that the learning of electrolysis is more effective on textbook. For ARCHEM, 21 respondents(70%) agree and 7 respondents(23.4%) strongly agree that the learning of electrolysis is more effective while only one respondent(3.3%) disagree and one respondent(3.3%) give neutral. From the data collected, ARCHEM will be chosen as the learning material which is more learnability than textbook.

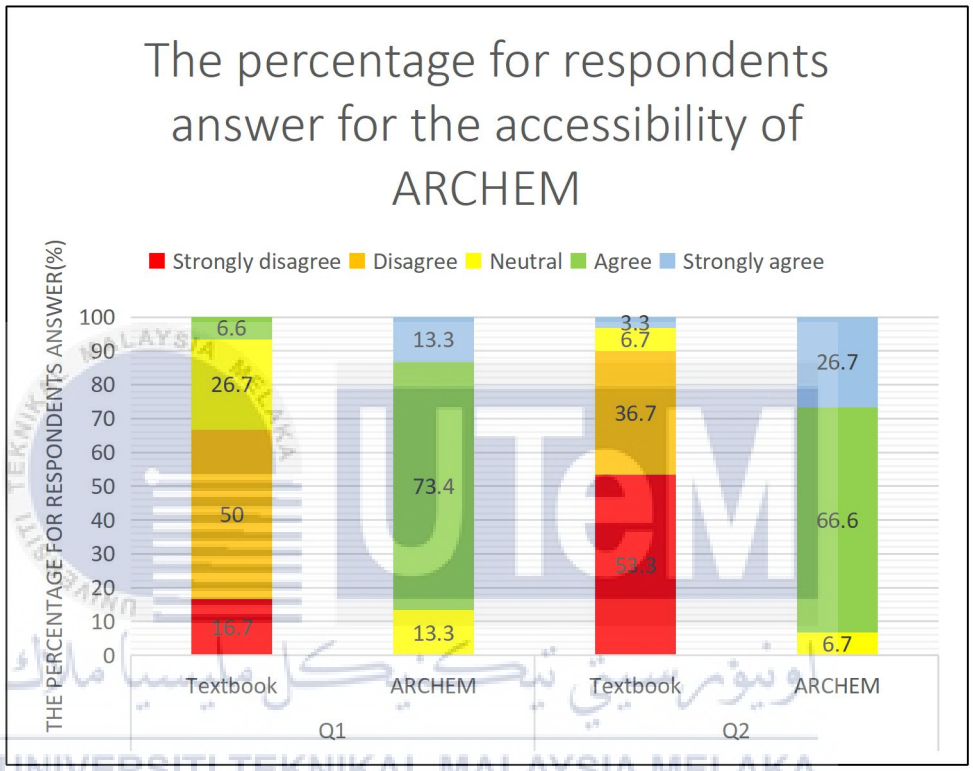

Figure 6.32 Graph of the percentage for respondents answer for accessibility of learning material

Figure 6.32 shows the graph of the percentage for respondents answer for accessibility of learning material. There are two questions that related to accessibility of the learning material. Question 1 is asking about the learning material is convenient to use to learn the electrolysis experiment. For textbook, there are 5 respondents(16.7%) strongly disagree, 15 respondents(50%) disagree and 8 respondents(26.7%) give neutral to this statement while 2 respondents(6.6%) agree that textbook is convenient to use. For ARCHEM, there are 4 respondents(13.3%) strongly agree and 22 respondents(73.4%) agree that ARCHEM is convenient while 4 respondents(13.3%) give the neutral answer to this statement. Question 2 is about the learning material can be used anytime or anywhere. There are 16

respondents(53.3%) strongly disagree, 11 respondents(36.7%) disagree, 2 respondents(6.7%) give the neutral answer and only one respondent(3.3%) strongly agree that the textbook can be used anytime or any places. For ARCHEM, 8 respondents(26.7%) strongly agree, 20 respondents(66.6%) agree and 2 respondents(6.7%) neutral that ARCHEM can be used anytime or anywhere. From the result, the respondents give the positive responses to choose ARCHEM because the accessibility of ARCHEM is good and able to use anytime or any places.

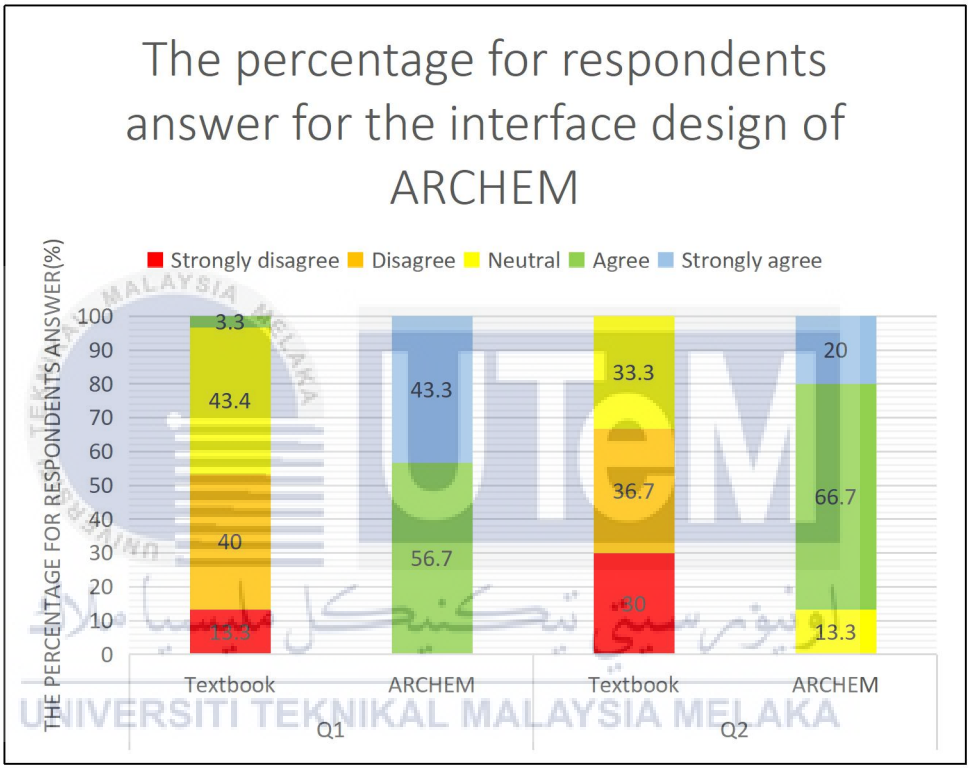

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Figure 6.33 Graph of the percentage for respondents answer for interface design of learning material

Figure 6.33 shows the graph of percentage for respondents answer for the interface design of learning material. In this part, two questions will be asked. Question 1 is about the interface design is attractive. One respondent(3.3%) agree, 13 respondents(43.3%) neutral, 12 respondents(40%) disagree and 4 respondents(13.3%) strongly disagree that the interface design of textbook is attractive. For ARCHEM, there are 17 respondents(56.7%) agree and 13 respondents(43.3%) strongly agree that ARCHEM have the attractive interface design. Question 2 is about the text and color used are readable. There are 10 respondents(33.3%) neutral, 11 respondents(36.7%) disagree and 9 respondents(30%) strongly disagree that the text

and color used in textbook are readable. On the other hand, 4 respondents(13.3%) neutral, 20 respondents(66.7%) agree and 6 respondents(20%) strongly agree that ARCHEM have the text and color which is readable. From the result, most of the respondents give good responses with agree statement that ARCHEM is better in interface design compared to textbook.

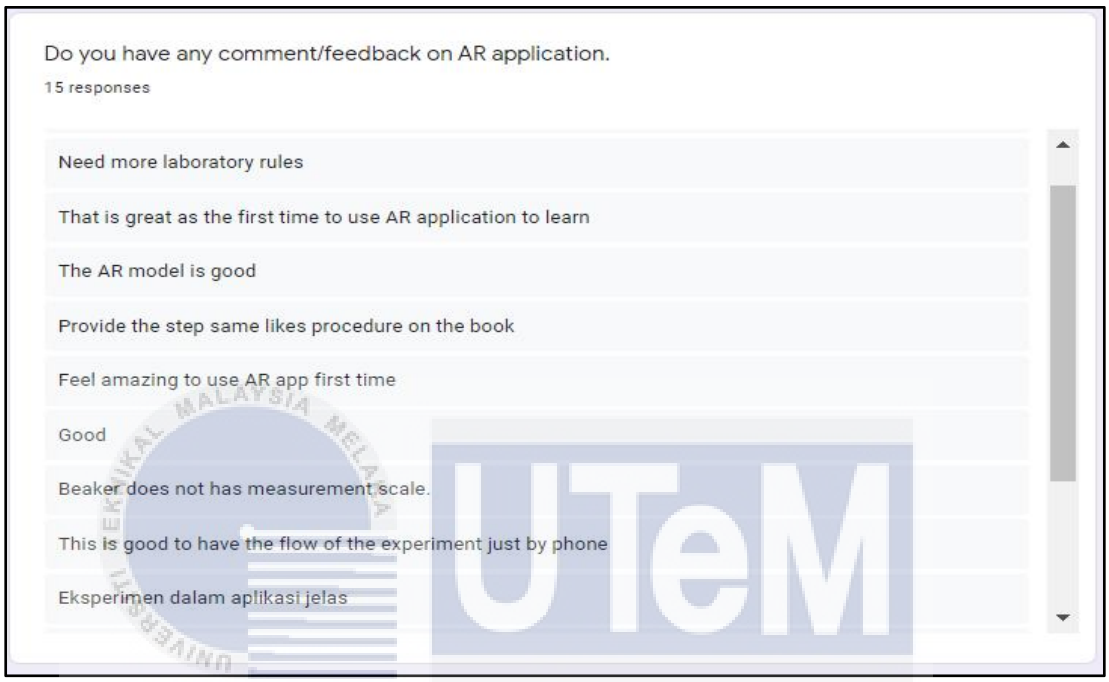

Figure 6.34 The feedback from respondents

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There are some respondents give the good feedback in user acceptance testing. A few of respondents feels great and amazing to use AR application to learn the Chemistry experiment for the first time. There are also the respondents give the suggestion on adding more rules, adding scale to the beaker design.

In a nutshell, all of the data collected from end users have proved that learning electrolysis experiment by using AR application is more effective than the learning by textbook. ARCHEM provide the clear procedure that user easy to understand and remember without conducting experiment. Most of the respondents give the good response to ARCHEM as it gives the learning electrolysis experiment that is interesting. ARCHEM also more convenient to use without considering anytime or any place. The interface design of ARCHEM is more better than textbook that enables user to learn easily.

6.6 Conclusion

The testing phase is aims to test the effectiveness of the ARCHEM application in learning electrolysis experiment compared to the textbook. The user acceptance testing for experts and end users help to evaluate the application in content, learnability, accessibility and interface design. The pre-test and post-test quizzes help to compare the effectiveness of ARCHEM and textbook. All of the result collected proved that the virtual electrolysis experiment through AR is more efficient than textbook. ARCHEM can help the user to imagine the procedures of electrolysis in their phone and avoid the accident might occur if they conduct the experiment in laboratory.

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CHAPTER 7: CONCLUSION

7.1 Observation on Weakness and Strengths

Most of the application have their own weakness and strengths especially for ARCHEM which developed in a few months. There are some weakness and strength that identified in the testing phase.

7.1.1 Weakness

From the data collected, there are some weakness in ARCHEM. First and foremost, experts give the feedback about the ARCHEM application should has IOS version. This is because ARCHEM only can be used for the Android smartphones that will make the IOS user cannot use. In addition, Android smartphones user also need make sure their smartphone at least Android 4.4.

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Other than that, the end user also list down the weakness of ARCHEM. One of the respondents stated that the rules part of ARCHEM application should add more rules. Another respondent give the feedback about the AR beaker as the 3D beaker only show the shape of beaker but does not provide the measurement scale of beaker. As we know, beaker has the measurement scale which enables the user to know the correct amount of chemical solution used based on the experiment's need. Therefore, the 3D apparatus model need to improve in modelling to make it more realistic.

7.1.2 Strengths

The strengths of the ARCHEM application is the use of marker-less based augmented reality technology in this application. This technology will help the user to interact in learning process. This is because they able to learn the AR apparatus by rotate and scale the AR apparatus model. The AR apparatus is more effective in helping the users to recognize the apparatus. In addition, AR procedures also enable user to remember the procedure of electrolysis experiment if they do not have the opportunities to conduct the experiment in school. The content of ARCHEM also follows the syllabus in the textbook. Thus, the students can learn the electrolysis by using ARCHEM.

Second, ARCHEM also enables users convenient to use it as ARCHEM is a mobile application. The user can learn the content of electrolysis experiment in their smartphones which is more convenient compared to the textbook. They can also use it anytime and any places to study.

7.2 Preposition for Improvement

Based on weakness and strengths from above, ARCHEM need to has the improvement in future. ARCHEM application should be able to download for the IOS users. It should also provide the application for IOS users to learn and experience it.

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In addition, another preposition of improvement is the adding of the rules in laboratory. There are only 9 rules that listed down in ARCHEM. The rules of laboratory should be increase. Besides, the 3D apparatus should be improved to make it more realistic as the real apparatus, For example, adding the measurement scale on the beaker that will make it more realistic. The 3D procedure also need to improve in the animation skill.

Based on the suggestion from evaluator, the testing phase should included the alpha testing and beta testing in future. The alpha testing should be performed to identify the bugs before releasing the product to real users. For development of AR application, the application should be tested by the developer who have the

knowledge of augmented reality to identify whether this application achieved the concept of augmented reality or not. Beta testing is the testing done by the respondents in a real environment. Another suggestion from evaluator is the pre-test and post-test should be conducted in two different groups of respondents to show the comparison between two learning materials effectively. For example, 15 respondents will answer the pre-test with the reading on textbook while another 15 respondents will answer the post-test after using AR application to learn.

7.3 Project Contribution

For ARCHEM application, this project will contribute to the Form 5 students who will learn the electrolysis experiment in school. This will help the students from some school that will not able to conduct this experiment in school due to the dangerous experiment reasons. The expert Madam Nurun Nadia from SMK Sultan Ibrahim Kulai gave the support and suggestions in the whole project development. Other teacher also spend their free time to view ARCHEM application and test for the user acceptance testing. Last but not least, 30 students from SMK Sultan Ibrahim Kulai also give the cooperation in answering the pres-test, post-test and user acceptance test. Thank you for all the respondents who help in this project.

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7.4 Conclusion

As a conclusion, the objectives have been achieved by ARCHEM based on each chapter above. The use of marker-less based technology in ARCHEM help the user to learn the electrolysis experiment in the way of more interesting. However, there are some of the improvement required to make ARCHEM become better to use. Therefore, the project is successfully developed and achieve all the objectives.

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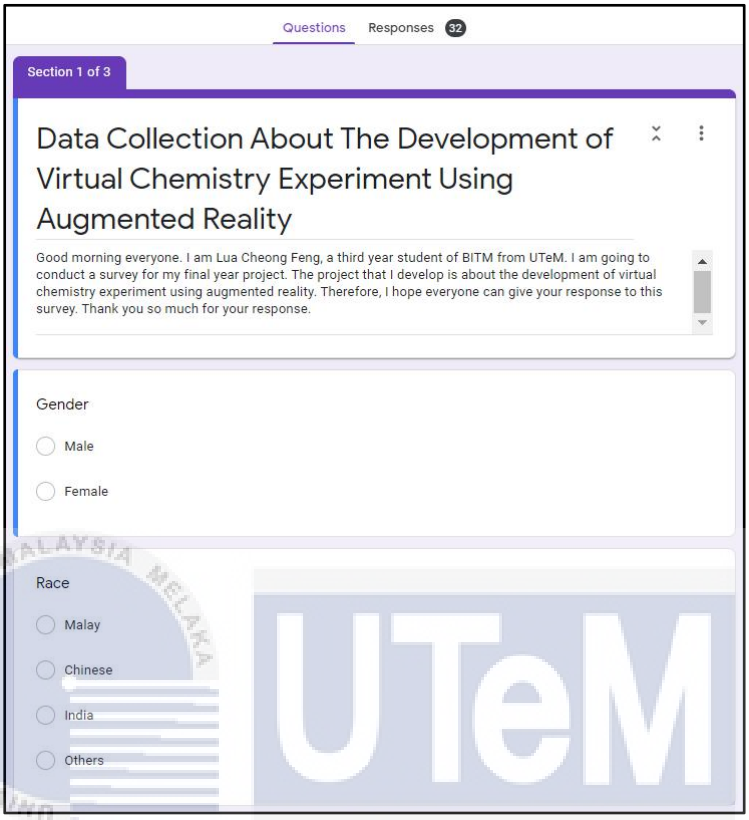
APPENDIX A



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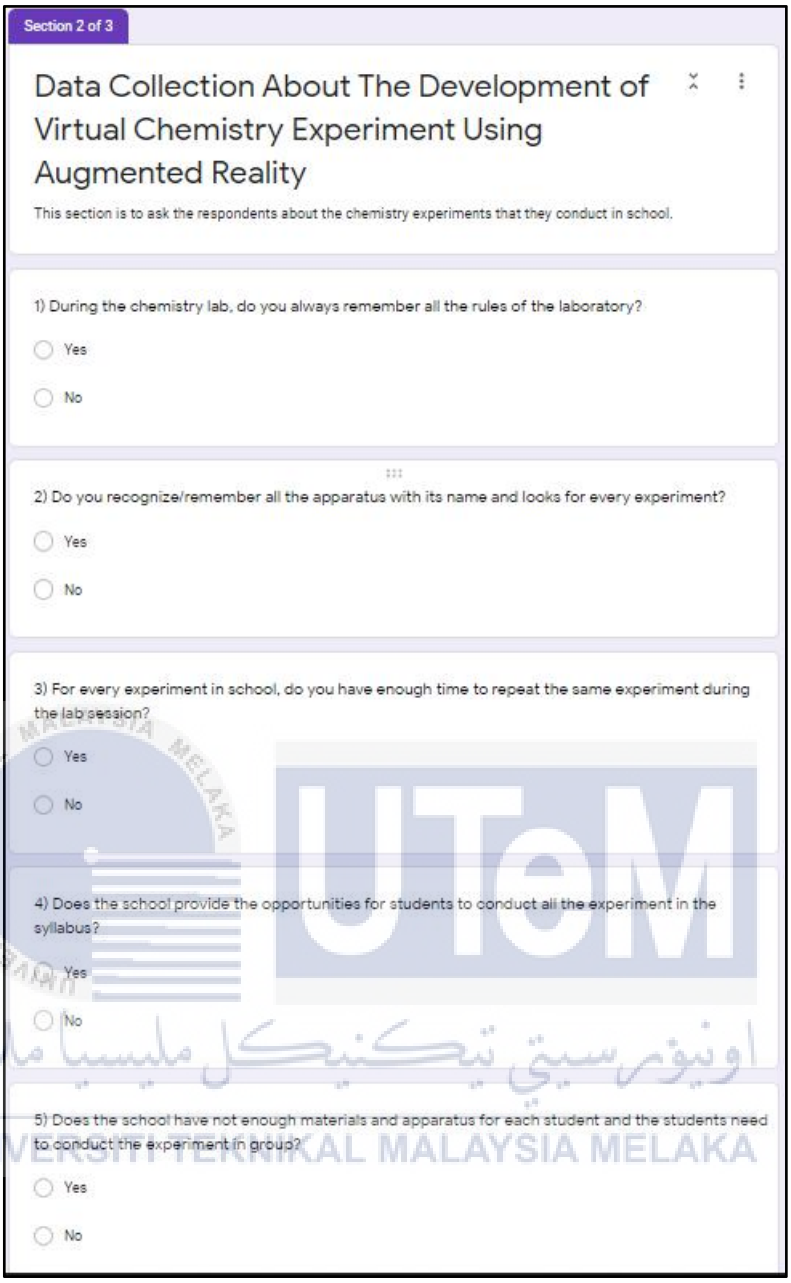

Section 2 of 3

Data Collection About The Development of Virtual Chemistry Experiment Using Augmented Reality

This section is to ask the respondents about the chemistry experiments that they conduct in school.

1) During the chemistry lab, do you always remember all the rules of the laboratory?

- Yes
- No

2) Do you recognize/remember all the apparatus with its name and looks for every experiment?

- Yes
- No

3) For every experiment in school, do you have enough time to repeat the same experiment during the lab session?

- Yes
- No

4) Does the school provide the opportunities for students to conduct all the experiment in the syllabus?

- Yes
- No

5) Does the school have not enough materials and apparatus for each student and the students need to conduct the experiment in group?

- Yes
- No

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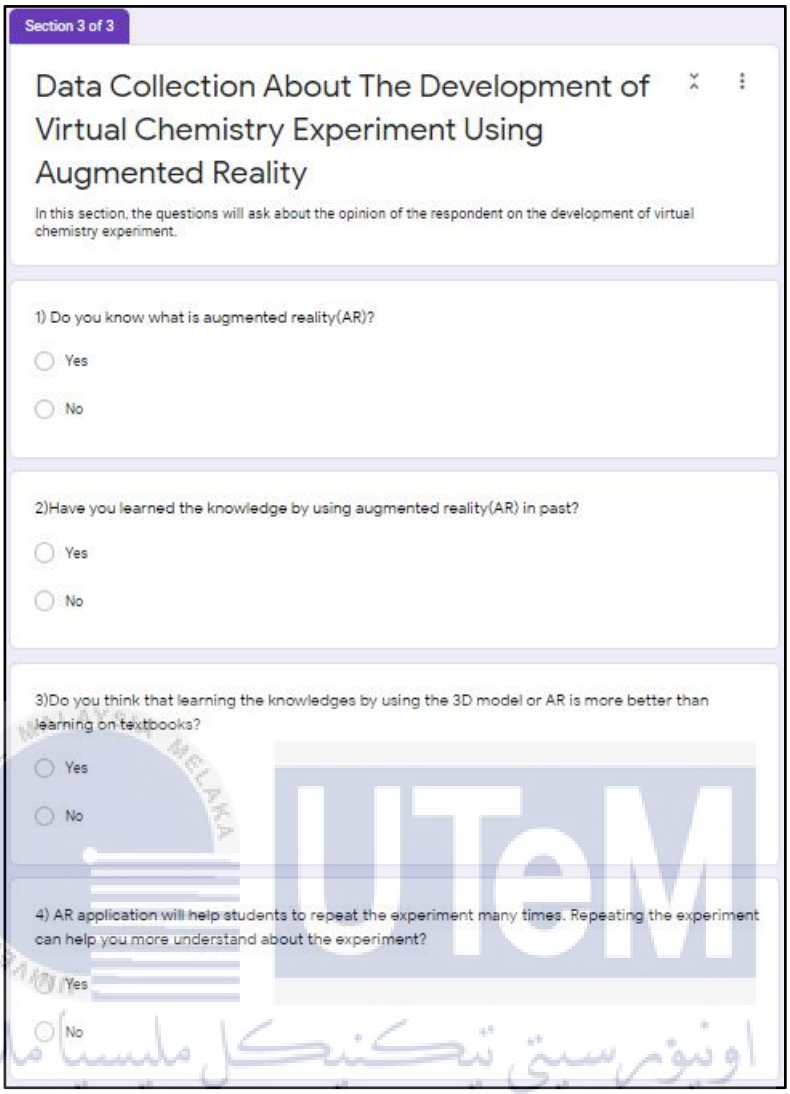


Section 3 of 3

Data Collection About The Development of Virtual Chemistry Experiment Using Augmented Reality

In this section, the questions will ask about the opinion of the respondent on the development of virtual chemistry experiment.

1) Do you know what is augmented reality(AR)?

- Yes
- No

2)Have you learned the knowledge by using augmented reality(AR) in past?

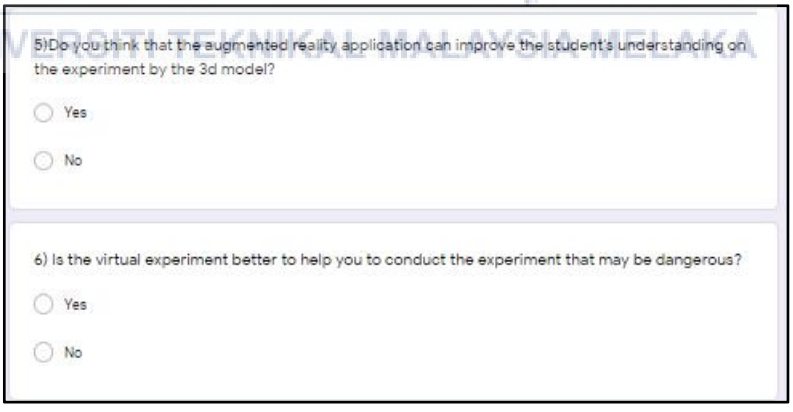
- Yes
- No

3)Do you think that learning the knowledges by using the 3D model or AR is more better than learning on textbooks?

- Yes
- No

4) AR application will help students to repeat the experiment many times. Repeating the experiment can help you more understand about the experiment?

- Yes
- No



5)Do you think that the augmented reality application can improve the student's understanding on the experiment by the 3d model?

- Yes
- No

6) Is the virtual experiment better to help you to conduct the experiment that may be dangerous?

- Yes
- No

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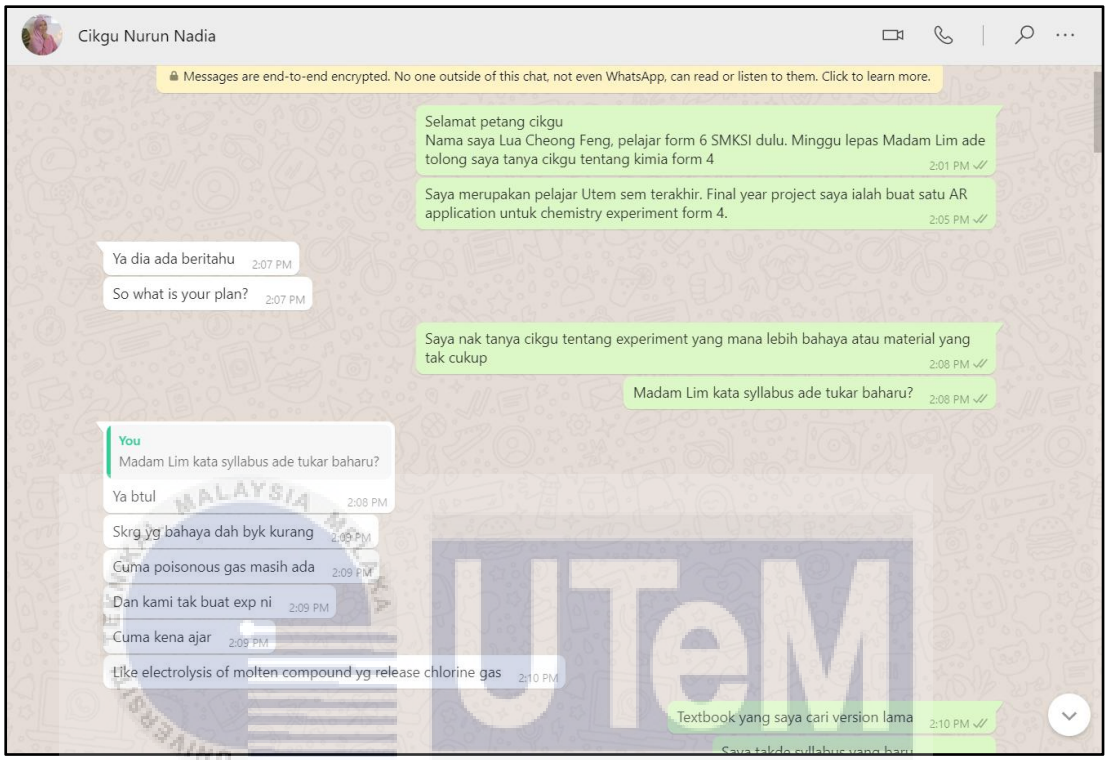
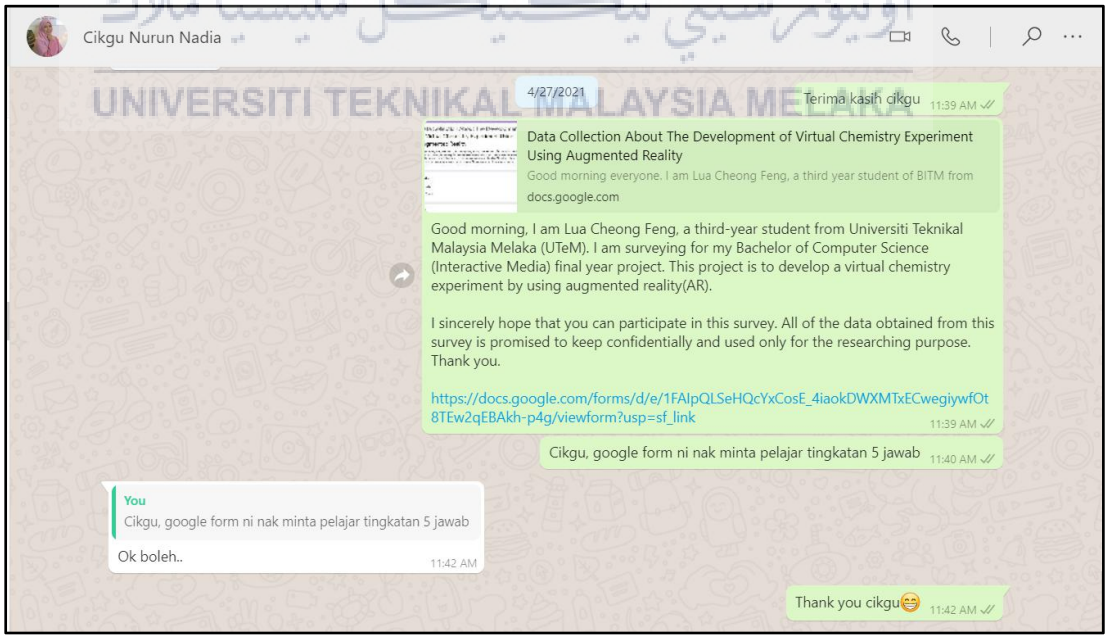
APPENDIX B





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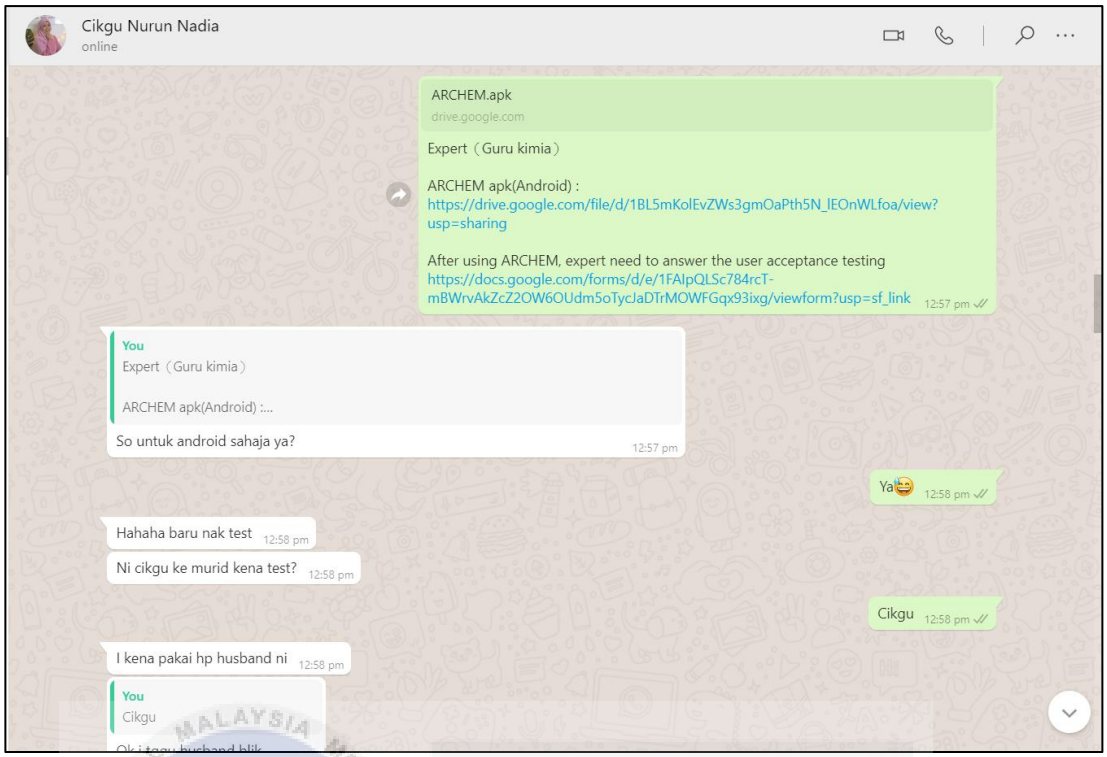

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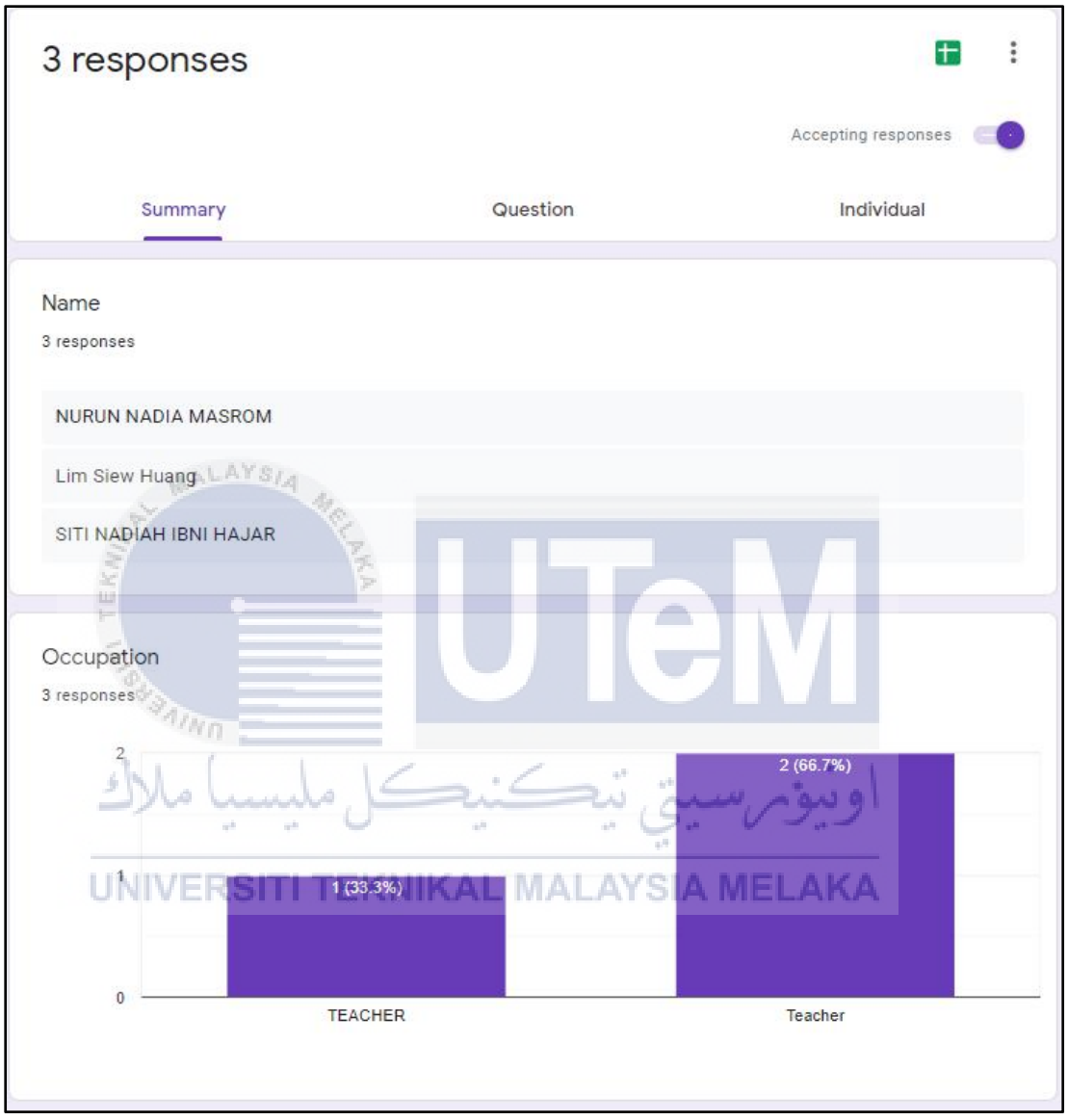
APPENDIX C



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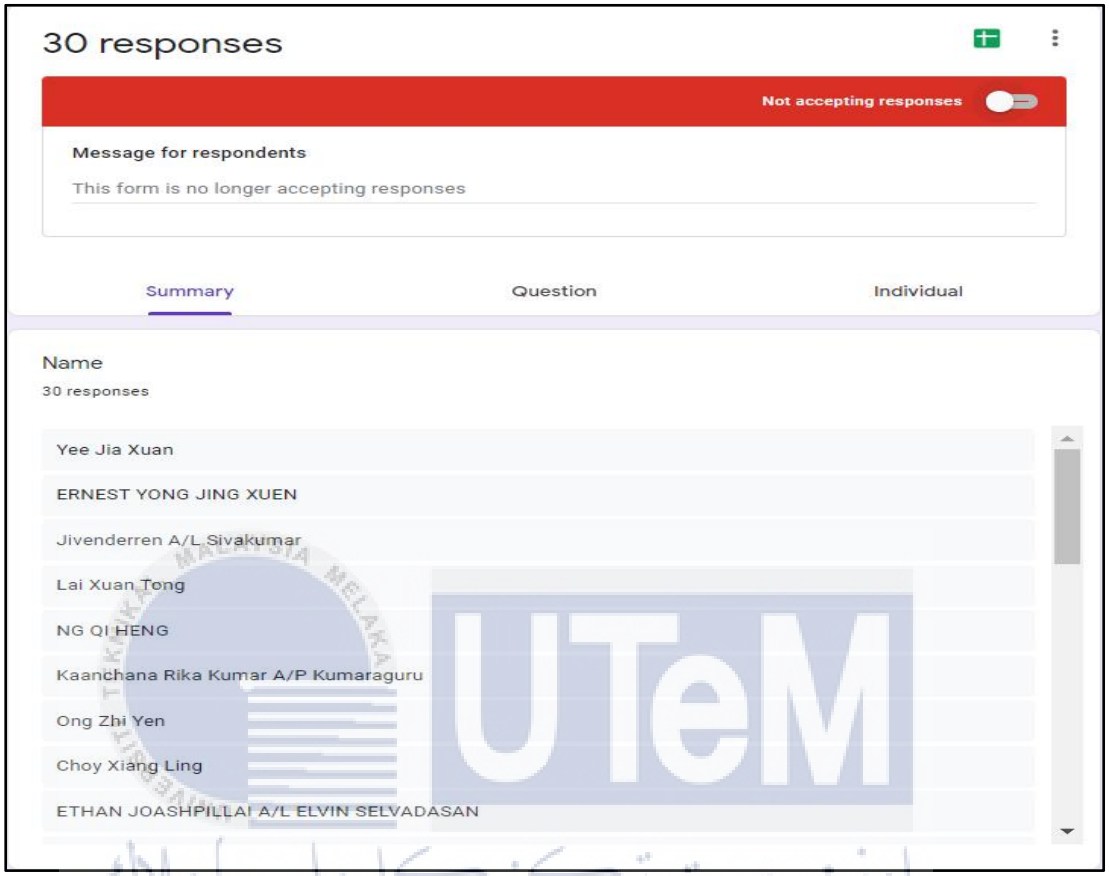
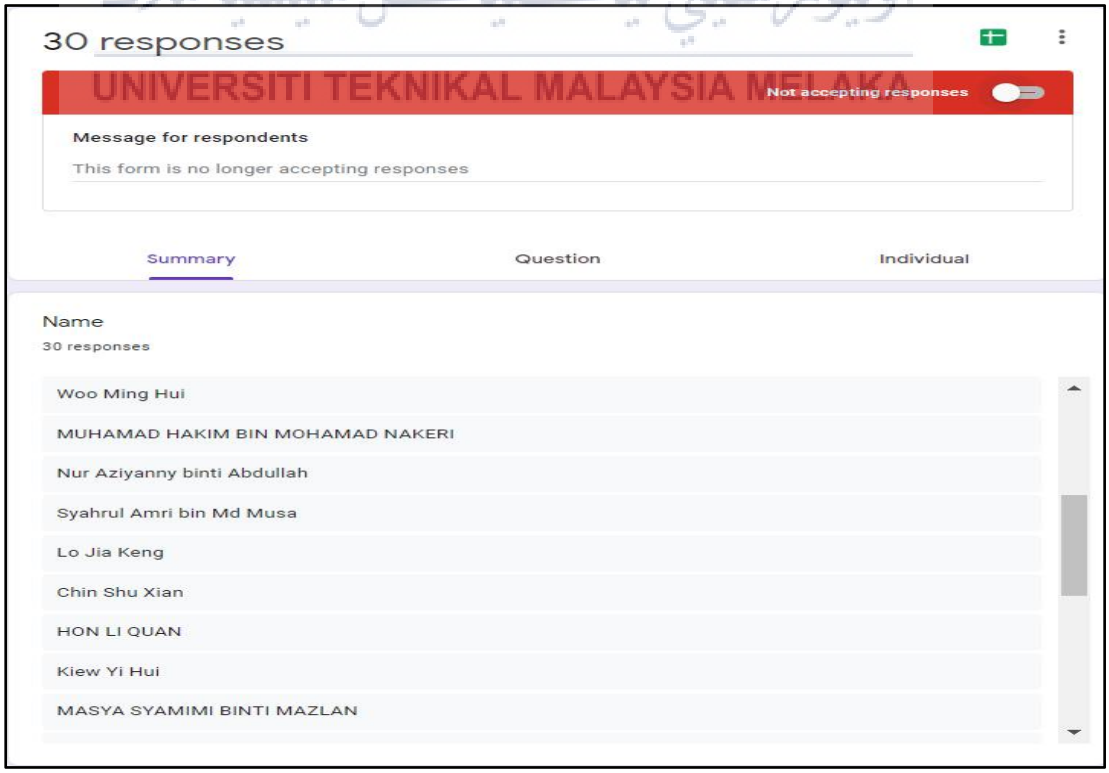
APPENDIX D





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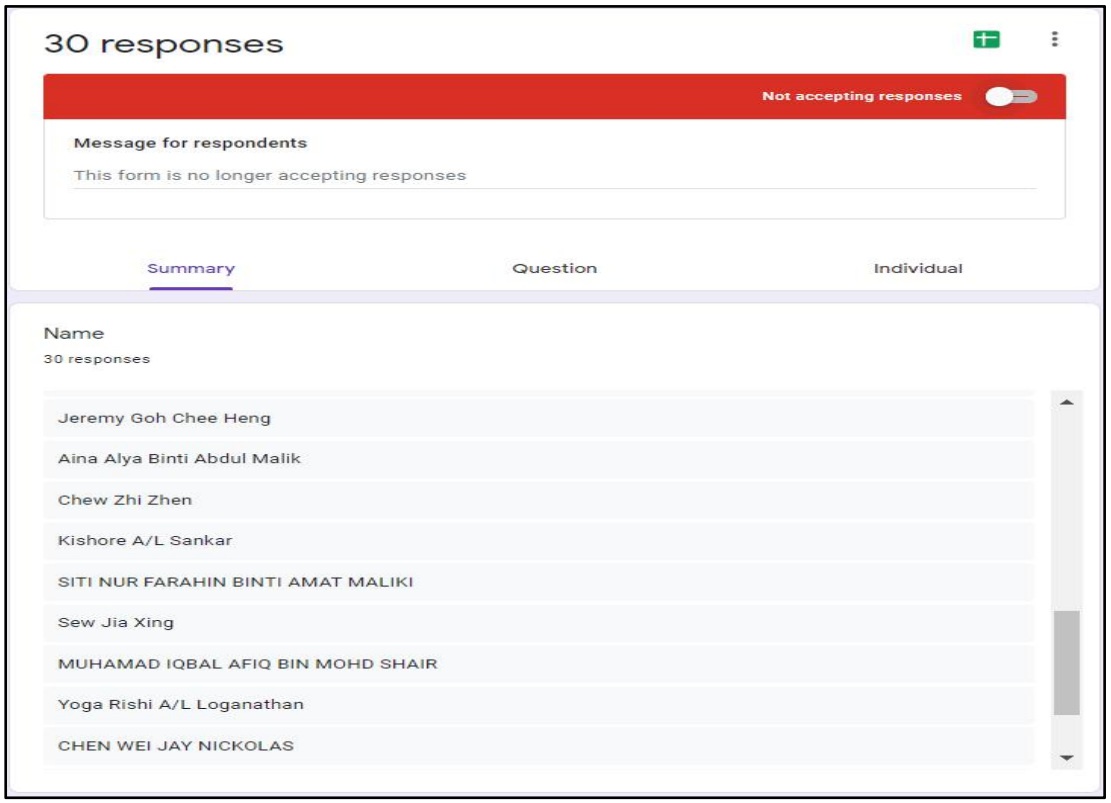
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Chew Zhi Zhen
Kishore A/L Sankar
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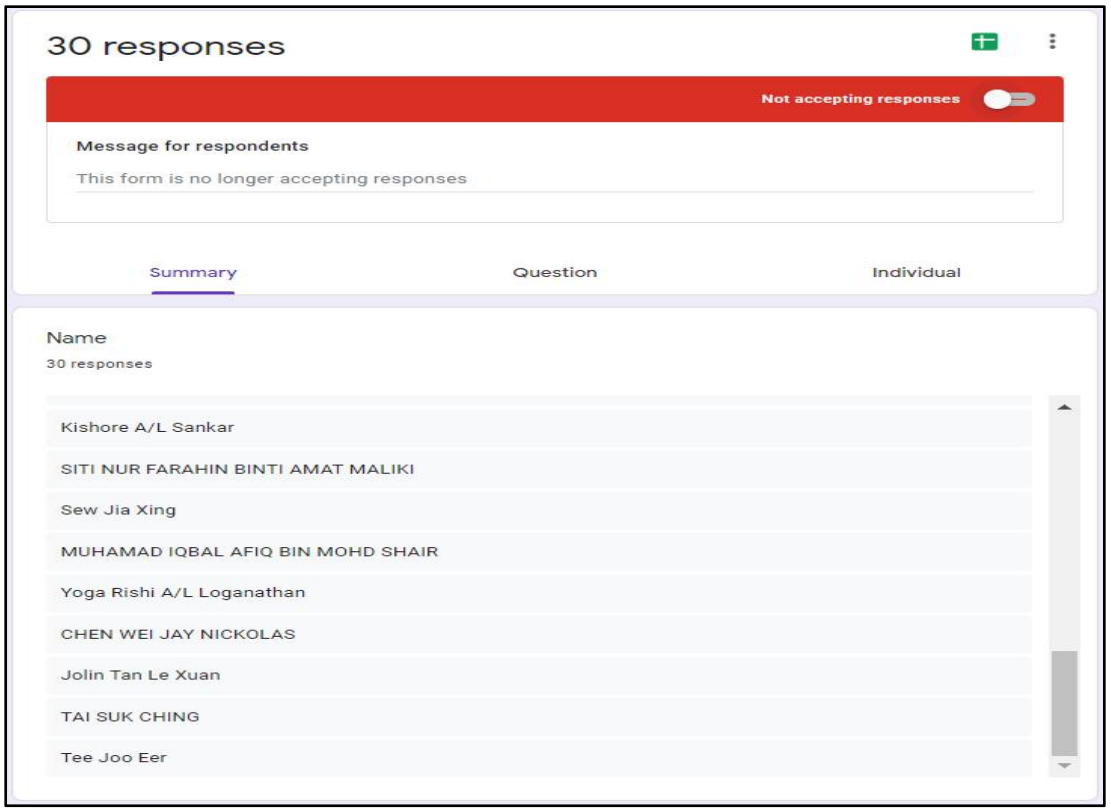
MUHAMAD IQBAL AFIQ BIN MOHD SHAIR
Yoga Rishi A/L Loganathan
CHEN WEI JAY NICKOLAS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Jolin Tan Le Xuan
TAI SUK CHING
Tee Joo Eer