DEVELOPMENT OF MOBILE APPLICATION ON LEARNING CRYSTAL THROUGH AUGMENTED REALITY

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DEVELOPMENT OF MOBILE APPLICATION ON LEARNING CRYSTAL THROUGH AUGMENTED REALITY

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

FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I hereby declare that this project report entitled

[DEVELOPMENT OF MOBILE APPLICATION ON LEARNING CRYSTAL

THROUGH AUGMENTED REALITY]

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

without citations.

STUDENT   : _____*huijie*_____ Date : 3/9/2021

(ONG HUI JIE)

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

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

Bachelor of [Computer Science (Interactive Media)] with Honours.

SUPERVISOR   : _____ Date : 12/9/2021

(TS.NORAZLIN BINTI MOHAMMED)

DEDICATION

Specially dedicated to my beloved family, friends and supervisor.

ACKNOWLEDGEMENTS

I would like to express my deep and sincere gratitude to my supervisor, Madam Ts. Norazlin Binti Mohammed for giving me invaluable guidance and assistant to complete this final year project successfully. I am extremely grateful for what she has offered me.

In addition, I would like to thank my beloved family and friends for their caring, love and mentally support throughout the journey of completing this project. Their encouragements are essential for me to finish the project.

ABSTRACT

The common platforms for learning crystals are website, book and mobile application. The learning materials in these learning platforms may work but lack of interactive, attractive and combination information of crystals chemical knowledge and their metaphysical properties. Hence, this project is proposed with the title "Development of Mobile Application on Learning Crystal through Augmented Reality". The project is aims to study on the marker-less augmented reality on learning the chemical knowledge and functionality of crystals, develop a marker-less augmented reality application in assisting user to learn and recognize crystals, and evaluate the user acceptance of augmented reality in learning the crystals compared to conventional learning methods. This project integrates the information of chemical knowledge and function of crystals. Users can learn the type of crystals through visualization of 3D models. Besides, users can interact with the crystal 3D models and crystal's structure 3D models by using slide bar and button. This project is developed by using Jmol, Blender, Adobe Photoshop and also Unity. The completion of the application will enhance the user understanding about the crystals. The AR mobile application will be the final product at the end of this project.

ABSTRAK

Platform yang biasa digunakan untuk belajar kristal adalah laman web, buku dan aplikasi mudah alih. Maklumat yang dibekalkan di platform tersebut mungkin boleh memanfaatkan pengguna tetapi susah menarik minat pengguna, kekurangan interaktif dan kekurangan gabungan pengetahuan kimia tentang kristal dan sifat metafizik kristal. Oleh itu, projek ini diusulkan dengan judul "Pengembangan Aplikasi Mudah Alih pada Pembelajaran Kristal melalui Augmented Reality". Projek ini bertujuan untuk mengkaji terhadap AR tanpa penanda pada pembelajaran pengetahuan kimia dan fungsi kristal, membangunkan aplikasi AR tanpa penanda yang dapat membantu pengguna mempelajari dan mengenali kristal dan menilai penerimaan pengguna terhadap AR dalam mempelajari kristal berbanding dengan kaedah pembelajaran konvensional. Projek ini menggabungkan maklumat pengetahuan kimia dan fungsi kristal. Pengguna dapat mengetahui jenis kristal melalui visualisasi model 3D. Selain itu, pengguna boleh berinteraksi dengan model 3D kristal dan model 3D struktur kristal dengan menggunakan slaid bar dan butang. Projek ini dibangunkan dengan menggunakan Jmol, Blender, Adobe Photoshop dan juga Unity. Penyiapan aplikasi ini akan meningkatkan pemahaman pengguna mengenai kristal. Hasil produk project ini adalah aplikasi mudah alih AR.
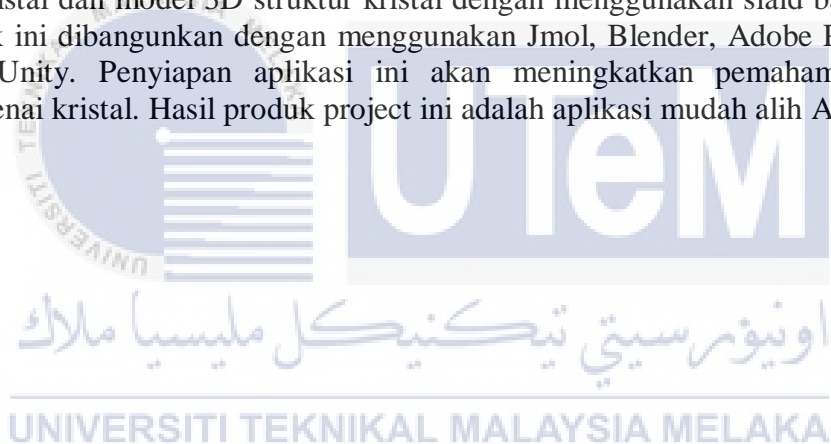
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LIST OF ABBREVIATIONS

FYP   **-**   **Final Year Project**

AR   **-**   **Augmented Reality**

3D   **-**   **3 Dimensional**

API   **-**   **Application Programming Interface**

UAT   **-**   **User Acceptance Test**

LIST OF ATTACHMENTS

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CHAPTER 1: INTRODUCTION

1.1   Introduction

Augmented Reality (AR) technology is widely used in learning and education now. According to the survey conducted by the law firm Perkins Coie and the XR Association, 41% of the respondents said the technology is the most applicable for education sectors (Molnar.M, 2019). AR technology is help to enhance the real environment with interactive computer generated input such as visual elements and sound. AR learning is much more interesting than traditional learning methods because the users can interact with the 3D model directly. Through the integration of AR technology with learning tools, users can learn in interactive way rather than self-learning with a dull book. From the results of the survey of use mobile augmented reality for teaching materials by M Fadhil and K Sumardi (2019), the response received from respondents are positive such as AR is fun and interesting and can produce a new learning experience.

Crystals are popular in worldwide to make bracelet, pendant, charm and so on. A crystal is a solid that has long-range positional order and come in many different colors. Natural crystals often form in nature and the process of crystal forming is called crystallization. Crystals can be classified based on the crystal structure, crystal system, lattices and properties. Nowadays, a lot people are using crystals as healing purpose. According to the survey which was performed in the Community Health Centre Paskintan by Ishaque.S, Saleem.T and Qidwai.W, 63% of the respondents were aware of the use of crystals therapy, 28% of them know the usage of gemstone other than jewelry， 24% were current gemstones therapeutics users and 38% had used it before. These healing crystals have particular frequency

and vibration which arise from their molecular composition. According to experts, natural extracted crystals harness the energies of the sun, moon, and oceans to improve human's state. Crystals have been proven scientifically that can induce a placebo effect in body which is helps in medical treatment (TNN, 2019).

This project is aim to integrate the AR technology with crystals learning. The general information of crystals and related chemistry knowledge will be combined to help the learners to differentiate the crystals easily.

1.2   Problem Statement

In chemistry lesson, crystals are discussed about its properties and structure. For the public, crystals are beautiful stones with healing function which are mainly used to make jewelry. The existing system normally just focused on one of the field and the platforms that introduce the crystals are rarely to combine both of the information.

Moreover, crystals can be identified by color, chemical structure and crystal system. The beginner of crystal learners may confuse of the type of crystals because some of the crystals are similar in color but with different chemical structure and vice versa.

Besides, most of the learners are gain the related knowledge from the book or website. The conventional learning methods are dull and some of the learners will give up in learning more about crystals because lack of attractive and interest.

As a conclusion, the current system transformed the crystals' information from offline to online but none of the technology provides visualization features for learning the crystals' knowledge.

1.3   Objective

This project embarks on the following objectives:

1. To study on the marker-less augmented reality on learning the chemical knowledge and functionality of crystals.

2. To develop a marker-less augmented reality application in assisting user to learn and recognize crystals.

3. To evaluate the user acceptance of augmented reality in learning the crystals compared to conventional learning methods.

1.4   Scope

The target user of this project is public especially for the beginners who are interested in crystals and chemistry students. The users can interact with the 3D crystals model and 3D crystals chemical structure model in interesting way. They can view the 3D model in augmented reality and view the information of crystals in the application. The project will use English language as medium to ensure all the people can understand it.

1.5   Project Significance

The project will provide the information of crystals in interactive way by using AR. Moreover, this project will help the public to enhance their knowledge of crystals such as function and chemical knowledge. This project will point out how to differentiate the type of crystals by its chemical structure and color. Augmented reality can improve the learning experience and make the process of learning crystals more interesting compare to conventional learning.

1.6   Conclusion

The project is expected to produce an augmented reality application that introduces the information about the crystals to users. Users are expected to learn the type of crystals, function of crystals, chemical composition of crystals and some others related information through the augmented reality application. The users are expected to learn the crystals in interactive way and get the knowledge more easier than conventional learning way. In conclusion, this chapter is briefly explained the purpose of the project.

CHAPTER 2: LITERATURE REVIEW AND PROJECT METHODOLOGY

2.1 Introduction

AR technology is widely used in education and learning. AR mobile learning has become a new trend as mobile classroom for learners to absorb knowledge at everywhere and every time. This chapter will discuss about the domain of the project, existing system and project methodology. The domain section will includes literature review about the topic discussed. Next, the existing system related to crystals learning will be compared later on. The methodology section describes the method, software and hardware that are being used in the whole development process of the project.

2.2 Domain

The domain of the project is focused on develop an AR learning mobile application. Definition and concept of AR mobile learning, type of AR, AR mobile application, AR in learning, AR in learning chemistry and information about crystals will be discussed in domain section.

2.2.1 Definition and Concept of AR Mobile Learning

Mobile learning is related to e-learning which serves as virtual classroom to provide education without any places or time restrictions (Chowdhury, Shahan. (2013). According to R.T. Azuma (1997), AR is defined as "virtual objects are superimposed upon or combined with the real world objects". The use of AR in learning provides the chance for learners to interact with the virtual learning object in

real time. Learning through AR application gives the learners an interesting learning experience and enhance the outcome of learning.

2.2.2   Type of Augmented Reality

There are four main types of augmented reality, which are Marker-Based AR, Marker-less AR, Projection-based AR and Superimposition Based AR.

2.2.2.1 Marker-based AR

Marker-based AR as known as Recognition based AR is a mobile application that requires camera function to scan marker and the related information such as 3D objects, text or animation will be appear on the screen. The marker is usually a unique design picture or QR code. Figure 2.1 shows the example for marker-based AR.

Figure 2.1: Example of the Marker-Based AR

(Example of the App Augmented Reality Chemistry (ARC) in use (rotateable 3D model).Retrieved from https://www.researchgate.net/figure/Example-of-the-App-Augmented-Reality-Chemistry-ARC-in-use-rotateable-3D-model_fig3_349573151)

2.2.2.2 Marker-less AR

Marker-less AR is also called Location-based AR. Marker-less AR does not need any marker so it is consider more versatile than Marker-based AR. It works by gathering the positional data from the devices such as GPS, accelerometer and digital compass to predict where the user is focusing. Figure 2.2 shows the example for marker-less AR.

Figure 2.2: Example of the Marker-less AR

(Chris Wood, 2015. Cimagine brings its markerless augmented reality shopping platform to the masses. Retrieved from https://newatlas.com/cimagine-augmented-reality-shop-direct-partnership/36521/)

2.2.2.3 Projection-Based AR

Projection-Based AR also refers as Spatial AR. According to the research "Projection-based Augmented Reality in Engineering Applications" by Stork, André & Bimber, Oliver and Amicis, Raffaele (2002), Projection-Based AR is a new concept which using semi-transparent mirrors as optical combiners to extends VR technology towards AR. The simplest description of projection-based AR is the projection of artificial light on a surface and the user can interact with it by hand. Figure 2.3 shows the example of projection-based AR.

Figure 2.3: Example of Projection-Based AR

(Poghpsyan.P. 2019. An example of projection-based AR in Geograpgy class. Retrieved from https://www.researchgate.net/figure/An-example-of-Projection-based-AR-in-Geography-Class_fig3_331181344)

2.2.2.4 Superimposition Based AR

Superimposition based AR uses the object recognition and replaces the following target object with an augmented view. It is allows to cover the original view of object partially or fully with a new augmented view. Figure 2.4 shows the example of superimposition based AR.

Figure 2.4: Example of Superimposition-based AR

(Poghpsyan.P. 2019.An example of Superimposition-based AR in a History Field-trip. Retrieved from https://www.researchgate.net/figure/An-example-of-Superimposition-based-AR-in-a-History-Field-trip_fig4_331181344)

2.2.3   Augmented Reality Mobile Application

Application of augmented reality in daily routine has become common in today's society. Mobile AR is rapid growth currently because it takes benefits of the widely distributed base of hardware such as tablets and smartphones (Alan B.Craig, 2013). AR mobile application are used in several fields such as gaming, medical, navigation, sightseeing, military, entertainment, maintenance and repair, advertising and promotion (kasetty sudarshan, Sneha, 2017). In gaming industry, the most popular AR application in worldwide is Pokémon GO. Pokémon GO is a location-based AR mobile game which using GPS to locate and explore the virtual creatures. The game is the first location-based AR games that reach a main stream status. AR technology contributes a lot in maintenance and repair field. For instance, RE'FLEKT is an augmented repair app which provides detailed instruction and guide for users to fix appliances, repair machines and build new furniture. Moreover, enterprise companies such as BOSCH, HITACHI, Brother Industries Medtronic and so on also cooperate with RE'FLEKT and use RE'FLEKT solutions. Besides, AR can enhance the real world environment by incorporating computer-generated perceptual information makes AR is ideal for navigation and sightseeing industry. There are plenty of AR mobile applications for travel such as World Around Me, Senditur, Smartify, Night Sky and AR City. World Around Me locates and indicates the buildings and facilities by using AR technology and the users can see the results and use as navigation. Senditur is an AR application specially designed for hiking in Spain. Next, Smartify focus on work of art and the application is available to use in The National Portrait Gallery and The Royal Academy of Arts in the United Kingdom, The San Donato Museum in Italy, The Metropolitan Museum of Art (New York), J. Paul Getty Museum (Los Angeles), Laguna Art Museum of Contemporary Photography (Chicago) in the United States, and Reina Sofía Museum in Spain. Night Sky is designed for users to identify stars, planets, constellations, and satellites. The application can be used in everywhere and no places restriction. Then, AR City can guide the user to travel in an unfamiliar city.

Figure 2.5: Example of Pokemon GO

Peter Clark, 2019. 'Pokemon Go' Creator on Augmented Reality's Massive Potential. Retrieved from https://variety.com/2019/gaming/features/pokemon-go-creator-on-augmented-realitys-massive-potential-1203169992/

Figure 2.6: Example of RE'FLEKT application

(Retrieved from https://www.youtube.com/watch?v=ixacsbRoMwY)

2.2.4   Augmented Reality in Learning

Augmented reality creates new teaching and learning methods that fulfill the requirement of 21st century learner. AR is considers as effective learning tool among the works done onto how advance technology can enhance the teaching. AR technology makes learning process become more effective and interesting because learner is possible to interact with the virtual objects, exploring the complicated concept and phenomena through the visualization and realization (Elmqaddem, N, 2019). AR can creates complex mechanism and theories and apply in subjects like astronomy, chemistry, biology, physics mathematics and geometry education (Lee, Kangdon, 2012).

2.2.5   Augmented Reality in Learning Chemistry

Augmented Reality has become supporting of traditional learning and defined as an effective learning way especially in chemistry (Camelia Macariua, Adrian Iftenea, Daniela Gîfua,b, 2020). AR provides innovative learning process by integrating multiple media element and theoretical instruction to strengthen the learners' science motivation (Valarmathie Gopalan, Juliana Aida Abu Bakar, Abdul Nasir Zulkifli1, 2017). AR technology solves the teaching obstacle related to 2-dimensions and 3-dimensions that help students to learn about crystallography concepts (Extremera, J., Vergara, D., Dávila, L. P., & Rubio, M. P. ,2020). According to the evaluation of Tavares et al. (2013) from five chemistry education application, 67% of the users felt these applications were more useful than traditional exercises.

2.2.5.1 ARChemistry Learning

The ARChemistry Learning consists of four modules which are "learn with the manual", "learn with the cards", "test your knowledge" and "add a substance". In the module "learn with manual", learners can scan certain unfamiliar chemistry words by phone's camera and the related information will shows on the screen. The "learn with cards" module is help learners to form chemical compound by focusing the camera on the card according to the indication. "Test your knowledge" module is

aim to test the learners can add any compound that created by themselves through "add a substance" function.
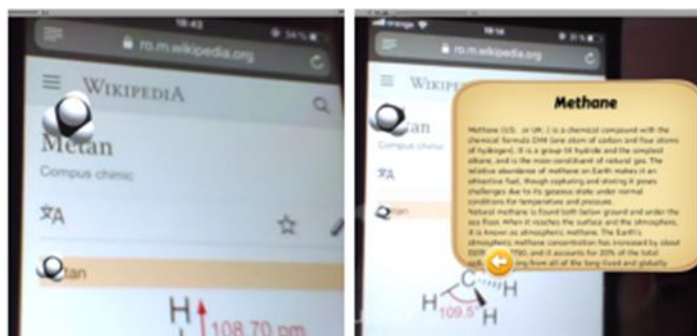
Figure 2.7: Example of screen in ARChemistry Learning

(Camelia Macariua, Adrian Iftenea, Daniela Gîfua,b, (2020). Learn Chemistry With Augmented Reality. Procedia Computer Science. Volume 176, Pages 2133-2142, ISSN 1877-0509. https://doi.org/10.1016/j.procs.2020.09.250.)

2.2.6 Crystals

According to Mahan, G. D. (2020), "Crystal is any solid material in which the component atoms are arranged in a define pattern and whose surface regularity reflects its internal symmetry". Crystals distinguish into seven categories of chemical structure which are cubic or isometric, tetragonal, orthorhombic, hexagonal, trigonal, triclinic and monoclinic. Crystals are believed having healing power and can help to improve human's state. Crystal therapy was grew popularity in 1980s and this kind of alternative therapeutic is conducting by placing the crystals at specific points of patient's body to balance the energy inside the body, release stress and induce deep relaxation (Living, 2018).

2.3 Existing System

2.3.1 Healing Crystals for you

Healing Crystals for you is a website written by Liz Oakes that provides information of healing crystals. In the website, users can search for the desired crystals according to the first letter of the crystals' name. A list of the crystals will

display when users select the alphabet within A to Z. Besides, the website also classified the crystals into few categories such as protection, medication, birthstones, chakras and so on. Thus, users can find and learn about the crystals based on their needs and interest. Figures below show the screenshot of the Healing Crystals for you website.
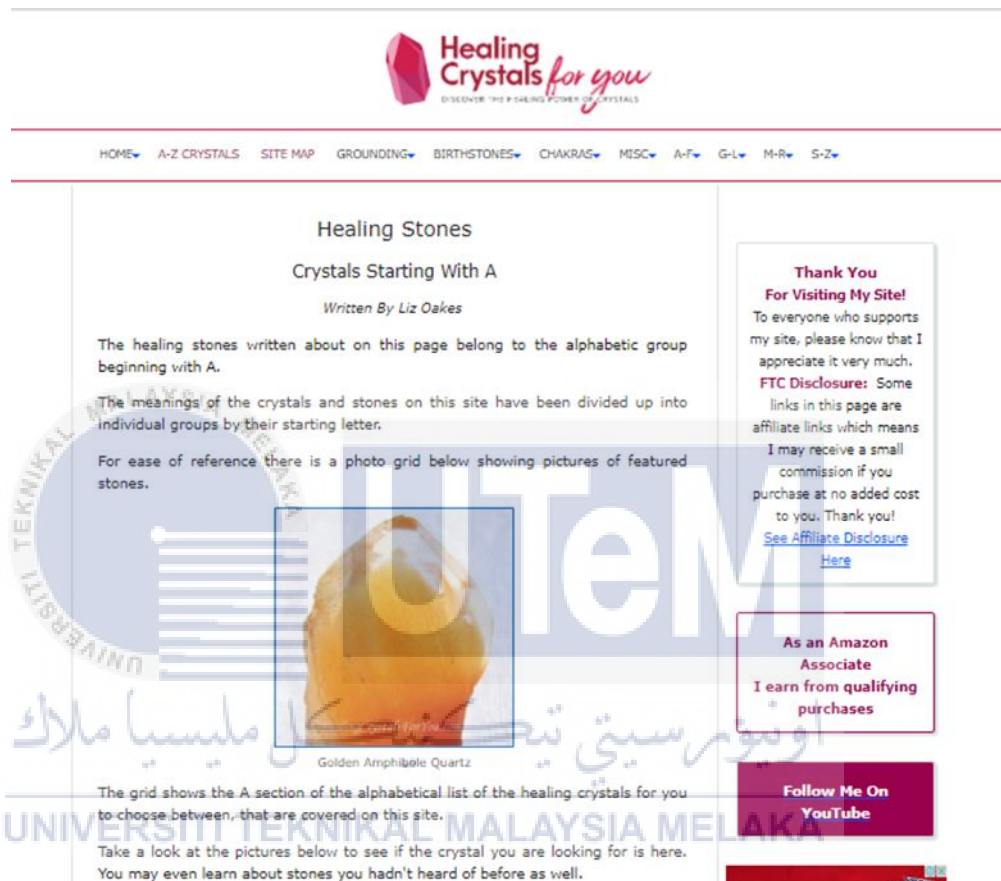
Figure 2.8: Screenshot of the Healing Crystals for you

(Liz Oakes. 2009-2021. Healing Crystals for you, Retrieved from https://www.healing-crystals-for-you.com/healing-stones.html)

2.3.2   A Guide To Crystals – The CC

A Guide To Crystals is a mobile application which developed by using unity. The mobile application consists of background, geological, chemical knowledge and healing function of the crystals. There are 389 types of crystals' information introduce in the application. The users can search for the crystals by using crystal's

names or filter by its colour, hardness, location, lustre, charkra, zodiac, element and metaphysical properties. In addition, the application provides simple pairs games and quiz for users. The users can test about their crystal knowledge after go through all of the crystals information.
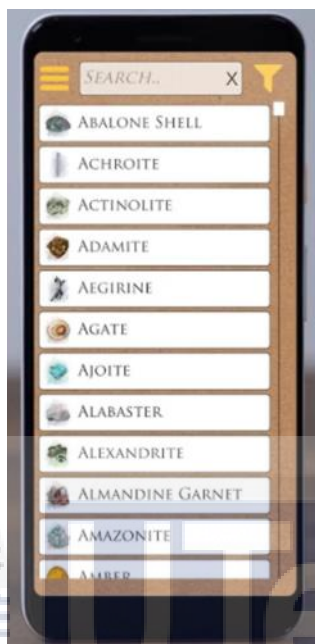
Figure 2.9: Screenshot of the A Guide To Crystals – The CC

(The Citrine Circle. 2020. A Guide To Crystals – The CC, Retrieved from https://play.google.com/store/apps/details?id=com.TheCitrineCircle.CrystalGuideTheCC&hl=en&gl=US)

Figure 2.10: Screenshot of the A Guide To Crystals – The CC

(The Citrine Circle. 2020. A Guide To Crystals – The CC, Retrieved from https://play.google.com/store/apps/details?id=com.TheCitrineCircle.CrystalGuideTheCC&hl=en&gl=US)

2.3.3   Minerals Guide: Rocks, Cryttals & Gemstone.Geology

Minerals Guide: Rocks, Crystals & Gemstone is a mobile application that allows users to explore rocks, crystals and minerals features. The application support voice search and advance search with autocomplete function. The dictionary guide is available when offline and it contains more than 4000 definitions of characteristics and terms. Users can learn about the crystals and minerals' definitions and chemistry knowledge like crystal system, crystal class and category formula through the application.

Figure 2.11: Screenshot of the Minerals Guide: Rocks, Cryttals & Gemstone.Geology

(99 Dictonaries: The world of terms, 2020. Minerals Guide: Rocks, Cryttals & Gemstone.Geology. Retrieved from https://play.google.com/store/apps/details?id=com.dictionary.MineralsGuide.Geology&hl=en&gl=US)

2.3.4   Comparison of Existing System

Table 2.1 shows the comparison of the three existing system. The system will be compared within the platform, information provided, convenience of searching function, target users and the interface and contents design.

Table 2.1: Comparison of Existing System

Existing System Name	Healing Crystals for you	A Guide To Crystals -The CC	Minerals Guide: Rocks, Crystals & Gemstone.Geology
Platform	Browser website	Mobile application	Mobile application
Information	General	General	General

Provided	information, crystals function	information, crystals function, chemical knowledge	information, chemical knowledge
Searching function	Search by alphabet - Inconvenience	Search bar, image gallery – Convenience	Advance search bar with autocomplete, voice search - Convenience
Target users	Public	Public	Geologists and hobbyists
Interface and contents design	Content design is messy	Attractive	Simple

2.4 Project Methodology

The methodology used in the development of the project is Multimedia Development Life Cycle (MDLC). The methodology has five phases, which is define, planning, implementation, construction and evaluation.

i. Define

In define phase, brainstorming about the project was done. Then, meeting with supervisor to discuss about the title of the project. Before preparing for the proposal, some research should be done to search for the idea and identify the target user.

ii. Planning

The main objective for the planning phase are analyze the objective and problem statement. The project requirements such as software and hardware and gantt chart will be analyze to make sure the project can be accomplished on time. The background and methods used in the project will be drafted in the proposal.

iii. Implementation

In implementation phase, all the software and hardware needed is prepared and installed.

iv. Construction

In construction phase, the AR element will be created by using the AR software and then added into the application. After finish the construction, technical testing and user testing will be done to check the bugs and errors. The application needs to make sure no any bugs or errors before demonstration and presentation.

v. Evaluate

In evaluation phase, the evaluation by the judge and target user will take place. The opinion of the judge and user feedback will be collected. The documentation for the development of project will proceed.

2.5   Project Requirement

Project requirement analyze the required software and hardware that used to develop the project.

2.5.1   Software Requirement

i. Blender

ii. Jmol

iii. Unity

iv. Balsamiq Mockups

v. Microsoft Visual Studio

vi. Microsoft word

vii. Microsoft Power Point

viii. Photoshop

2.5.2　Hardware Requirement

i. Mobile phone devices

ii. Laptop

CHAPTER 3: ANALYSIS

3.1 Introduction

This chapter will be a further study of chapter 2 that covers the current scenario analysis and the requirements analysis. The current scenario analysis will using flowchart to analyze the approach of the current scenario. The requirements analysis will includes the interview and analyze the collection data based on the Google form questionnaires to identify the demands of the users. Besides, the software requirements, hardware requirements and milestone will be included.

3.2 Current Scenario Analysis

The existing system of crystals learning was explained clearly in last chapter. In this part, the current scenario will be briefly discussed. There are three scenarios which are learning crystals by using books, learning crystals through web-based system and learning crystals through mobile application.

3.2.1 Learning Crystals by Using Book

The primitive way to learn crystals is using book. A lot of people still using books to learn crystals' knowledge nowadays. The scenario starts from the user open the first page of book and the table of contents state the page number of contents. Then, user can search for the page number of content from the table of contents and open the page. The information of crystals such as picture, properties and function will be shown.
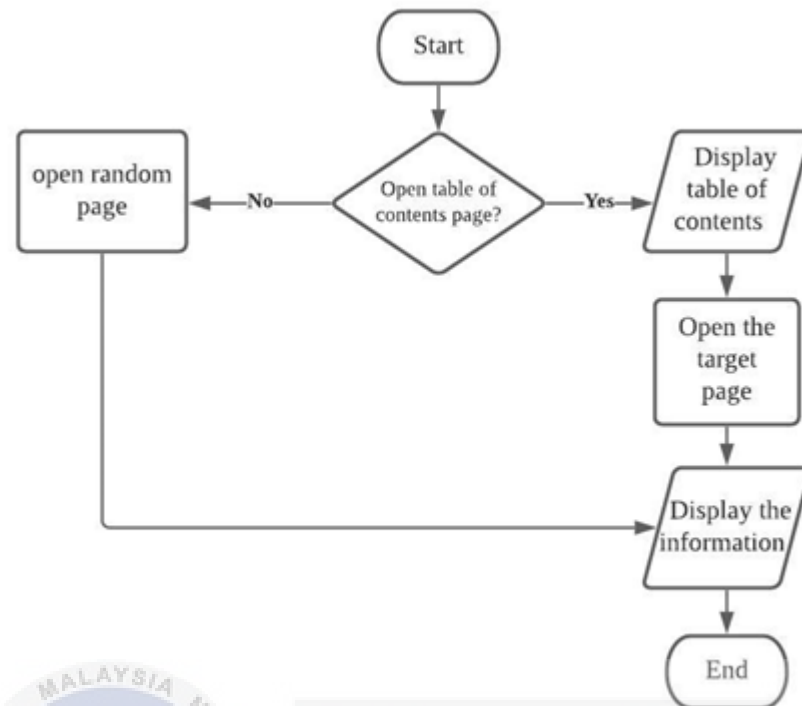
Figure 3.1: Flowchart for learning crystals by using books

3.2.2 Learning Crystals through Web-Based System

Web-based crystals learning system is considered as the most common learning way among the public. Users can search the crystal's knowledge and related information by searching function through web-based system. Figure below shows the flowchart for learning crystals through web-based system.
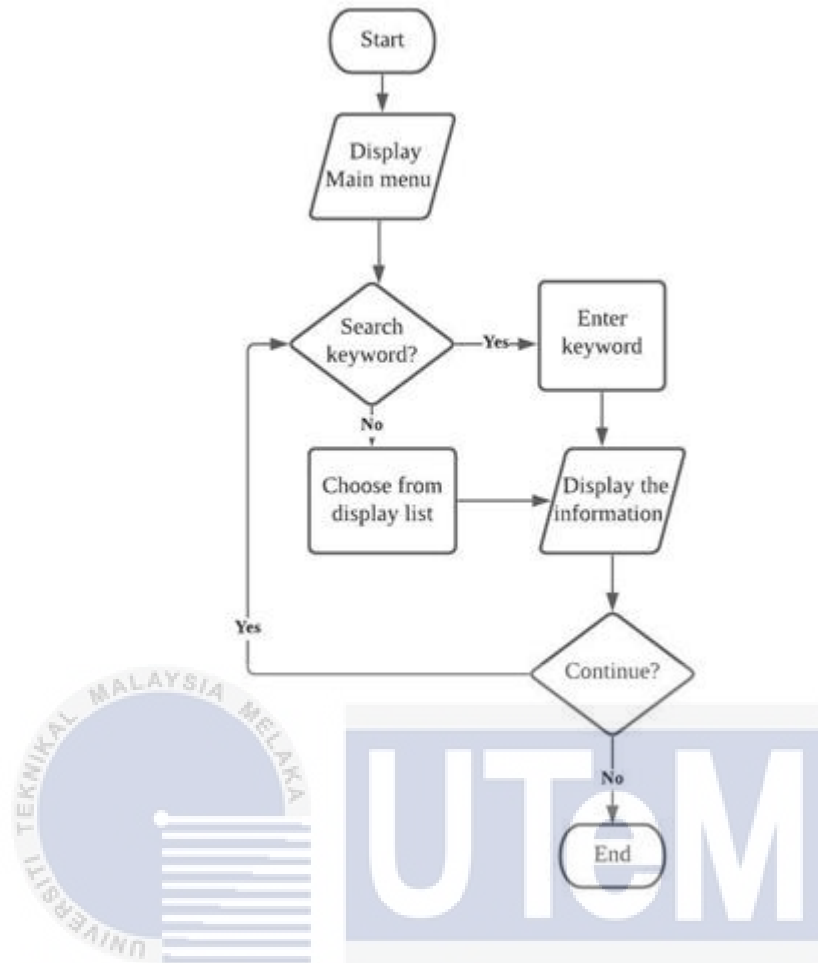
Figure 3.2: Flowchart for learning crystals through web-based system

3.2.3 Learning Crystals through Mobile Application

The mobile application learning is convenience because it can be used when offline. The information of the mobile application may be change and updated and user need to update the application from time to time to get the newest version. Figure 3.3 shows the flowchart for learning crystals through mobile application.
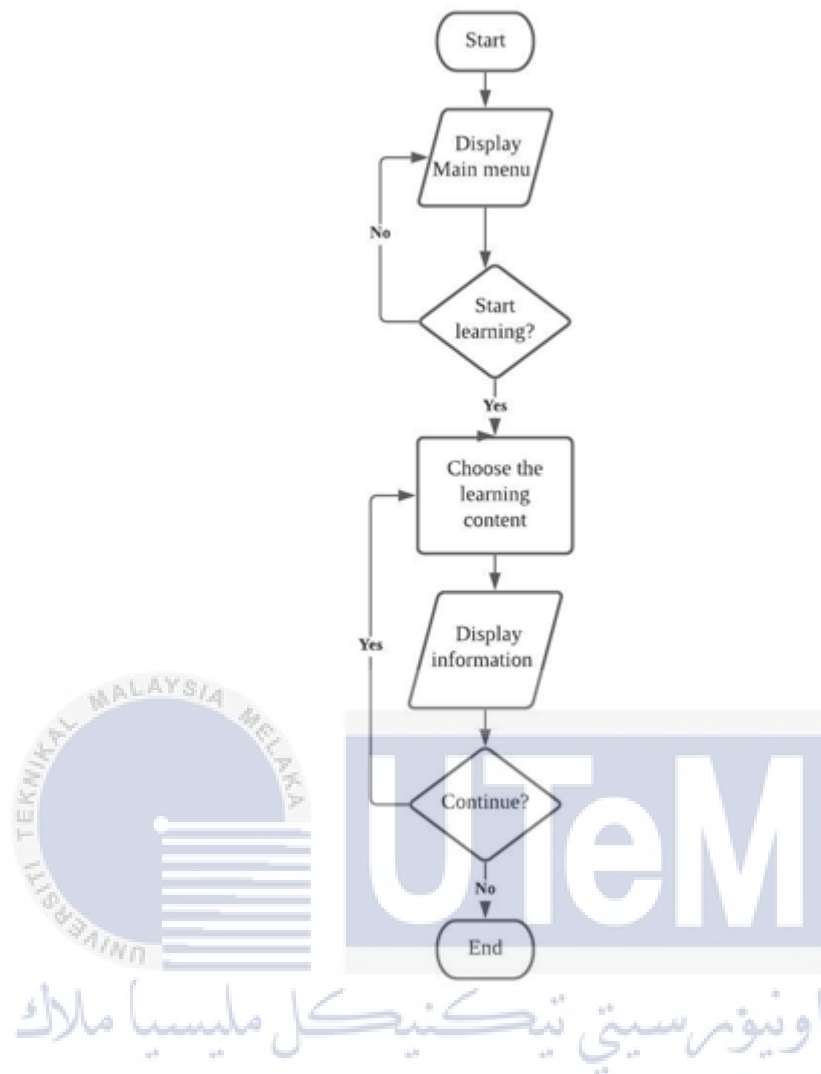
Figure 3.3: Flowchart for learning crystals through mobile application

3.3   Requirement Analysis

The requirement analysis will includes project requirements, software requirements and hardware requirements.

3.3.1   Project Requirement – Analysis of system to be developed

3.3.1.1 Requirement Gathering

Qualitative assessment and quantitative assessment are used for gathering the requirement. For qualitative assessment, interviews are conducted with the gemologist at Asia Gemological Laboratory and the crystals seller of 123 Live Mall Malaysia Sdn Bhd in Malacca. Then, questionnaire is distributed to target users to collect the requirement data.

(a)   Interview

An interview was carried out with the gemologist, Tan Ser Yuen. He gave some crucial point of view and suggestions in the interview. He agreed with the current crystals learning way is too boring and lack of interaction. From his point of view, AR learning is a great idea and makes the dull learning process more attractive and interesting. He suggested the system to visualize the crystals according to the crystal system and this can help the beginner learners to distinguish the crystals.

In addition, another interview was conducted with the Gan Koyi, who's the crystals seller of 123 Live Mall Malaysia Sdn Bhd. From her experience, customers are concerned and curious about the crystals' functions the most. Customers usually will ask about the crystals for health, study, love, wealth and protection. She thinks the AR learning mobile application is useful for the beginner crystals lover to learn the function of crystals and gain some related extra knowledge.

(b)   Questionnaire

A set of Google form questionnaire are distributed to the target users to collect their opinion and feedback. The questionnaire contains 10 questions and the data is collected from 25 respondents. Please refer to appendix A for the questionnaire.

The first question is asked about the respondents whether they know about crystals. The Figure 3.4 shows 100% of the 25 respondents know about crystals.
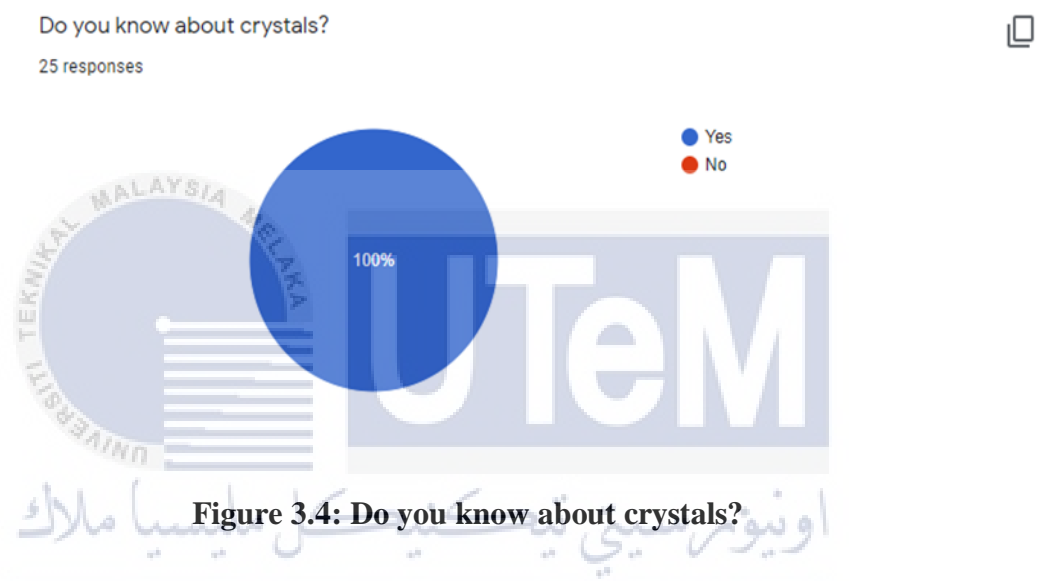
Figure 3.4: Do you know about crystals?

The second question is asked about whether the respondents have any related knowledge about crystals. From the Figure 3.5, 100% of the respondents have the knowledge related to crystals such as healing function, chemical structure and so on.

Do you have any knowledge related to crystals? (healing function, chemical structure and etc.)

25 responses

● Yes
● No

100%
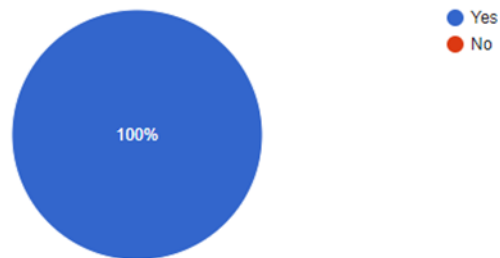
Figure 3.5: Do you have any knowledge related to crystals?

Based on Figure 3.6, 60% of the respondents learn the crystals' knowledge through website, 36% of them know the crystals' knowledge from book. There were only 1 respondents (4%) knows the crystals' knowledge through mobile application.

From where you learn/know about crystals' knowledge?

25 responses

● Website
● Book
● Mobile Application

36%

60%
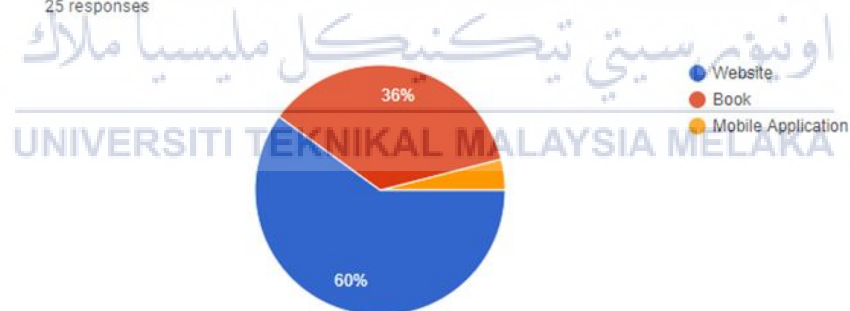
Figure 3.6: From where you learn/know about crystals' knowledge?

Figure 3.7 shows the result of the question 4 about whether the respondents face any problem during the learning crystals process. All of the 25 respondents (100%) did face some problem when learning the crystals' knowledge.

Do you face any problem when learning crystals' knowledge?

25 responses

- ● Yes
- ● No

100%

Figure 3.7: Do you face any problem when learning crystals' knowledge?

From the Figure 3.8, 19 respondents (76%) face the problem that the source of the crystals knowledge is limited. 81% of the respondents feel hard to understand the structure of crystals and 92% of them feel the learning process is dull and lack of interactive. 100% of the respondents are hard to find the complete information about the crystals.

What kind of problem had you face when learning crystals' knowledge?

25 responses

Source to find is limited	19 (76%)
Hard to understand the structure of crystals	21 (84%)
Learning process is dull and lack of interactive	23 (92%)
Hard to find complete information about crystals (background+ chemical knowledge + function)	25 (100%)
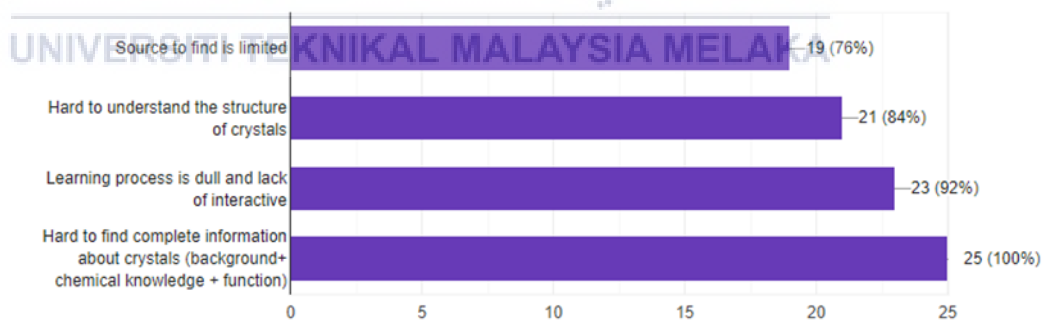
Figure 3.8: What kind of problem had you faced when learning crystals knowledge?

Based on the result of Figure 3.9, there are 96% of the respondents know about the mobile AR learning and only 1 respondent (4%) never know about mobile AR learning.
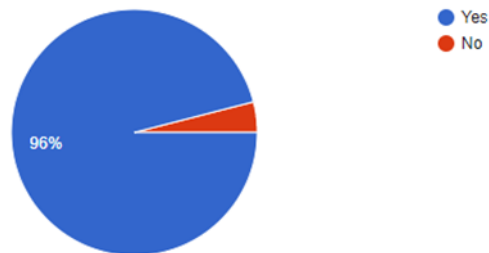
Figure 3.9: Do you know about mobile AR learning?

Question 7 is about the respondents experience whether they have ever tried any mobile AR learning before. 68% of the respondents have tried the AR mobile learning in the past and 32% of the respondents do not have related experience.
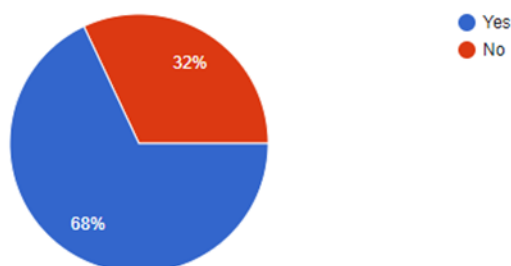
Figure 3.10: Do you try any AR learning before?

Figure 3.11 shows all of the 25 respondents (100%) are interested in learning crystals' knowledge through the AR mobile application.

Are you interested in learning crystals through AR mobile application?

25 responses
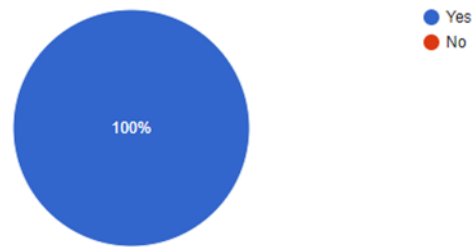
Figure 3.11: Are you interested in learning crystals through AR mobile learning?

The next question is about whether the respondents are interested to learn the crystals' structure and crystals' system through visualization of 3D models. Figure 3.12 shows 100% of the 25 respondents are interested to learn the knowledge.

Are you interested to learn crystals' structure and crystals' system through visualization of 3D models?

25 responses
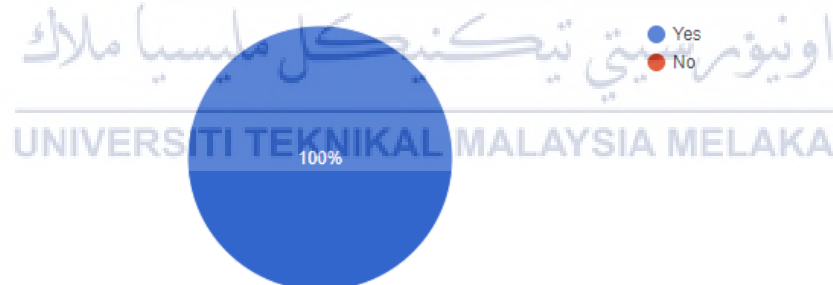
Figure 3.12: Are you interested to learn crystals' structure and crystals' system through visualization of 3D models?

The last question is asked about the opinion of respondents whether they think learning crystals through AR mobile application is effective. Based on Figure 3.13, 100% of the respondents think that this way of learning crystals is effective.
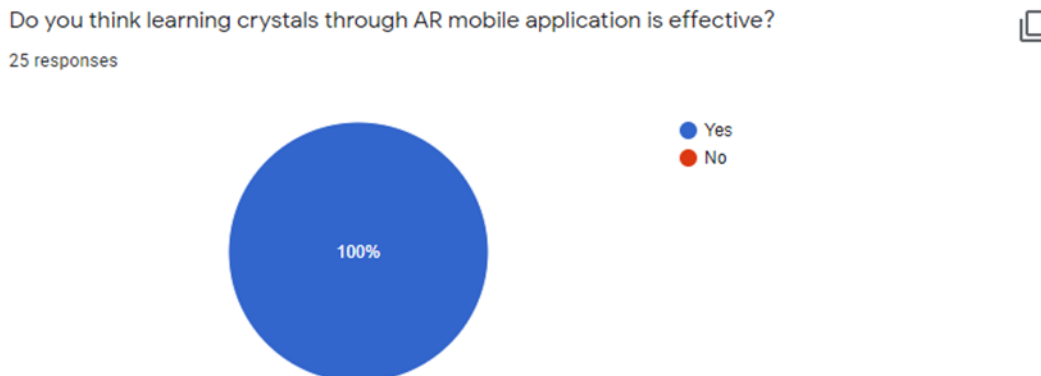
Figure 3.13: Do you think learning crystals through AR mobile application is effective?

(c)   *Project Functionality*

This project develops an AR mobile application that allows users to learn the chemical information and metaphysical properties of crystals. The crystals are classified by functions and the users can select their interested crystals from the menu to view the 3d model of crystals and crystals' structure. Each model will be visualized according to the crystals' system and help users to distinguish the crystals easily if the crystals are having similar color. Each crystal will provides related basic knowledge for users to improve their understanding about crystals.

(d)   *User Interaction*

User interaction that included in this project is the users can rotate and scale the 3D models. Virtual buttons are provided for the users to view the related information.

(e)   Analysis of Raw Data/Source

Before developing the project, many sources and references were searched to ensure the quality of the system. The knowledge of crystals are collected from trusted website, application, research paper and experts. The 3D models of crystals will be created by using Blender and the models of chemical structure are created by using JMol. The scripts of the chemical structure are obtained from Crystallography Open Database. After that, the models of crystal structure are imported into the Blender for coloring.

3.3.1.2 Technique Used

The technique will be used in this project are modeling, user interaction and AR. The 3D model of crystals and their chemical structure are modeling in Blender and Jmol. The 3D models can improve the knowledge of user when learning the crystals. Specified color is used to represent each atom. Users can understand the structure easily with the coloring atoms. Next, users are allowed to move, rotate and scale the 3D models. The interaction between the users and mobile application provides a fun and interesting learning experience. AR technique will be used in this project and users can use the camera to focus on a flat surface or plane. After that, the 3D model will appear and users can interact with the model.

3.3.2   Software Requirement

Software is crucial to develop a success project. The chosen of software must be careful to ensure it can fulfill all the requirements during the developing process. The chosen of software to develop the project is based on functionality and effectiveness. For documentation software, the format and ease of use are considered.

3.3.2.1 Software Development Requirement

i. Blender

Blender is a free and open source 3D computer graphic software tools. Blender is used in the project to create the 3D models of crystals and coloring the atoms.

ii. Jmol

Jmol is computer software for molecular modeling chemical structures in 3-dimensions. Jmol is used to model the chemical structure of crystals in the project.

iii. Unity

Unity is a cross-platform game engine developed by Unity Technologies. Unity used as a platform to combine all the elements of media and then build it to a mobile application.

iv. Balsamiq Mockups

Balsamiq Mockups is a tool used for creating low-fidelity prototype. Balsamiq Mockups is used to create the storyboard of the project.

v. Microsoft Visual Studio

Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft. Visual Studio is used as C# script editor in the project.

vi. Microsoft Word

Microsoft Word is a document editor developed by Microsoft. Microsoft Word is used to do proposal and final report.

vii. Microsoft Power Point

Microsoft Power Point is a presentation program by Microsoft. Microsoft Power Point is used for presentation purpose.

viii. Adobe Photoshop

Adobe Photoshop is published by Adobe Inc and used for raster graphic editing. Adobe Photoshop is used for logo and interface design in the project.

3.3.3   Hardware Requirement

i. Mobile Phone Device

Mobile phone device is used to install and testing the mobile application. The device must at least Android 7.0 and support camera function.

ii. Laptop

Laptop is used for documentation and to develop the project. The laptop must have sufficient RAM and suitable performance to support the required software.

3.3.4   Other Requirement

i. Google Form

Google form is a survey administration software that allow collecting information from users. Google form is used to collecting opinion and feedback from the target users.

3.4   Project Schedule and Milestones

Project schedule and milestone is act as guideline for the developer to ensure the task in each phrases can be completed in time. Table 3.1 shows the project milestone and Figure 3.14 is the gantt chart of the project.

Table 3.1: Project Milestone

Activity	Duration (Day)	Start Date	End Date
1.0 Define			
Brainstorming idea	4	1 Mac 2021	4 Mac 2021
Discuss with supervisor	1	5 Mac 2021	5 Mac 2021
2.0 Planning			
Analyze the objective and problem statement.	2	5 Mac 2021	6 Mac 2021
Prepare of proposal	3	6 Mac 2021	8 Mac 2021
3.0 Implementation			
Software installation and hardware preparation	4	9 Mac 2021	12 Mac 2021
4.0 Construction			
Development of project and report preparation	93	13 Mac 2021	13 June 2021
Technical testing	6	14 June 2021	19 June 2021
5.0 Evaluation			
Testing and publishing	6	20 June 2021	25 June 2021

	Activity	Duration	Start	Finish	
1	1.0 Define	0 days	1-3-2021	1-3-2021	◆ 3/1
2	Brainstorming idea	4 days	1-3-2021	4-3-2021	
3	Discuss with supervisor	1 day	5-3-2021	5-3-2021	
4	2.0 Planning	0 days	5-3-2021	5-3-2021	◆ 3/5
5	Analyze the objective and problem statement	2 days	5-3-2021	6-3-2021	
6	Preparation of report	3 days	6-3-2021	8-3-2021	
7	3.0 Implementation	0 days	9-3-2021	9-3-2021	◆ 3/9
8	Software installation and hardware preparation	4 days	9-3-2021	12-3-2021	
9	4.0 Construction	0 days	13-3-2021	13-3-2021	◆ 3/13
10	Development of project and report preparation	93 day	13-3-2021	13-6-2021	
11	technical testing	6 days	14-3-2021	19-3-2021	
12	4.0 Evaluation	0 days	20-3-2021	20-3-2021	◆ 3/20
13	testing&publishing	6 days	20-3-2021	25-3-2021	

Figure 3.14: Gantt Chart

3.5   Conclusion

In conclusion, this chapter is analyzed the current scenario, requirements and project schedule and milestone. The current scenario is clearly analyzed by flow chart and the requirements of project include interview with expert, user requirement, project functionality, technique used, software and hardware requirements. The project milestone and schedule are used to ensure the project can be finished on time.

CHAPTER 4: DESIGN

4.1   Introduction

This chapter defines the results of the analysis of the preliminary design and the result of the detailed design. There are three parts in this chapter, which are system architecture, preliminary design and user interface design.

4.2   System Architecture

The system architecture briefly explains the overview of the application. First, the user interface will display to enable the users to know the information about the system. The project is an AR mobile application and users need to give permission to access the mobile camera before using AR function. After that, the application will process the visual rendering and load the 3D models. The users are allowed to view and interact with the models such as rotate and scale.
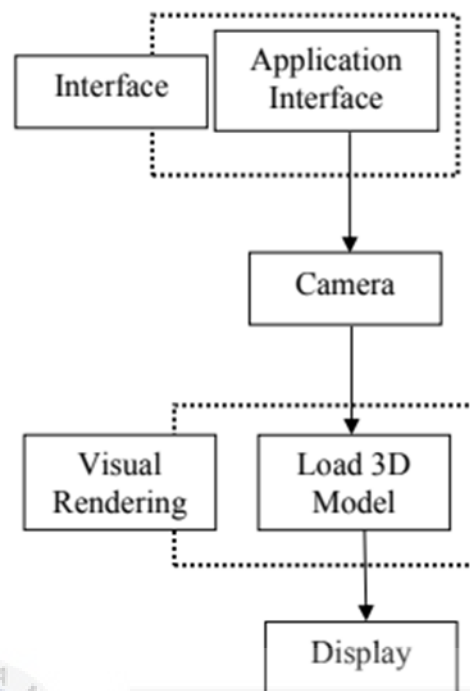
Figure 4.1: System Architecture

4.3 Preliminary Design

4.3.1 Interactive Storyboard

Figure 4.1 shows the storyboard of Crystal AR application. First, there are three buttons on home page, "START", "How to Use" and "Exit". The next storyboard is "How to Use" page and the page will give the instruction of using the application to users. If users click the "START" button on home page, the application will proceed to menu page. There are 6 categories of crystals for user to choose on menu page which are health, study, protective, love, career and beauty. When the users make the selection from the menu page, the application will navigate the users to the crystal group page. Then, users can choose the crystal from the page and the application will enter the AR mode. Users can view, rotate, and scale the crystal model in Crystal AR page. There are two slide bars and one auto rotate button for users to interact with the 3D model. The first slide bar is used to scale the model and the second slide bar is for rotating. When users click on the auto button, the 3D

model will be auto rotate to convenience the users to view the model. The users are able to view the information of crystal such as crystal's system, crystal's benefits, crystal's characteristics and the crystal's usage by clicking the virtual buttons on the screen. Besides, the crystal's AR structure page enables the users to interact with the 3D crystal structure model. Users can view the crystal system and chemical element by clicking the button in the side bar. When the users click the "label" button, the "a", "b" and "c" labels will show on the 3D model and users can click the button again to hide these labels. The "Exit" button will navigate the users back to the home page.

Table 4.1: Storyboard of Crystal AR application

| Home Page | "How To Use" | Menu Page |
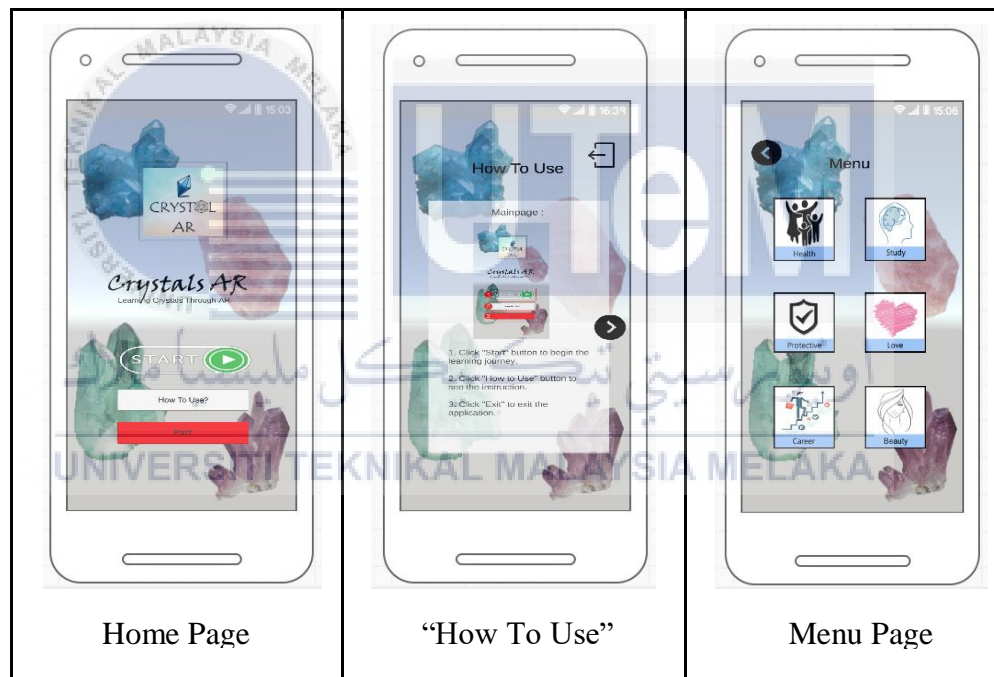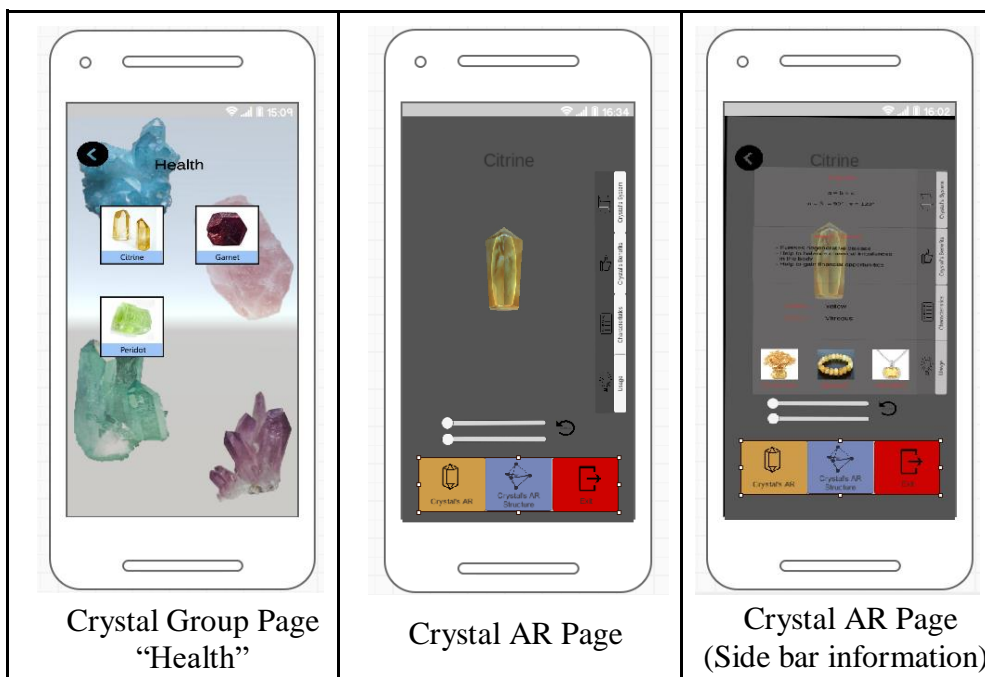
Crystal Group Page "Health"

Crystal AR Page

Crystal AR Page (Side bar information)
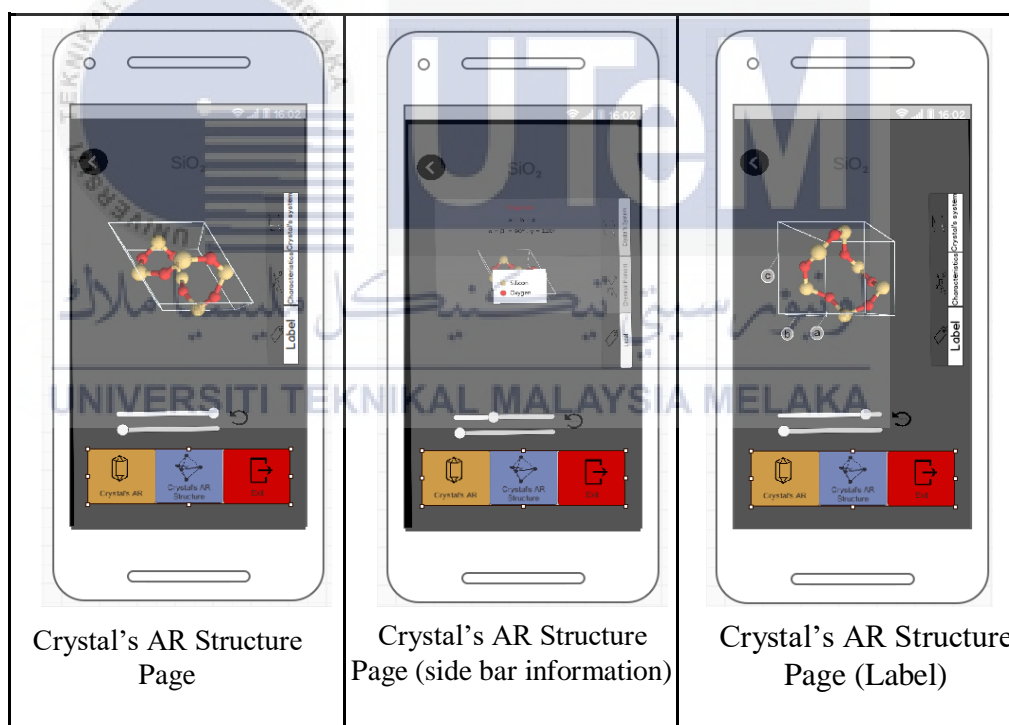
Crystal's AR Structure Page

Crystal's AR Structure Page (side bar information)

Crystal's AR Structure Page (Label)

4.4   User Interface Design

4.4.1   GUI Navigation Flow Diagram

GUI navigation flow diagram simply shows the navigation flow of the application. The navigation diagram is used to model the interactions that users have with the mobile application as defined in a single use case. Figure 4.2 shows the GUI navigation diagram for the Crystal AR mobile application.
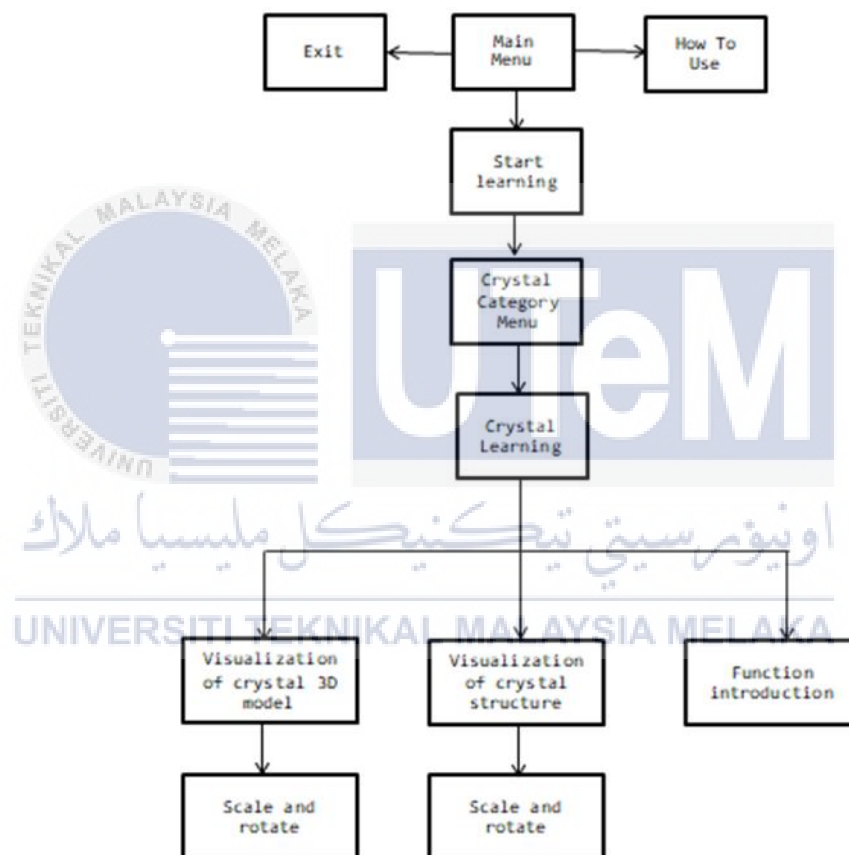
Figure 4.2: GUI Navigation Flow Diagram

4.4.2 Logo Design

The logo design of the mobile application consists of the name of application, "CRYSTAL AR" and picture of crystal. Besides, the alphabet "A" of the word "crystal" is substitute by a model of crystal structure. The crystal structure model represents the chemical knowledge that will be introduced inside the application. The background colors are immersed by tiffany blue color and rose pink color. The background represents the function of crystal which can be used to improve the human state harness by integrate the energies of natural with human energies. From the logo design, user can understand the AR application is about the crystal.

Figure 4.3: Logo Design

4.4.3 Three-Dimensional Model Design

The 3D models of crystal and crystal structure are created and used in the AR application. The 3D models of the crystals are designed according to the crystal system. User can differentiate the crystal by their crystal system and crystal structure if the crystals are having the similar color. For example, the color of Emerald crystal and Peridot crystal are similar but they are in different crystal system group. Emerald is orthorhombic consists of $Be_3Al_2(SiO_3)_6$ but Peridot crystal is hexagonal with chemical formula, Mg_2SiO_4. Figure 4.4 shows the Emerald crystal model and Figure 4.5 is the Peridot crystal model.
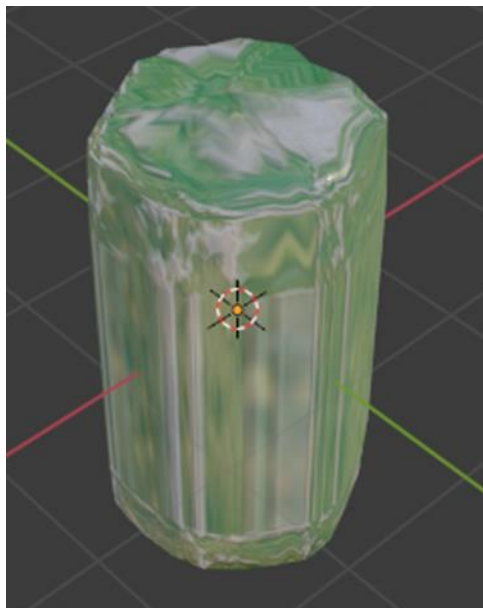
Figure 4.4: The crystal model (Emerald) used in Crystal AR application

Figure 4.5: The crystal model (Peridot) used in Crystal AR application
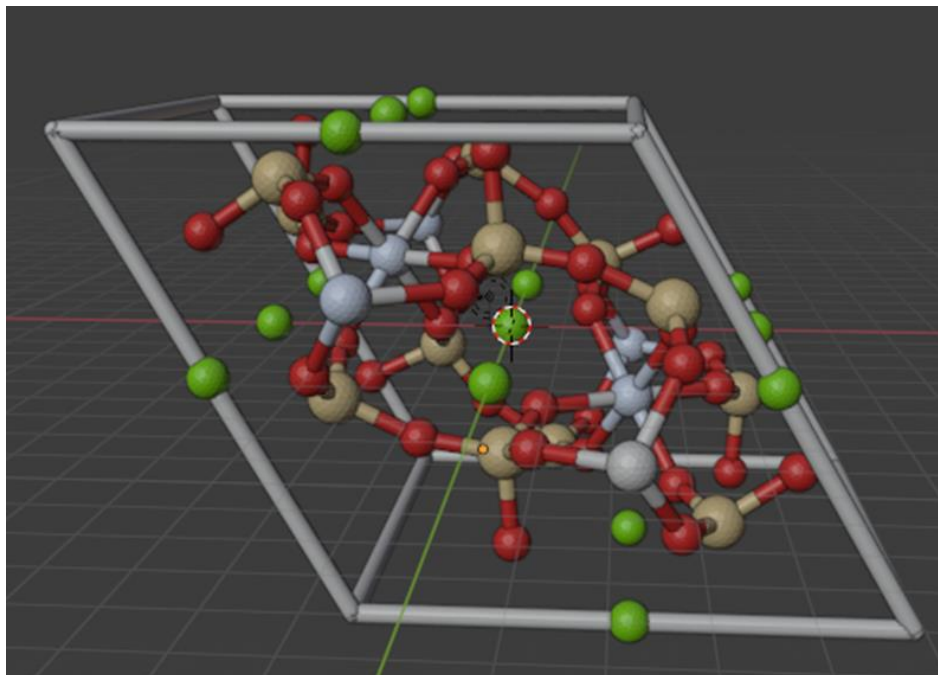
Figure 4.6: Emerald structure model (Be₃Al2(SiO₃)₆) used in Crystal AR
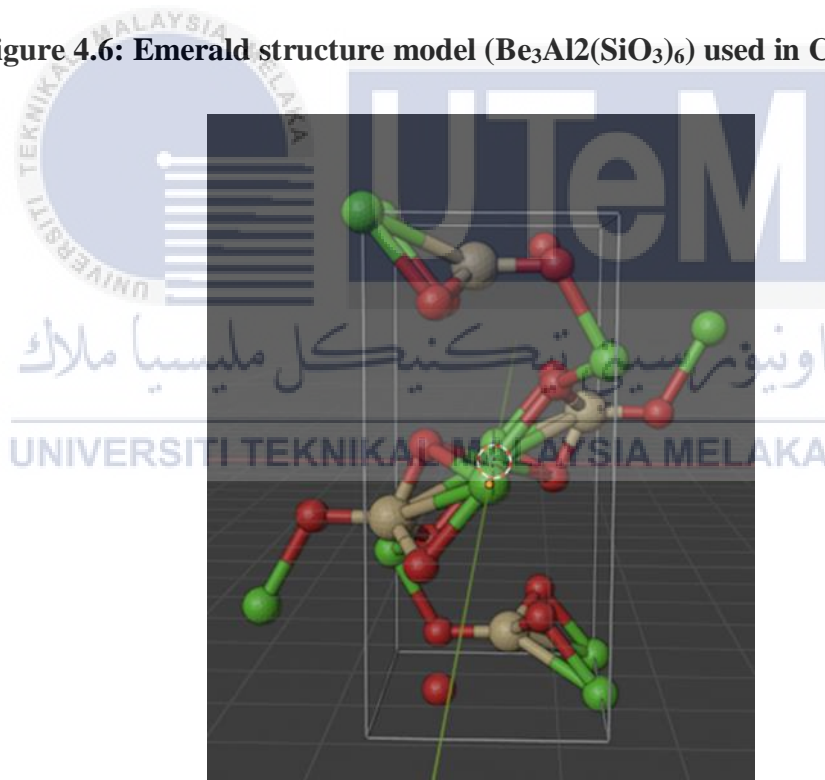
Figure 4.7: Peridot structure model (Mg2SiO4) used in Crystal AR

4.5   Conclusion

In short, this chapter is discussing the system architecture, preliminary designs and user interface design in details. The design phase is to determine the design of the application and it is crucial to produce a standard application that gives user a good user experience.

CHAPTER 5: IMPLEMENTATION

5.1   Introduction

The chapter is going to discuss the implementation phase of the project. The implementation phase activities include media creation, media integration, product configuration management, and implementation status.

5.2   Media Creation

In this project, the media creation is composited by texts production, graphic production and 3D models production. Each specification of element will be described in details below.

(a) Production of Texts

This section describes the types of texts, fonts handling and texts format that used in the project. Texts selection is important in the project for user to easy to read the information. Table 5.1 shows the specification of production of texts in details.

Table 5.1: Production of Texts

No	Use	Fonts	Format	Size
1	Main page project's title	Viner hand ITC	Regular	30pt
2	Menu page (button description)	Leelawadee	Regular	18pt

3	How to Use page/ Menu page title	Arial	Regular	80pt
4	Chemical Structure (atom)	Leelawadee	Regular	18pt
5	Logo text	Tempus Sans ITC	Regular	30pt
6	Information in AR page	Arial	Regular	11pt / 20pt

(b)   Production of Graphics

The production of graphics includes the image used for the background application, button, icon, logo and texture of 3D model. Figure 5.1 shows the step of graphics production that created by using the Adobe Photoshop CS6. First, create a new template in Adobe Photoshop CS6. Next, create the design by using shape, text and color or import the suitable .png image. For icon creation, delete the background color before export. Then, save and export the image in .png format before importing into Blender.
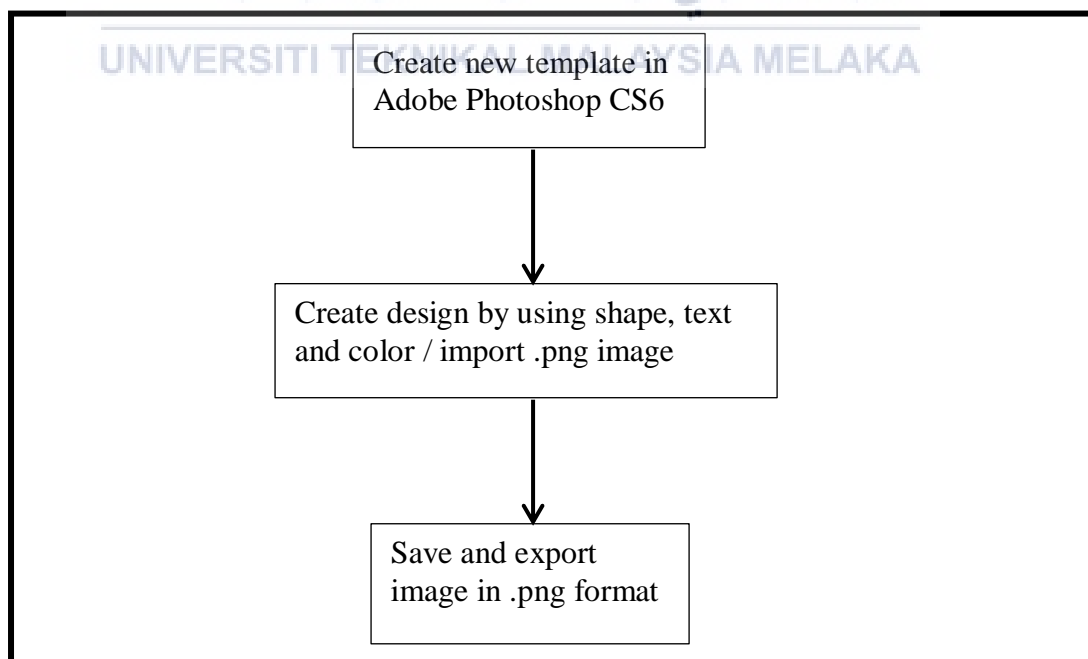
Figure 5.1: Production of graphics by using Adobe Photoshop CS6

Figure 5.2 shows the step of production of the texture of 3D models by using Blender. First import the image texture into the blender and unwrapping in UV editor. Next, adjust the color and the texture effect in shading editor. The last step is bake the image and export the image as .png format.
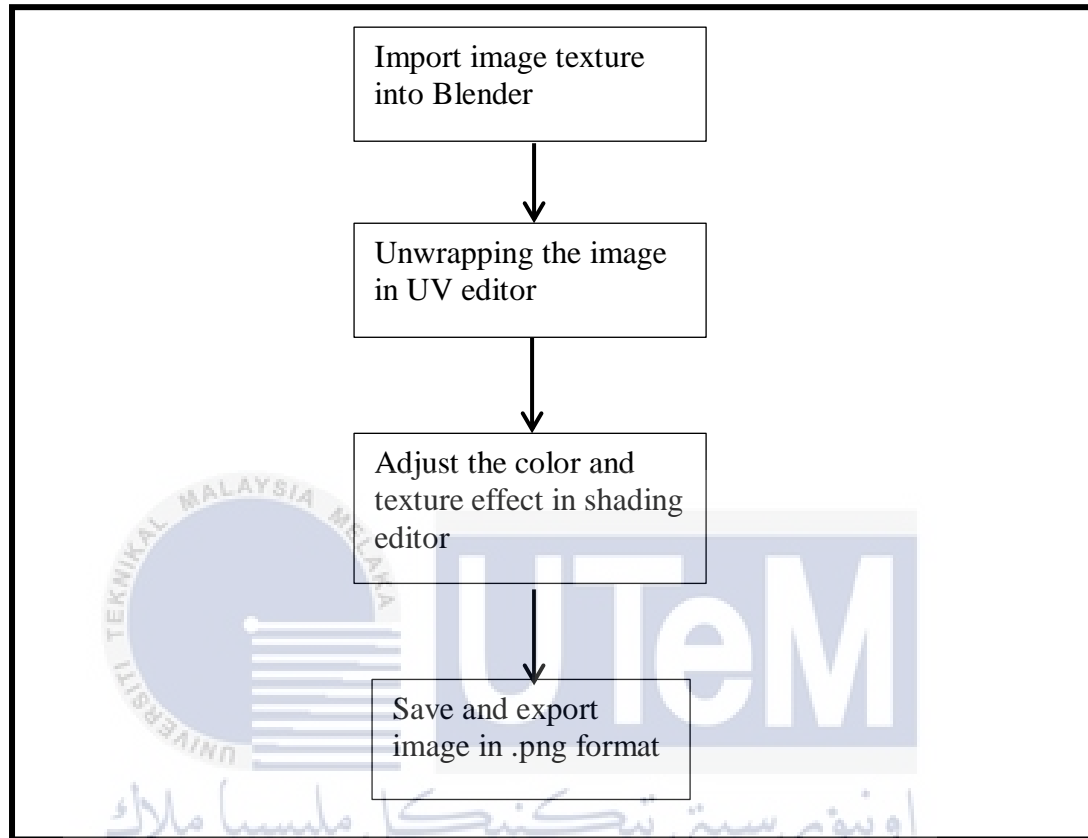
Figure 5.2: Production of the texture of 3D models by using Blender

(c)   *Production of 3D models*

There are two types of 3D models created in this project which are crystal model and crystal's structure model. The crystal 3D models modeling process are done by using Blender. First, create a new file in Blender and delete the default model by clicking "shift + F". Then, click "shift + A" and choose the suitable mesh for the 3D model. Change the mode from object mode to edit mode and click "ctrl + R" to add loop cut. Select the vertex of model by pressing "1" on keyboard, pressing"2' for selecting the edge and "3" is for selecting the faces of model. After that, adjust and modeling the model by clicking "E" to extrude the model. Save the 3D model in .fbx format to import into Unity. The Figure 5.3 shows the step of the production of crystal model in Blender.
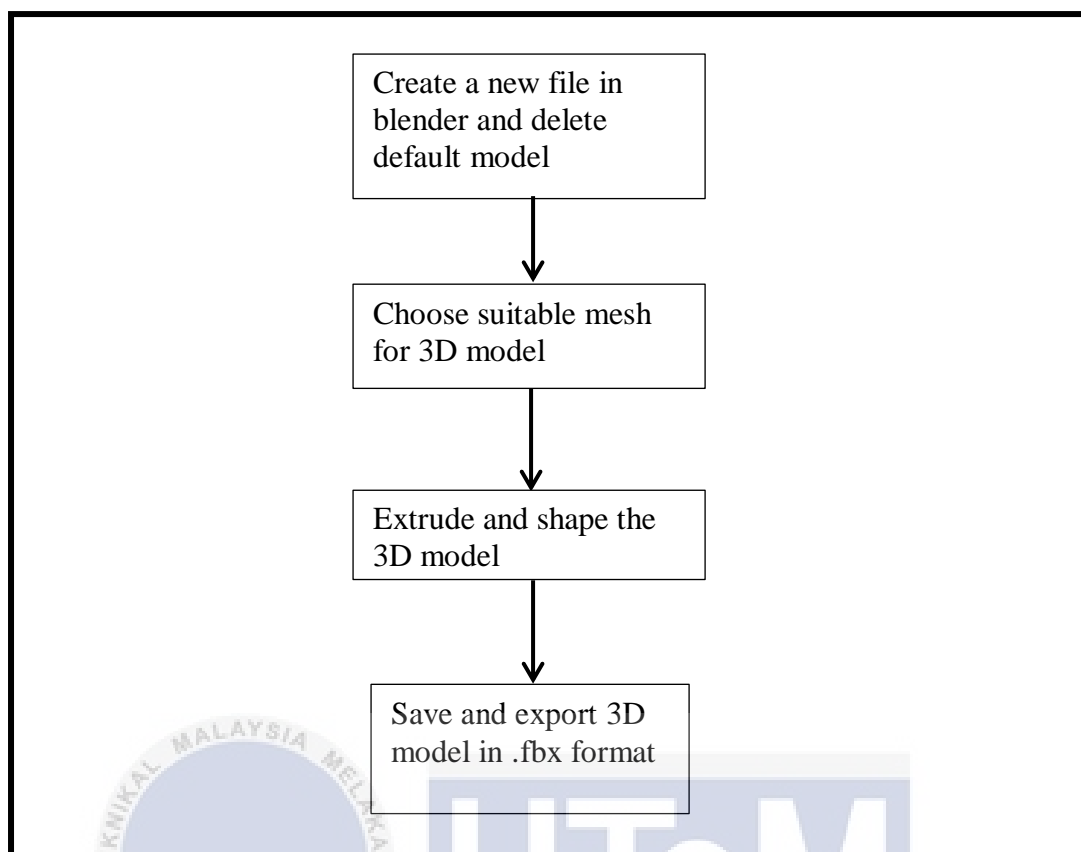
Figure 5.3: Production of crystal 3D model in Blender

Besides, the process of crystal's structure models creations are involves crystallography.net open source, Jmol and Blender. First, search for the chemical structure script from crystallography.net and save the script. Next, open the script in Jmol and adjust the symmetry of the model. Export the 3D model as .X3D format and import into Blender. After import into Blender, assign the color for the 3D model in material properties. The last step is save and export the 3D model in .fbx file. Figure 5.4 shows the step of create the crystal structure 3D model.

```
┌─────────────────────────────────┐
│   Search for the crystal        │
│   structure script from         │
│   open source                   │
└─────────────────────────────────┘
              │
              ▼
┌─────────────────────────────────┐
│   Open script in Jmol and       │
│   adjust symmetry of            │
│   model                         │
└─────────────────────────────────┘
              │
              ▼
┌─────────────────────────────────┐
│   Export the model              │
│   in .X3D format                │
└─────────────────────────────────┘
              │
              ▼
┌─────────────────────────────────┐
│   Import into Blender           │
└─────────────────────────────────┘
              │
              ▼
┌─────────────────────────────────┐
│   Coloring the 3D model         │
│   in material properties        │
└─────────────────────────────────┘
              │
              ▼
┌─────────────────────────────────┐
│   Save and export 3D            │
│   model in .fbx format          │
└─────────────────────────────────┘
```
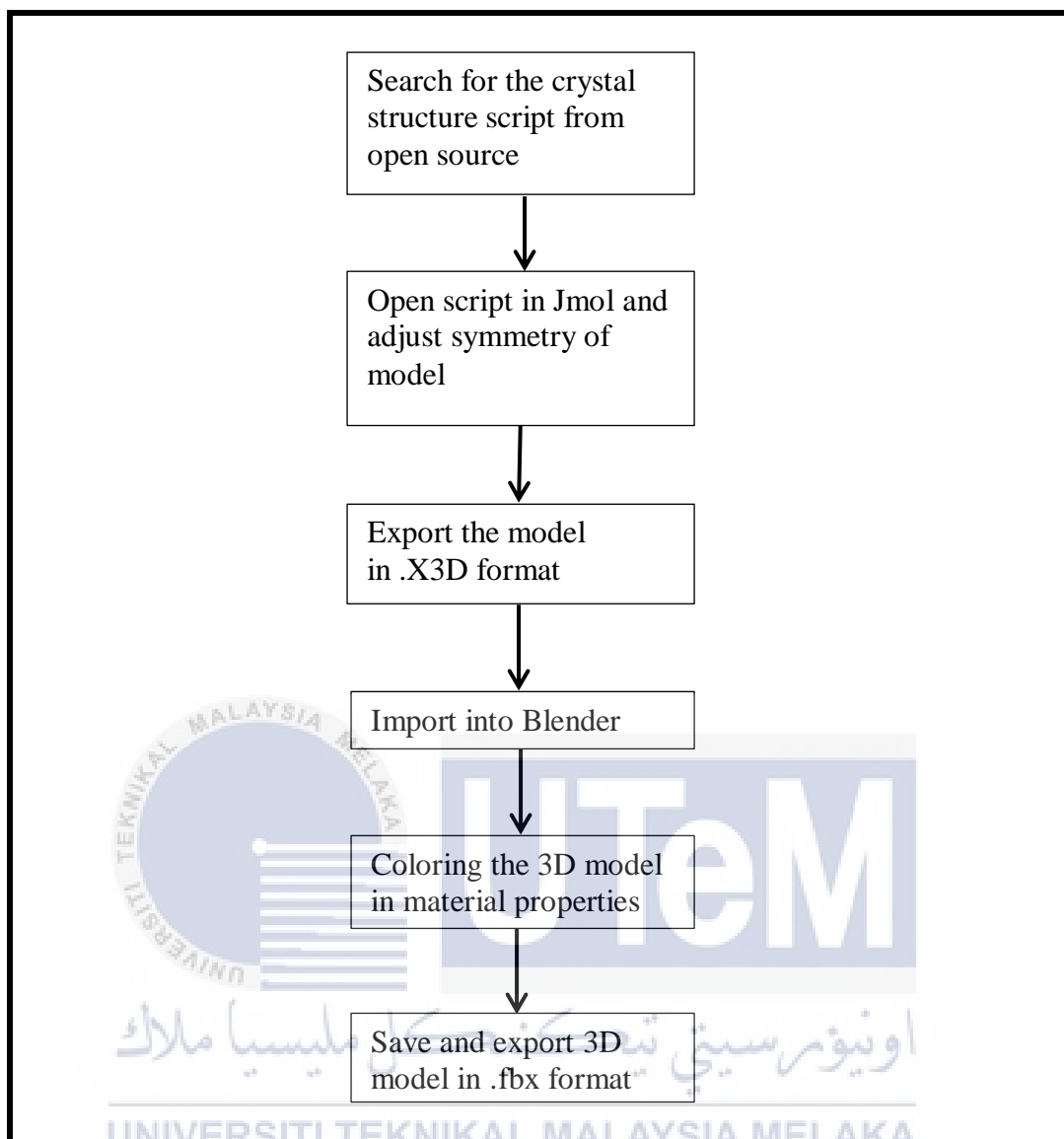
Figure 5.4: Production of crystal structure 3D model

5.3   Media Integration

The media integration will combined all the media creation with the augmented reality technology by using a software platform and develop into mobile application. The software used in the media integration process is Unity (version 2019.4.24f1).

Firstly, the models of crystal structure are created in Jmol, exported to Blender in .X3D format and then coloring in Blender. Next, the crystals 3D models

are created by using Blender. All of the 3D models are exported as .fbx format. By using the Adobe Photoshop CS6, the texts, logo design, button design and background design are created. The images are then saved in .png format. The next step is creates a new scene in Unity and import all of the media creation. The user interfaces of the application are created and designed in Unity by using the media creation. For the AR scene, C# script is needed to set up the markerless-AR camera. Besides, C# script is also used on the buttons to link the scenes. When all of the scenes are done in Unity, the project will be able to build and run on android devices.
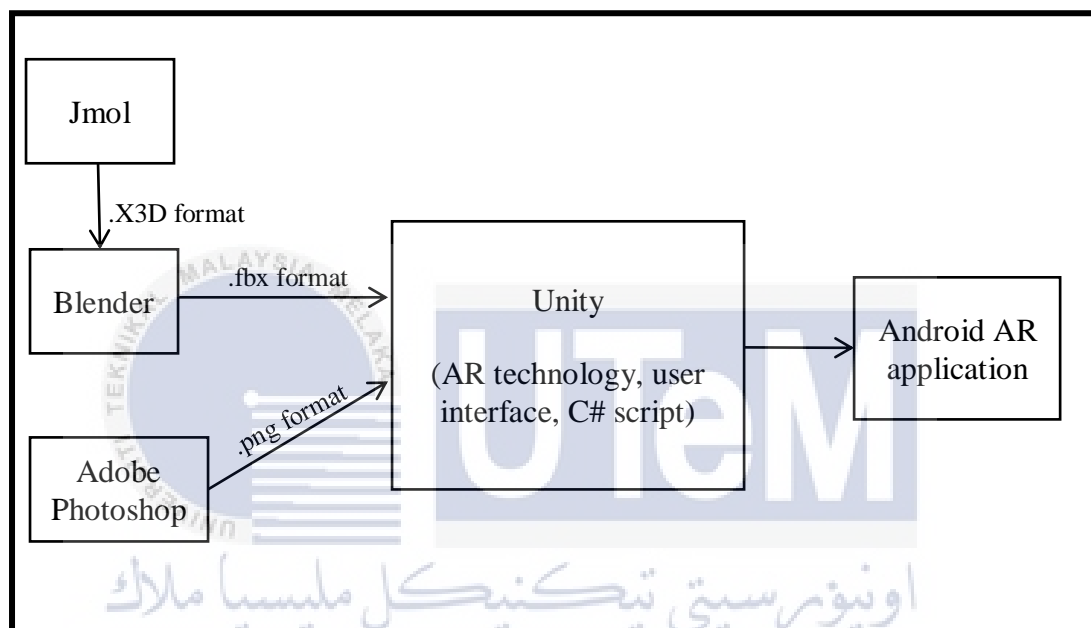
Figure 5.5: Process of media integration

5.4   Product Configuration Management

The product configuration management will briefly explain the configuration environment setup. The configuration environment setup includes the configuration management setup and the process of product implementation.

5.4.1   Configuration Environment Setup

Before building the Unity project into android apk format, there are a few setting need to set up in Unity. Firstly, go to File →Build Settings →Player Settings →Player, fill in the product name and select the minimum API level.
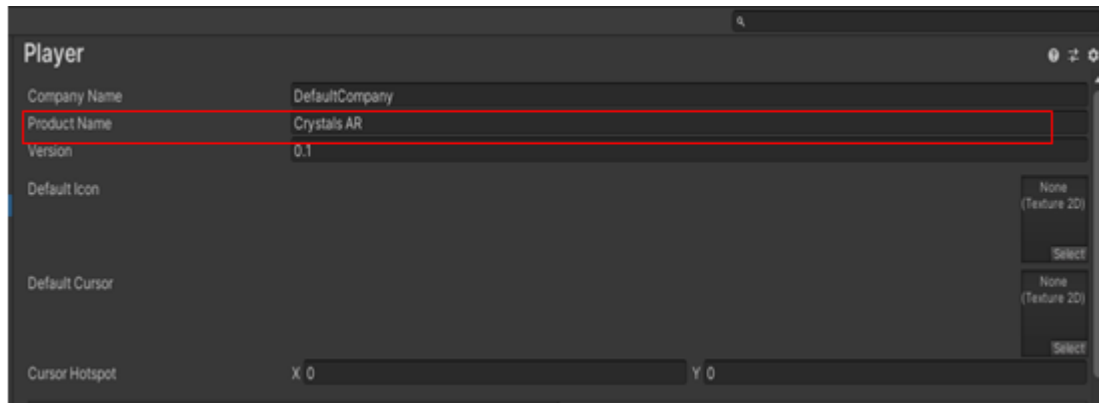
Figure 5.6: Set up the product name
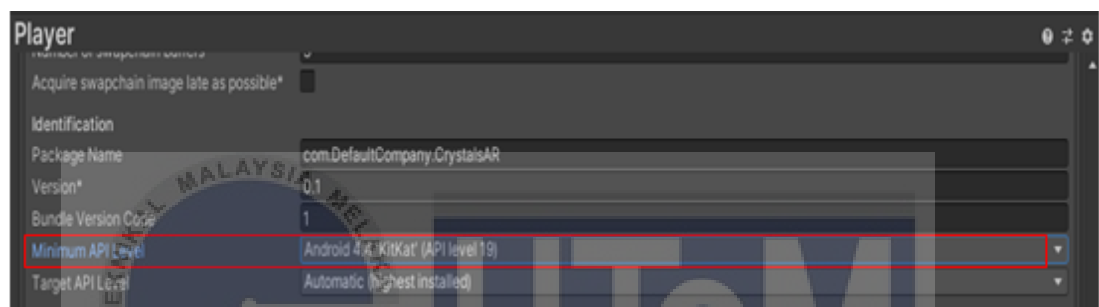
Figure 5.7: Set up the minimum API level

Next, open the File → Build Setting → Add Open Scenes to add all the scenes and arrange them in order.
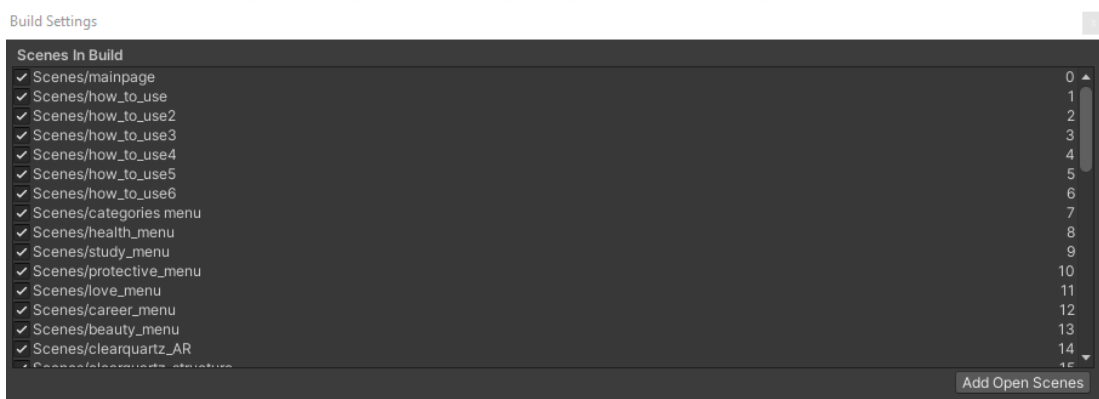
Figure 5.8: Add all the scene that created in Unity

Connect the mobile phone devices to laptop by using USB wire and select the "File Transfer" option. Open the Setting → About Phone and click on the build

number for several times to activate the developer mode. After that, go to Developer Options and turn on USB Debugging function.

Lastly, set the run device in Unity Build Settings to the mobile phone device and click Build And Run. Choose the path to build the application, the application will automatically export in .apk format and installed in mobile phone device.

5.5 Implementation Status

The implementation status is used to keep track and record the development progress of the project. Table shows the implementation status of the project

Table 5.2: Implementation status of the project

Activity	Expected Date	Actual Date	Status
1.0 Define			
Brainstorming idea	1 Mac 2021- 6 Mac 2021	6 Mac 2021	On- time
2.0 Planning			
Analyze the objective and problem statement	1 Mac 2021- 6 Mac 2021	6 Mac 2021	On-time
Prepare of proposal	6 Mac 2021- 8 Mac 2021	8 Mac 2021	On-time
3.0 Implementation			
Software installation and hardware preparation	9 Mac 2021- 12 Mac 2021	10 Mac 2021	On-time
4.0 Construction (Development of project and report preparation)			

Report Chapter 1 & Chapter 2	13 Mac 2021- 13 April 2021	9 April 2021	On-time
Report Chapter 3 & Chapter 4	14 April 2021- 15 May 2021	7 May 2021	On-time
Interface design / button design/ logo design/ 3D model modeling	16 May 2021- 30 May 2021	7 May 2021	On-time
Integrating final output	31 May 2021- 13 Jun 2021	11 Jun 2021	On-time
Technical testing	14 Jun 2021- 19 Jun 2021	19 June 2021	On-time
5.0 Evaluation	20 Jun 2021- 25 Jun 2021	24 Jun 2021	On-time

5.6   Conclusion

In conclusion, this chapter discussed the implementation phase of the project. The media creation, media integration, product configuration management and the implementation status of the project are described in details. The next chapter will discuss the application testing.

CHAPTER 6: TESTING

6.1   Introduction

The chapter will discuss about the testing phase for this project. The activities of testing phase includes a complete test plan which are test user, test environment, test schedule, test strategy and test result with analysis. The testing phase is conducted to test the effectiveness of Crystal AR application acing as assistive medium in learning the crystals' knowledge.

6.2   Test Plan

6.2.1   Test User

There are two categories of respondents involved in the testing phase which are expert and end user. The expert test is involved 5 experts from the gem and crystal field. User acceptance test will be given to the expert to collect their feedback towards the Crystal AR application. For the end user test, there are 30 respondents will be involved. The test divided into two types, which are user acceptance test and pre-post test.

6.2.2   Test Environment

The testing will be conducted through online due to the pandemic Covid-19. All of the documents files, testing forms and .apk file required for the testing will be uploaded to the Google Drive. Then, the testing file will be delivered to the experts and respondents via messaging platform.

The hardware requirement for the user testing is Android based mobile device with minimum Android Version 4.4'KitKat' and above. The requirement is important to ensure the Crystal AR application can be downloaded and install on user's mobile devices for testing.

The preparation before conducted the testing are preparing the learning material and convert it into .pdf form. The next preparation is prepare for the pre-post test question and user acceptance test form. In addition, prepare for the .apk file and upload all the files to the Google drive.

6.2.3   Test Schedule

Test schedule is used to define the duration of the testing phase. Table 6.1 shows the schedule of the testing.

Table 6.1: Test Schedule

Task	Date	Duration
User Acceptance Test For Expert	23 August 2021- 27 August 2021	30 minutes
Pre-test For End User	24 August 2021- 25 August 2021	10 minutes
Post-test For End User	24 August 2021- 25 August 2021	10 minutes
User Acceptance Test For End User	24 August 2021- 25 August 2021	1 hours

6.2.4   Test Design
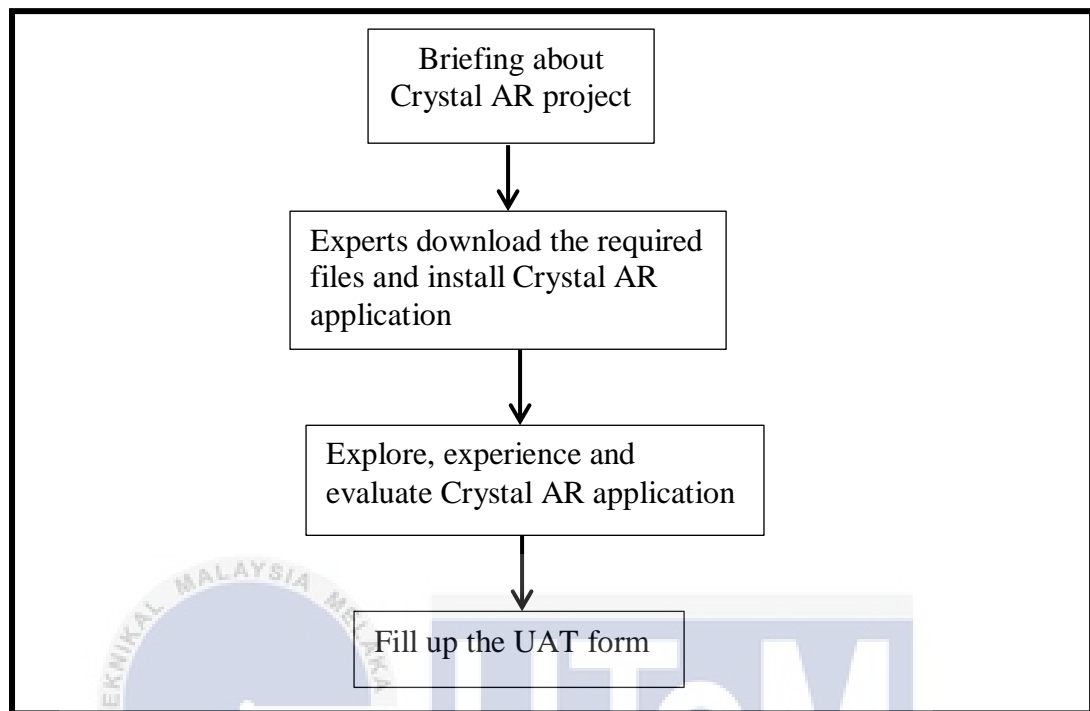
Figure 6.1: Test Design for Expert Test

For the expert test, the apk file and user acceptance test form of the Crystal AR application will be delivered to the expert via Google Drive link. The experts will be given a short briefing about the Crystal AR project before testing the application. Then, the experts will be given some time to explore and test the AR application. After testing, the experts have to give evaluation and feedback towards the AR application by filling up the user acceptance test form.
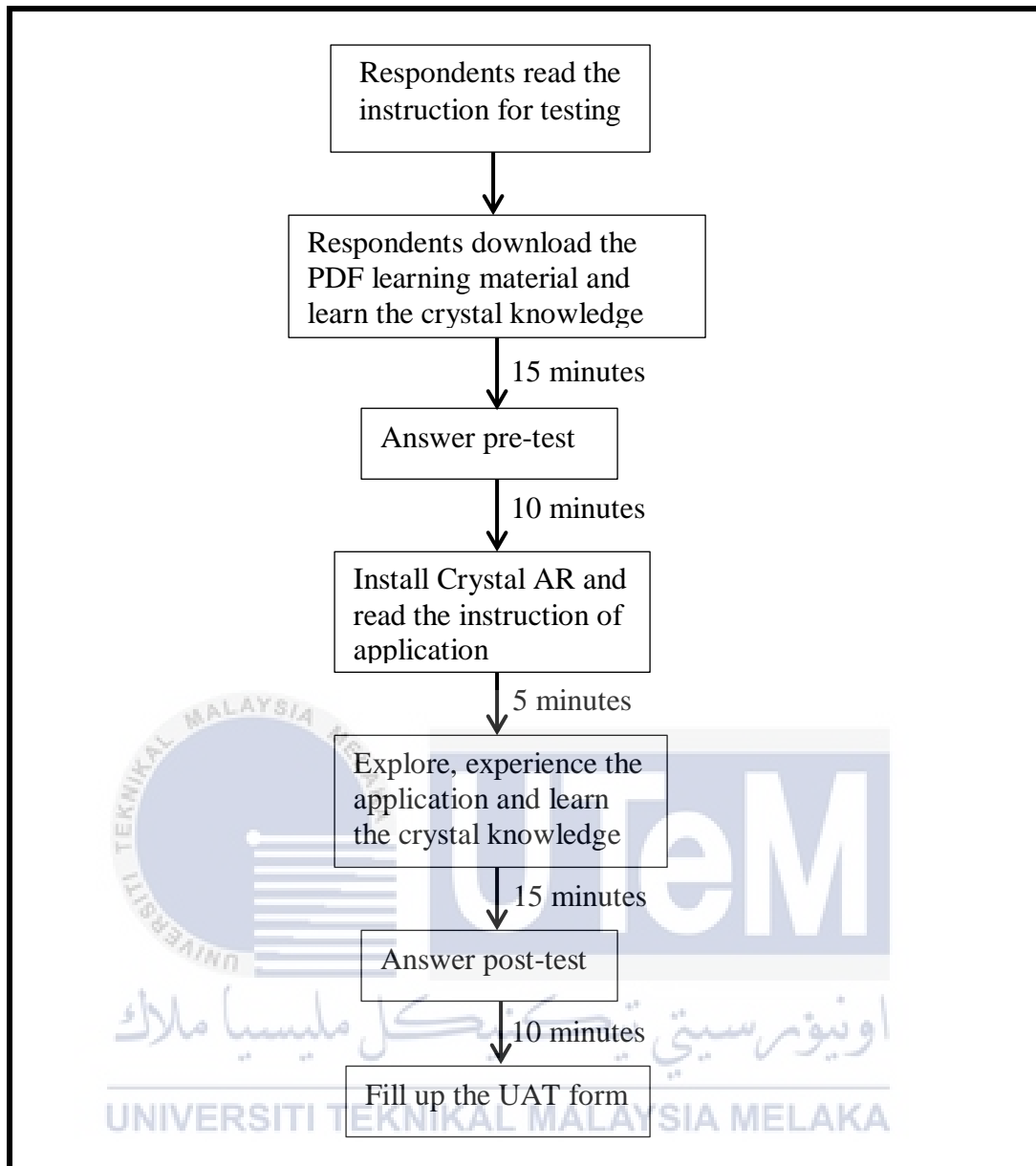
Figure 6.2: Test Design for End User Test

Besides, the end user test will includes pre-test, post-test and user acceptance test. The 30 respondents will be involved in the user testing. The respondents need to do the pre-post test and user acceptance test. The respondents need to download the learning material and .apk file through the Google drive link given. They will be given 15 minutes to read the learning material before answer the pre-test. After the pre-test, the respondents will be given some time to download and install the Crystal AR application. They will learn the crystal knowledge through the application and answer the post-test. Lastly, the end user acceptance test form will be provided for them to response.

6.3 Test Strategy

6.3.1 User Acceptance Test (UAT)

The user acceptance testing is used to evaluate the Crystal AR application. The testing for the expert is more focus on the content of Crystal AR application. There are 4 components will be evaluated in expert UAT, which are functionality, content, learnability and interface design. The likert scale 1 to 5 is used for evaluation. Table below shows the UAT form for expert.

Table 6.2: Table for User Acceptance Testing Form for Expert

NAME:		SIGNATURE:				
Please tick (/) to answer the question.						
	Scale	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		1	2	3	4	5
A)	FUNCTIONALITY OF APPLICATION					
1	The application is suitable as a learning platform for the user to learn crystal's knowledge.					
2	The application's instruction is clear to guide the user how to use the application to learn crystal's knowledge.					
3	The AR technology that applied in the application is functional.					
4	The visualization of crystals' model, crystal's structure and crystal's information is useable.					
B)	CONTENT OF APPLICATION					
1	The content of application is understandable.					

2	The information of the crystals is correct and matched.					
3	The categories of the crystals are correct and complete.					
4	The 3D crystal models and crystal structure models are recognizable.					
5	The 3D crystal models in the application look like the real crystals.					
6	The color and the surface of the 3D crystal models are correct and matched.					
7	The content in the application is delivered effectively to user.					
C)	**LEARNABILITY OF APPLICATION**					
1	The content of application is easy to learn and understand.					
2	The 3D model enables the user to visualize and recognize the crystals.					
3	The content of the application is suitable for the public to learn crystals' knowledge.					
4	The application is more effective than conventional learning methods to learn crystals' knowledge.					
D)	**INTERFACE DESIGN OF APPLICATION**					
1	The interface design of application is suitable.					
2	The interface design of application is attractive.					
3	The font and colors of application is readable and recognizable.					
4	The interface design of application is consistence and comfortable.					

E)	FEEDBACK AND COMMENT

Besides, the user acceptance test for end user is to evaluate the conventional learning material and Crystal AR application. The given scale is from 1 to 5 which are strongly disagree, disagree, neutral, agree and strongly agree. Table below shows the UAT form for end user.

Table 6.3: Table for User Acceptance Testing Form for End User
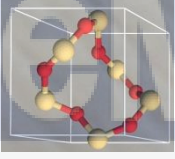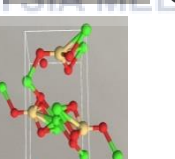
NAME:			DATE:		
Strongly Disagree	**Disagree**	**Neutral**		**Agree**	**Strongly Agree**
1	**2**	**3**		**4**	**5**
A)	**FUNCTIONALITY**			**PDF**	**Crystal AR**
1	The learning material is suitable to learn crystals' knowledge.				
2	The learning material can function well after downloaded.				
3	The learning material is easy to access the learning content.				
4	The learning material is easy to use.				
B)	**CONTENT**			**PDF**	**Crystal AR**
1	The information and learning content is clear.				
2	The information and learning content is understandable.				
3	The information and learning content is attractive.				
4	The information and learning content is complete and useful.				

C)	**LEARNABILITY**	**PDF**	**Crystal AR**
1	The learning experience is fun and interesting.		
2	The learning material is easy to understand.		
3	The learning material is easy to learn and memorize the crystal's knowledge.		
4	The learning process is sped up.		
D)	**INTERFACE DESIGN**	**PDF**	**Crystal AR**
1	The interface design is attractive and easy to understand.		
2	The interface design is beautiful and comfortable.		
3	The font and text of learning material is readable and recognizable.		
4	The color used in the learning material is attractive.		
E)	**FEEDBACK AND COMMENT**		

6.3.2   Pre-post Testing
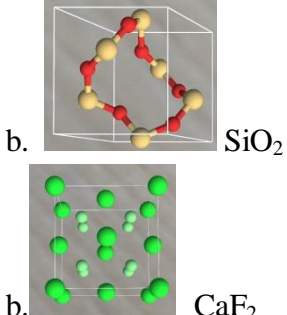
The pre-post testing is used to test the effectiveness of learning crystals' knowledge through conventional learning material and Crystal AR application. Two sets of test with the same level of difficulty will be prepared for the respondents to answer. Each set of the test contains 10 questions. Table 6.3 and Table 6.4 shows the pre-test and post-test question.
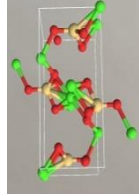
Table 6.4: Pre-test Question for Conventional Learning Method

Question 1: **What is the color of Citrine?**	a. White b. Yellow c. Red
Question 2: **Which one is Amazonite?**	 a.　　　　b.　　　　c.
Question 3: **What is the crystal system of Tiger's Eyes?**	a. Isometric b. Trigonal c. Orthorhombic
Question 4: **Which crystal is not in beryl $(Be_3Al_2(SiO_3)_6)$ group?**	a. Emerald b. Rose Quartz c. Aquamarine
Question 5: **Which crystal is help for "Health"?**	a. Peridot b. Rose Quartz c. Rhodochrosite
Question 6: **Which one is the chemical structure of fluorite?**	 a.　　SiO_2 b.　　CaF_2 c.　　Mg_2SiO_4
Question 7: **Garnet is help to regulate blood circulation in body.**	a. True b. False
Question 8: **Rhodochrosite is red/pink in colour, with vitreous lustre and have concentric/zigzag pattern.**	a. True b. False
Question 9: **The crystal system of Aquamarine is trigonal.**	a. True b. False

Question 10: Choose the correct one.	a. Love - Peridot, Clear Quartz b. **Study - Amethyst, Clear Quartz** c. Beauty – Garnet, Citrine

Table 6.5: Post-test Question for Crystal AR Application

Question 1: **What is the color of Garnet?**	d. Blue e. Yellow f. **Red**
Question 2: **Which one is Rose Quartz?**	 b.　　　b.　　　c.
Question 3: **What is the crystal system of Amethyst?**	a. **Trigonal** b. Orthorhombic c. Triclinic
Question 4 : **Which crystal is not in Silicon dioxide (SiO_2) group?**	a. Citrine b. Clear Quartz c. **Peridot**
Question 5 : **Which crystal is help in "Love"?**	c. Fluorite d. Clear Quartz e. **Rose Quartz**
Question 6: **Which one is the chemical structure of Peridot?**	 b.　　　SiO_2 b.　　　CaF_2

	c. Mg_2SiO_4
Question 7: **Aquamarine is help to improve communication skill.**	a. True b. False
Question 8: **Clear Quartz is white in colour and with vitreous lustre.**	a. True b. False
Question 9: **The crystal system of Citrine is trigonal.**	a. True b. False
Question 10: **Choose the correct one.**	d. Health - Clear Quartz, Rhodochrosite e. Study - Aquamarine, Rose Quartz f. Protective - Fluorite, Tiger's Eyes

6.4   Test Implementation

6.4.1   Test Description

For the expert test, five experts from the gem or crystal field will be involved in the testing. A briefing about the Crystal AR project will be conducted to explain and introduce the application. Then, the experts will be given the .apk of the Crystal AR and user acceptance test form. They will test the application and explore the function by themselves. After testing, the experts will evaluate the application and give feedback by filling up the user acceptance test form. The whole testing process is estimated to take 30 minutes.

For the end user test, the 30 respondents will be given a Google meet link and carry out the testing through Google meeting. After they enter the online meeting, a Google Drive link that includes the PDF form learning material, .apk file of Crystal AR, pre-test question, post-test question and end user acceptance test form will be given in chat box. Firstly, the respondents are required to download the learning material and read through the content within 15 minutes. After that, the respondents

need to answer the pre-test in 10 minutes. Next, they have to download the .apk file to install the Crystal AR application on their mobile device. They are given 5 minutes to read through the instruction of Crystal AR application and 15 minutes to explore and learn the crystal knowledge. The post-test will be conducted in the duration of 10 minutes after they done the application testing. Lastly, the respondents are required to response the user acceptance test form to compare between the conventional learning material and Crystal AR application.

6.4.2   Test Data

There are 5 experts and 30 respondents involved in this project testing phase. The table below shows the name and occupation of experts involved in the expert testing. Please refer to Appendix F for the expert profile.

Table 6.6: Details of Experts

NO	NAME	OCCUPATION
1	Tan Ser Yuen	Senior Gemologist
2	Gan Koyi	Crystal Shop Owner
3	Carrie Wong Yee Yin	Junior Gemologist
4	Amber Liu Li Ping	Junior Gemologist
5	Lim Kah Yee	Trainee Gemologist

Besides, all the data collected from the experts and end users will be listed in table form. Table 6.7 shows the test data of user acceptance test for expert, Table 6.8 shows the results of pre-post testing and Table 6.9 shows the test data of user acceptance test for end user.

Table 6.7: Test Data of Expert User Acceptance Test

	Question	Total Responses Received From 5 Experts				
		Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
A)	**FUNCTIONALITY OF APPLICATION**					
1	The application is suitable as a learning platform for the user to learn crystal's knowledge.	0	0	0	0	5
2	The application's instruction is clear to guide the user how to use the application to learn crystal's knowledge.	0	0	0	2	3
3	The AR technology that applied in the application is functional.	0	0	0	2	3
4	The visualization of crystals' model, crystal's structure and crystal's information is useable.	0	0	0	1	4
B)	**CONTENT OF APPLICATION**					
1	The content of application is understandable.	0	0	0	0	5
2	The information of the crystals is correct and matched.	0	0	0	5	0
3	The categories of the crystals are correct and complete.	0	0	1	4	0
4	The 3D crystal models and crystal structure models are recognizable.	0	0	0	3	2
5	The 3D crystal models in the application look like the real crystals.	0	0	1	3	1
6	The color and the surface of the 3D crystal models are correct and matched.	0	0	0	4	1

7	The content in the application is delivered effectively to user.	0	0	0	2	3
C)	**LEARNABILITY OF APPLICATION**					
1	The content of application is easy to learn and understand.	0	0	0	2	3
2	The 3D model enables the user to visualize and recognize the crystals.	0	0	0	2	3
3	The content of the application is suitable for the public to learn crystals' knowledge.	0	0	1	2	2
4	The application is more effective than conventional learning methods to learn crystals' knowledge.	0	0	0	3	2
D)	**INTERFACE DESIGN OF APPLICATION**					
1	The interface design of application is suitable.	0	0	0	4	1
2	The interface design of application is attractive.	0	0	1	1	3
3	The font and colors of application is readable and recognizable.	0	0	0	1	4
4	The interface design of application is consistence and comfortable.	0	0	0	3	2
E)	**FEEDBACK AND COMMENT**					

Lee Ser Yuen- Good application for beginner to learn about Crystals. Can add more crystals in future.

Carrie Wong Yee Yin- Crystal model can be improved.

Amber Liu Li Ping- There is room for improvement for the colour and lustre of crystals.

Lim Kah Yee- Good Crystal Learning App!

Table 6.8: Result of Pre-post Testing

Respondents	Number of correct answer in test / 10 questions			
	Pre-test (PDF)	Percentage (%)	Post-test (Crystal AR)	Percentage (%)
1	4	40%	10	100%
2	2	20%	8	80%
3	4	40%	9	90%
4	5	50%	10	100%
5	5	50%	9	90%
6	3	30%	7	70%
7	3	30%	9	90%
8	4	40%	8	80%
9	5	50%	10	100%
10	6	60%	10	100%
11	2	20%	6	60%
12	4	40%	8	80%
13	5	50%	9	90%
14	3	30%	7	70%
15	4	40%	9	90%
16	5	50%	9	90%
17	3	30%	10	100%
18	3	30%	7	70%

19	4	40%	9	90%
20	3	30%	8	80%
21	6	60%	10	100%
22	2	20%	8	80%
23	3	30%	10	100%
24	4	40%	9	90%
25	4	40%	9	90%
26	4	40%	10	100%
27	5	50%	9	90%
28	2	20%	7	70%
29	2	20%	10	100%
30	4	40%	8	80%

Table 6.9: Test Data of End-User User Acceptance Test

Question		Learning Material	Total Responses Received From 30 Respondents (End-User)				
			Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
A)	**FUNCTIONALITY**						
1	The learning material is suitable to learn crystals' knowledge.	**PDF**	1	6	18	5	0
		Crystal AR	0	0	0	12	18
2	The learning material can function well after downloaded.	**PDF**	0	0	5	25	0
		Crystal AR	0	0	0	20	10
3	The learning material is easy to access the learning content.	**PDF**	4	10	2	6	8
		Crystal AR	0	1	2	18	9
4	The learning material is easy to use.	**PDF**	0	8	10	5	7
		Crystal AR	0	0	2	7	21
B)	**CONTENT**						
1	The information and learning content is clear.	**PDF**	4	8	6	12	0
		Crystal AR	0	0	0	2	28
2	The information and learning content is understandable.	**PDF**	11	8	3	4	4
		Crystal AR	0	0	2	17	11
3	The information and learning content is attractive.	**PDF**	12	12	2	4	0
		Crystal AR	0	0	0	2	28
4	The information and learning content is complete and useful.	**PDF**	15	10	3	2	0
		Crystal AR	0	0	1	12	17
C)	**LEARNABILITY**						
1	The learning experience is fun and interesting.	**PDF**	23	3	4	0	0
		Crystal AR	0	0	0	1	29

2	The learning material is easy to understand.	**PDF**	15	11	2	2	0
		Crystal AR	0	0	3	16	11
3	The learning material is easy to learn and memorize the crystal's knowledge.	**PDF**	2	18	9	1	0
		Crystal AR	0	0	1	12	17
4	The learning process is sped up.	**PDF**	18	10	2	0	0
		Crystal AR	0	0	0	9	21
D)	**INTERFACE DESIGN**						
1	The interface design is attractive and easy to understand.	**PDF**	17	6	4	3	0
		Crystal AR	0	0	0	14	16
2	The interface design is beautiful and comfortable.	**PDF**	17	6	6	1	0
		Crystal AR	0	0	0	22	8
3	The font and text of learning material is readable and recognizable.	**PDF**	2	7	16	4	1
		Crystal AR	0	0	4	18	8
4	The color used in the learning material is attractive.	**PDF**	22	8	0	0	0
		Crystal AR	0	0	5	12	13

6.5   Test Result and Analysis

The results of User Acceptance Test for expert, User Acceptance Test for end user and pre-post test will be analyzed and describe along with graph in this part.

6.5.1   Result of User Acceptance Test for Expert

Table 6.10: Percentage of Expert Responses For Functionality of Crystal AR

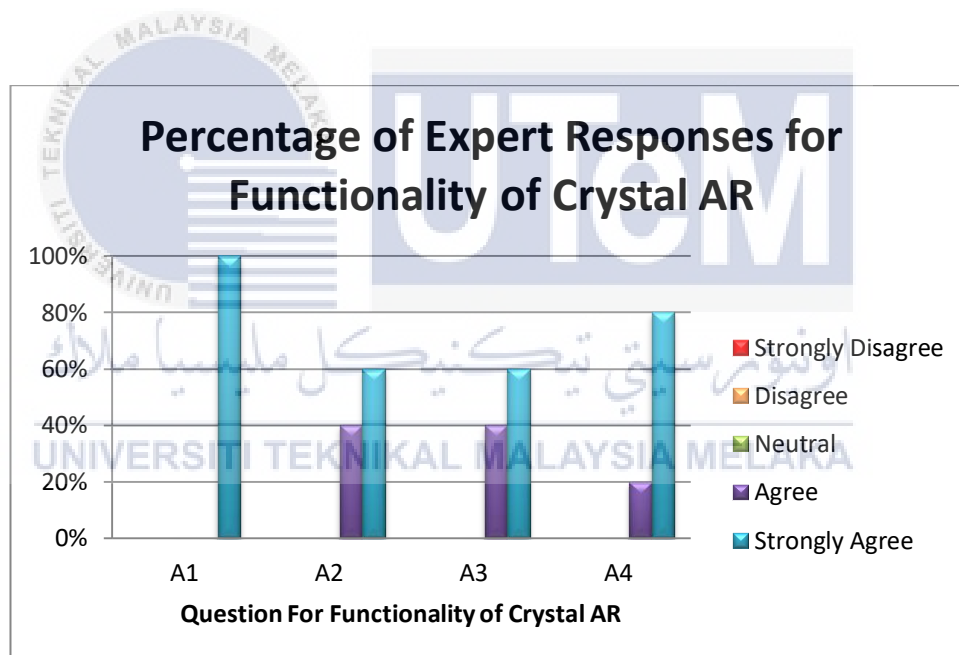| Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
A1	0%	0%	0%	0%	100%
A2	0%	0%	0%	40%	60%
A3	0%	0%	0%	40%	60%
A4	0%	0%	0%	20%	80%

Figure 6.3: Percentage of Expert Responses for Functionality of Crystal AR

Figure 6.3 shows the graph of the percentage of expert responses for functionality of Crystal AR in user acceptance test (UAT). There are four questions in the functionality part of UAT. All of the experts (100%) are strongly agreed to the A1 which is the application is suitable as a learning platform for the user to learn crystal's knowledge. Next, A2 regarded that the application's instruction is clear to guide the user how to use the application to learn crystal's knowledge. For A2, three experts (60%) are strongly agreed while another two experts (20%) are agreed that

the instruction is clear. A3 is about the AR technology that applied in the application is functional. 60% of the experts are strongly agreed the A3 and 40% of them are agreed that the AR technology applied in the application is functional. For A4, majority of experts (4 out of 5) are strongly agreed that the visualization of crystals' model, crystal's structure and crystal's information is useable and one of them is agreed to the statement. In conclusion, all the experts give a positive response with strongly agree and agree to the functionality part questions of UAT.

Table 6.11: Percentage of Expert Responses for Content of Crystal AR

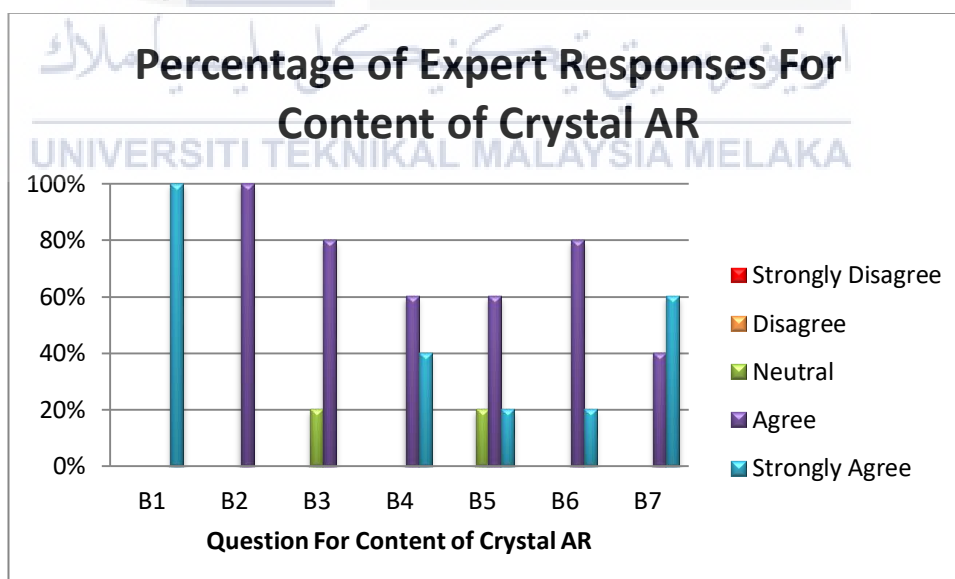| Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
B1	0%	0%	0%	0%	100%
B2	0%	0%	0%	100%	0%
B3	0%	0%	20%	80%	0%
B4	0%	0%	0%	60%	40%
B5	0%	0%	20%	60%	20%
B6	0%	0%	0%	80%	20%
B7	0%	0%	0%	40%	60%

Figure 6.4: Percentage of Expert Responses for Content of Crystal AR

There are seven questions in the content section of UAT. Based on Figure 6.4 and Table 6.11, all the experts are strongly agreed to B1 which is the content of application is understandable and all of them are agreed that the information of the

crystals is correct and matched (B2). Besides, B3 is about the categories of the crystals are correct and complete. For B3, one of the experts (20%) responds neutral and another 4 experts (80%) are agreed to the statement. For B4, two experts (40%) are strongly agreed that the 3D crystal models and crystal structure models are recognizable and three experts are agreed. One expert (20%) is strongly agreed to B5 which is about the 3D crystal models in the application look like the real crystals, three experts (60%) are agreed with B5 and one of the expert (20%) answers neutral. B6 is about the color and the surface of the 3D crystal models are correct and matched. For B6, one expert (20%) is strongly agreed and another four experts (80%) are agreed. The last question Q7 is about the content in the application is delivered effectively to user. 60% of the experts are strongly agreed that the content in the application is delivered effectively to user and 40% of them answer agreed for Q7. Overall, the experts responses for the content of the application are above average with majority agree and strongly agree to the statement.

Table 6.12: Percentage of Expert Responses for Learnability of Crystal AR

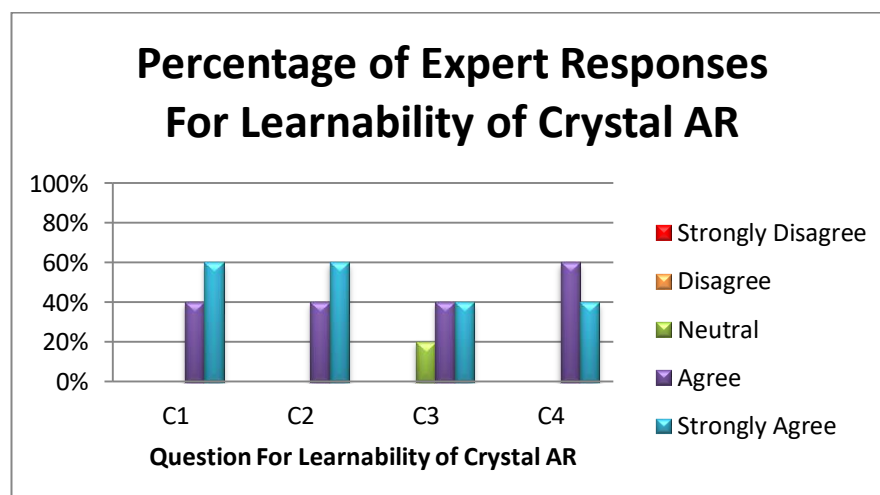| Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
C1	0%	0%	0%	40%	60%
C2	0%	0%	0%	40%	60%
C3	0%	0%	20%	40%	40%
C4	0%	0%	0%	60%	40%

Figure 6.5: Percentage of Expert Responses for Learnability of Crystal AR

Figure 6.5 and Table 6.12 show the percentage of expert responses for learnability of Crystal AR. In this part, there are four questions in total. C1 is about the content of application is easy to learn and understand and C2 is about the 3D model enables the user to visualize and recognize the crystals. For C1 and C2, three experts (60%) are strongly agreed and two experts (40%) are agreed. In addition, C3 is about the content of the application is suitable for the public to learn crystals' knowledge. For C3, one of the experts (20%) answers neutral, two experts (40%) answer agree and another two experts (40%) answer strongly agreed. 40% of the experts are strongly agreed to C4, which is the application is more effective than conventional learning methods to learn crystals' knowledge and 60% of the experts are agreed to the statement. As conclusion, experts are satisfied for the learnability of the Crystal AR application.

Table 6.13: Percentage of Experts Response for Interface Design of Crystal AR

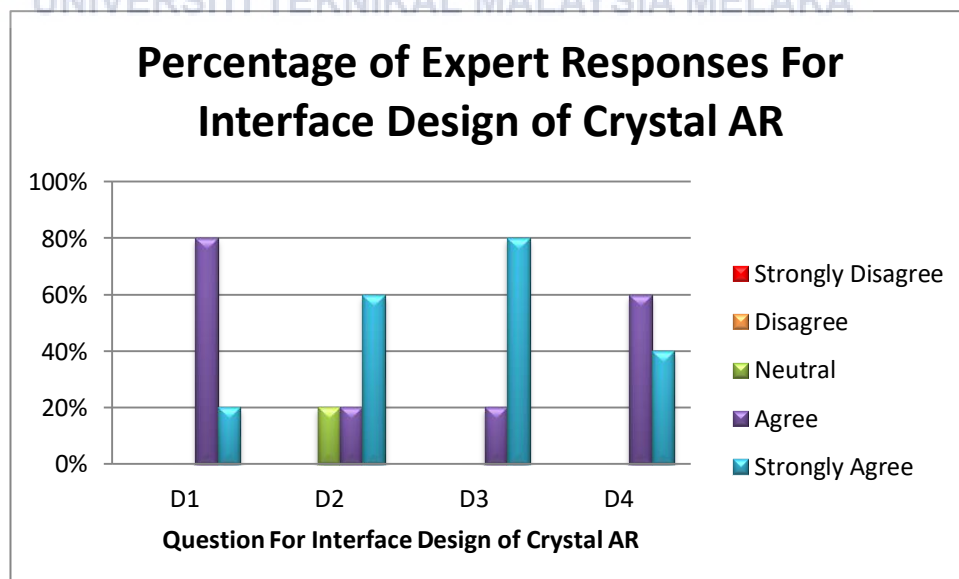| Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
D1	0%	0%	0%	80%	20%
D2	0%	0%	20%	20%	60%
D3	0%	0%	0%	20%	80%
D4	0%	0%	0%	60%	40%

Figure 6.6: Percentage of Experts Response for Interface Design of Crystal AR

There are four questions in the interface design part of UAT. Based on Figure 6.6 and Table 6.13, four experts (80%) are agreed to D1, which is the interface design of application is suitable and one expert is answered strongly agree. D2 is about the interface design of application is attractive. For D2, three experts (60%) are strongly agreed that the interface design is attractive, one of the expert (20%) is agreed and another one experts (20%) answers neutral. For D3, most of the experts (4 out of 5) are strongly agreed that the font and colors of application is readable and recognizable and one of them is agreed to the statement. Lastly, two experts (40%) are strongly agreed to C4, the interface design of application is consistence and comfortable and three experts (60%) are agreed. Overall, experts are given positive response to the interface design of the Crystal AR application.

Table 6.14: Comment and Feedback of Experts towards Crystal AR application

Lee Ser Yuen	Good application for beginner to learn about Crystals. Can add more crystals in future.
Carrie Wong Yee Yin	Crystal model can be improved.
Amber Liu Li Ping	There is room for improvement for the colour and lustre of crystals.
Lim Kah Yee	Good Crystal Learning App!

Based on the comment and feedback from experts, Crystal AR application is a good crystals learning application for beginner to learn the crystals. However, there is a room of improvement for the crystal model and the type of crystals can be increased.

In a nutshell, the result for the functionality, content, learnability and interface design of application are overall satisfied. Crystal AR application is suitable for user to learn the crystal's knowledge effectively based on the result of expert UAT test.

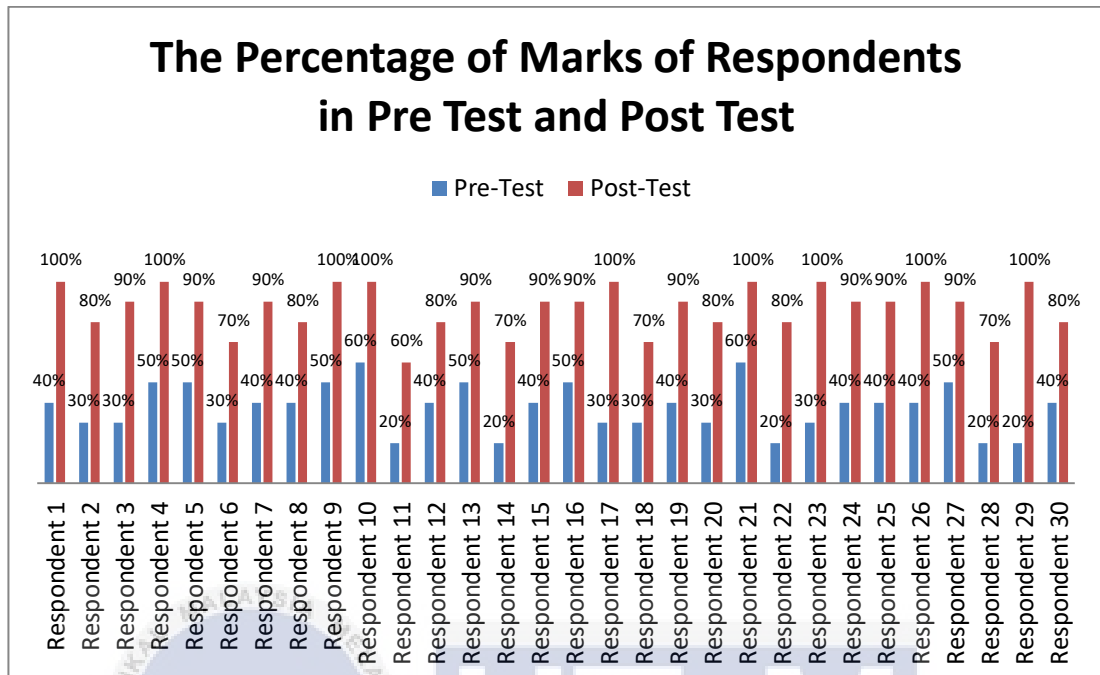## 6.5.2 Result of Pre-Test and Post-Test

Figure 6.7: The Percentage of Marks of 30 Respondents in Pre-Test and Post-Test

For the pre-test and post-test, there are 30 respondents involved in this testing. Pre-test is for conventional learning material and post-test is to evaluate the effectiveness of Crystal AR application. Each test consists of 10 questions for the respondents to answer. The test marks are calculated based on the number of correct answer divided by total number of question and multiply by 100%. Figure 6.7 shows the percentage of marks of 30 respondents in pre-test and post-test. For the pre-test, the lowest mark is 20% and the highest mark is 60%. However, the lowest mark for the post-test is 60% and the highest mark is 100%. In conclusion, all the respondents are getting higher mark in post-test compared to pre-test.
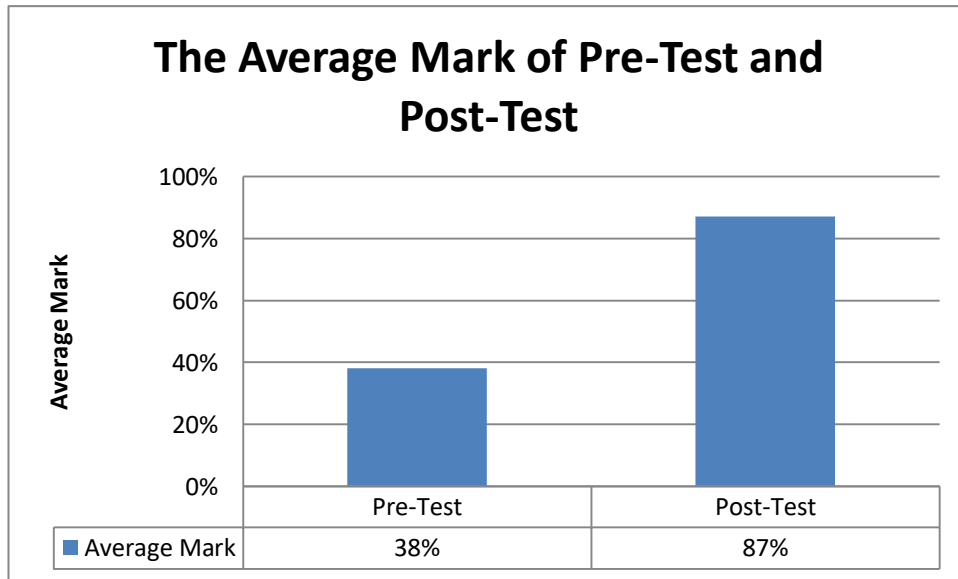
Figure 6.8: The Average Mark of Pre-Test and Post-Test

The average mark is calculated based on the total marks of 30 respondents divided by total number of respondents and multiply by 100%. Based on the Figure 6.8, the average mark of post-test (87%) is higher than the average mark of pre-test (38%). The result means that the performance of respondents learn the crystal's knowledge by using Crystal AR application is higher than the performance of using PDF learning material. In conclusion, the result has proved that learning crystals by using augmented reality technology is effective than conventional learning methods.

6.5.3 Result of User Acceptance Test for End-User

Table 6.15: Percentage of End User Responses for Functionality of Learning Materials

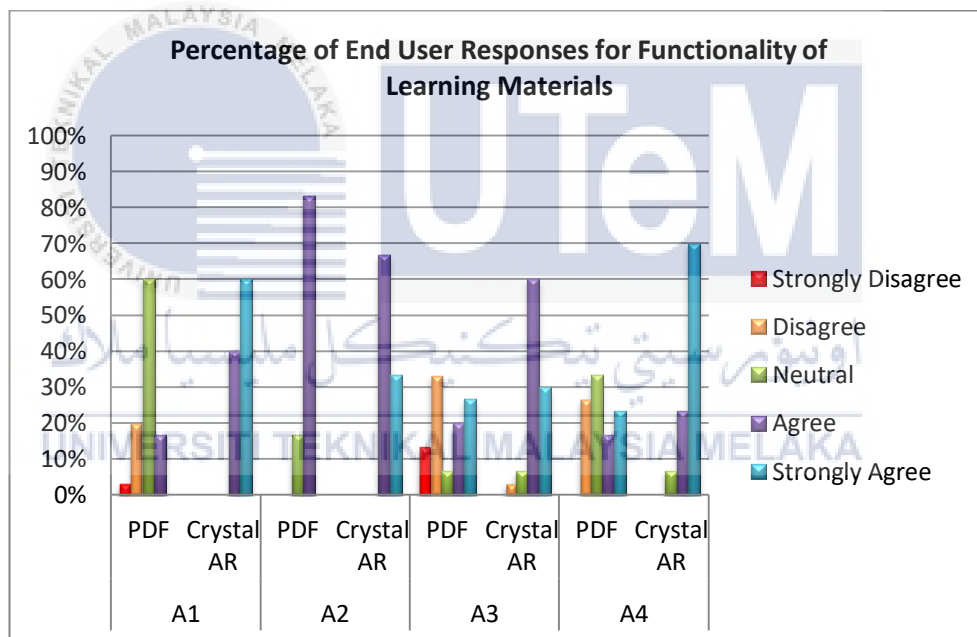| Question	A1		A2		A3		A4	
Learning Material	PDF	Crystal AR	PDF	Crystal AR	PDF	Crystal AR	PDF	Crystal AR
Strongly Disagree	3%	0%	0%	0%	13%	0%	0%	0%
Disagree	20%	0%	0%	0%	33%	3%	27%	0%
Neutral	60%	0%	17%	0%	7%	7%	33%	7%
Agree	17%	40%	83%	67%	20%	60%	17%	23%
Strongly Agree	0%	60%	0%	33%	27%	30%	23%	70%

Figure 6.9: Percentage of End User Responses for Functionality of Learning Materials

Figure 6.9 and Table 6.15 show the percentage of end user responses for functionality of learning materials. Question A1 is about the learning material is suitable to learn crystals' knowledge. For the PDF, 3% of the respondents are strongly disagreed, 20% of the respondents are disagreed, 60% of respondents are neutral and only 17% of the respondents are agreed. For the Crystal AR application, 60% of the 30 respondents are strongly agreed that Crystal AR is suitable to learn the

crystals' knowledge and the rest are answered agreed. For A2, 17% of respondents are neutral, and 83% of them are agreed to PDF learning material can function well after downloaded. For the Crystal AR application, 67% of respondents are agreed to the application can function well and 33% of them are strongly agreed to A2. A3 is about the learning material is easy to access the learning content. For A3, 13% of the respondents is strongly disagreed to the PDF is easy to access the learning content, 33% are disagreed, 7% are neutral, 20% are agreed and 27% are strongly agreed. However, most of the respondents are strongly agreed and agreed to the Crystal AR application is easy to access the learning content, which is 30% and 60%. A4 is about the learning material is easy to use. For PDF, the percentage for strongly disagree, disagree, neutral, agree and strongly agree are 0%, 27%, 33%, 17% and 23%. Besides, 70% of the respondents are strongly agreed to the Crystal AR is easy to use, 23% of them are agreed and only 7% of the respondents are neutral. Overall, the functionality of Crystal AR application is better than the PDF learning material based on the graph and result analyzed.

Table 6.16: Percentage of End User Responses for Content of Learning Materials

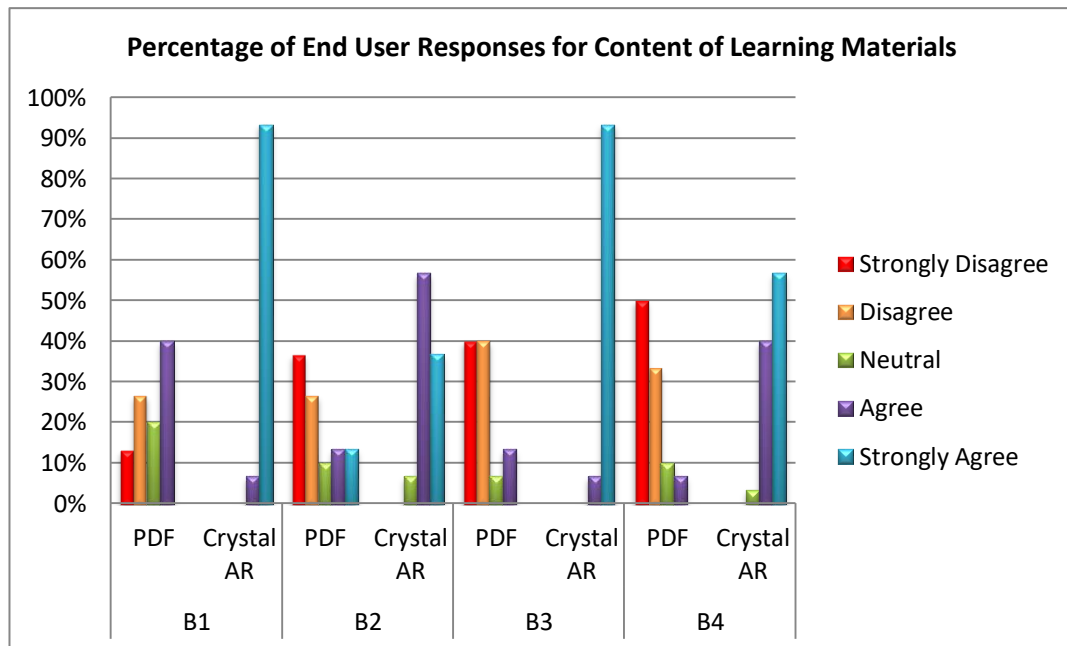| Question	B1		B2		B3		B4	
Learning Material	PDF	Crystal AR	PDF	Crystal AR	PDF	Crystal AR	PDF	Crystal AR
Strongly Disagree	13%	0%	37%	0%	40%	0%	50%	0%
Disagree	27%	0%	27%	0%	40%	0%	33%	0%
Neutral	20%	0%	10%	7%	7%	0%	10%	3%
Agree	40%	7%	13%	57%	13%	7%	7%	40%
Strongly Agree	0%	93%	13%	37%	0%	93%	0%	57%

Figure 6.10: Percentage of End User Responses for Content of Learning Materials

Figure 6.10 and Table 6.16 show the percentage of end user responses for content of learning materials. Question B1 is about the information and learning content is clear. From the graph and table, majority of the respondents (93%) are strongly agreed to the learning content of Crystal AR application is clear and 7% of them are agreed. For PDF, only 40% are agreed the information is clear. Next, 37% of the respondents are strongly agreed to the information and learning content of Crystal AR is understandable, 57% are agreed and 7% are answered neutral. Most of the respondents are strongly disagreed (37%) and disagreed (27%) to the PDF learning content is understandable. B3 is asked about the information and learning content is attractive. 93% of the respondents are strongly agreed to the content of Crystal AR is attractive and 7% of them are agreed to B3. In contrast, 40% of the respondents are strongly disagreed to the content of PDF is attractive, 40% of them are disagreed, 13% are agreed and no one is strongly agreed to the statement. For Crystal AR, 57% of the respondents are strongly agreed to the content of application is complete and useful and 40% are agreed to the B4. However, 50% and 33% of the respondents are strongly disagreed and disagreed to the information and learning content of PDF is complete and useful. As conclusion, the content of Crystal AR application is more understandable, clear, attractive and complete if compared to the conventional learning material (PDF).

**Table 6.17: Percentage of End User Responses for Learnability
of Learning Materials**

Question	C1		C2		C3		C4	
Learning Material	PDF	Crystal AR	PDF	Crystal AR	PDF	Crystal AR	PDF	Crystal AR
Strongly Disagree	77%	0%	50%	0%	7%	0%	60%	0%
Disagree	10%	0%	37%	0%	60%	0%	33%	0%
Neutral	13%	0%	7%	10%	30%	3%	7%	0%
Agree	0%	3%	7%	53%	3%	40%	0%	30%
Strongly Agree	0%	97%	0%	37%	0%	57%	0%	70%
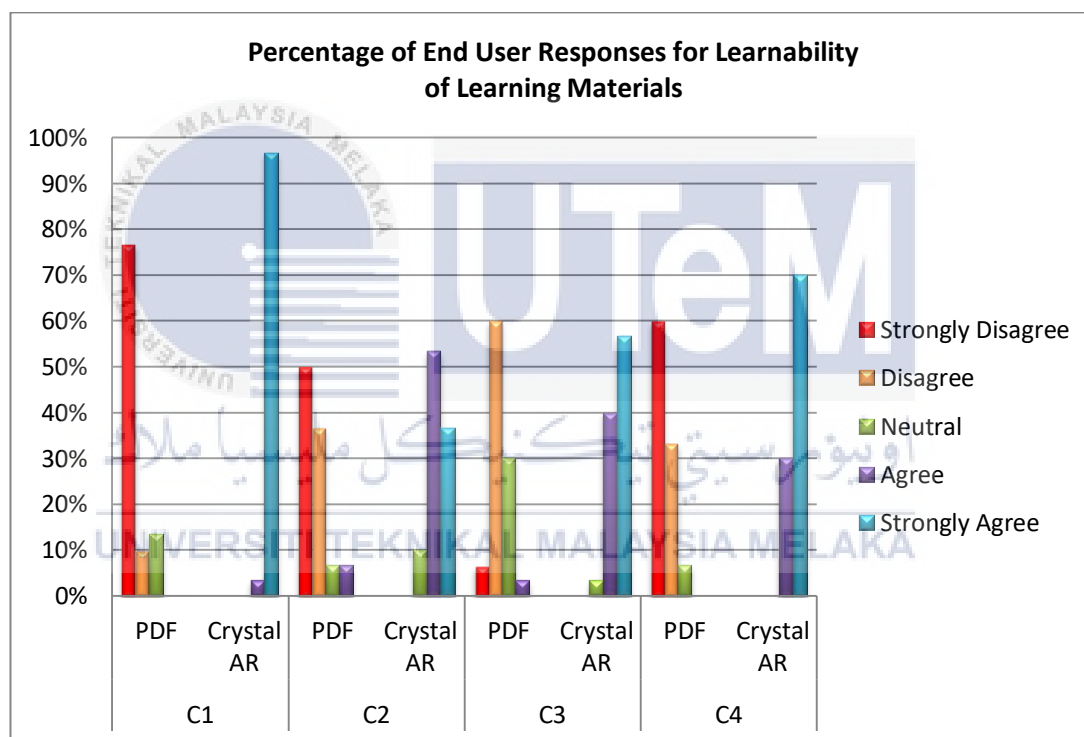
**Figure 6.11: Percentage of End User Responses for Learnability
of Learning Materials**

Figure 6.11 and Table 6.17 show the percentage of end user responses for learnability of learning materials. Question C1 is about the learning experience is fun and interesting. Majority of the respondents feel the learning experience are not fun and interesting with 77% strongly disagreed and 10% disagreed to C1. In contrast, 97% of the respondents are strongly agreed that the learning experiences is fun and

interesting by using Crystal AR and 3% of them answered agreed. 50% and 37% of the respondents are strongly disagreed and disagreed to the PDF is easy to understand, 7% is neutral and another 7% is agreed to C2. For Crystal AR application, 53% of the respondents are agreed and 37% are strongly agreed to the content of application is easy to understand and only 10% of them are neutral. C3 is about the learning material is easy to learn and memorize the crystal's knowledge. For PDF, most of the respondents (60%) are disagreed to C3 and majority of them are strongly agreed (57%) and agreed (40%) to the Crystal AR is easy to learn and memorize the crystal's knowledge. C4 is about the learning process is sped up, 60% of the PDF respondents are strongly disagreed to C4 while 70% of Crystal AR respondents are strongly agreed to C4. In short, the learnability of Crystal AR application is better than PDF learning material.

Table 6.18: Percentage of End User Responses for Interface Design of Learning Materials

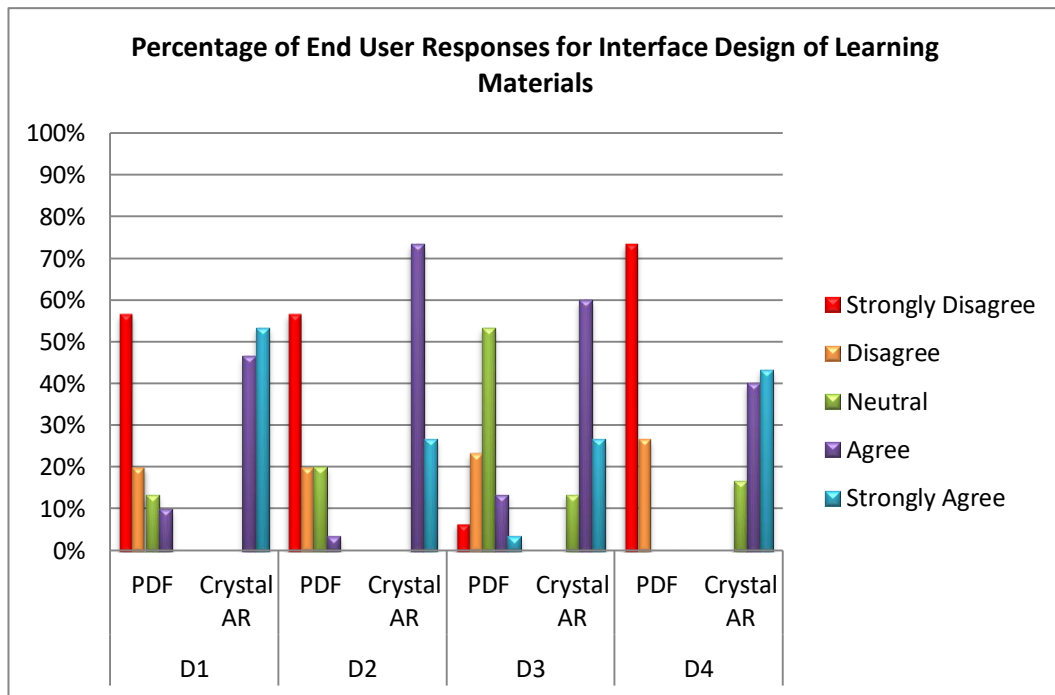| Question	D1		D2		D3		D4	
Learning Material	PDF	Crystal AR	PDF	Crystal AR	PDF	Crystal AR	PDF	Crystal AR
Strongly Disagree	57%	0%	57%	0%	7%	0%	73%	0%
Disagree	20%	0%	20%	0%	23%	0%	27%	0%
Neutral	13%	0%	20%	0%	53%	13%	0%	17%
Agree	10%	47%	3%	73%	13%	60%	0%	40%
Strongly Agree	0%	53%	0%	27%	3%	27%	0%	43%

Figure 6.12: Percentage of End User Responses for Interface Design of Learning Materials

Figure 6.12 and Table 6.18 show the percentage of end user responses for interface design of learning materials. For D1, 47% of the respondents are agreed and 53% of the respondents are strongly agreed that the interface design of Crystal AR is attractive and easy to understand. However, 57% of the respondents are strongly disagreed that the interface design of PDF is attractive and easy to understand, 20% is disagree, 13% is neutral and 10% is agree. For question D2, the interface design is beautiful and comfortable, 57% of the PDF respondents are strongly disagreed, 20% of them are disagree, another 20% are neutral and only 3% is agreed. Next, majority of respondents (73%) are agreed that the Crystal AR's interface design is beautiful and comfortable and the rest are agreed to the statement. D3 is about the font and text of learning material is readable and recognizable. For D3, 53% of the PDF respondents are neutral, 7% strongly disagree, 23% disagree, 13% agree and 3% strongly agree. 60% of the Crystal AR respondents are agreed that the font and text of is readable and recognizable, 27% of them are strongly agreed and 13% is neutral. For PDF, 73% of the respondents are strongly disagreed to the D4 which is the color used in the learning material is attractive. Meanwhile, 43% and 40% of the Crystal AR respondents are strongly agreed and agreed to the D4. In summary, the interface

design of Crystal AR application is better than the conventional learning material (PDF) and it is more attractive and comfortable to use.
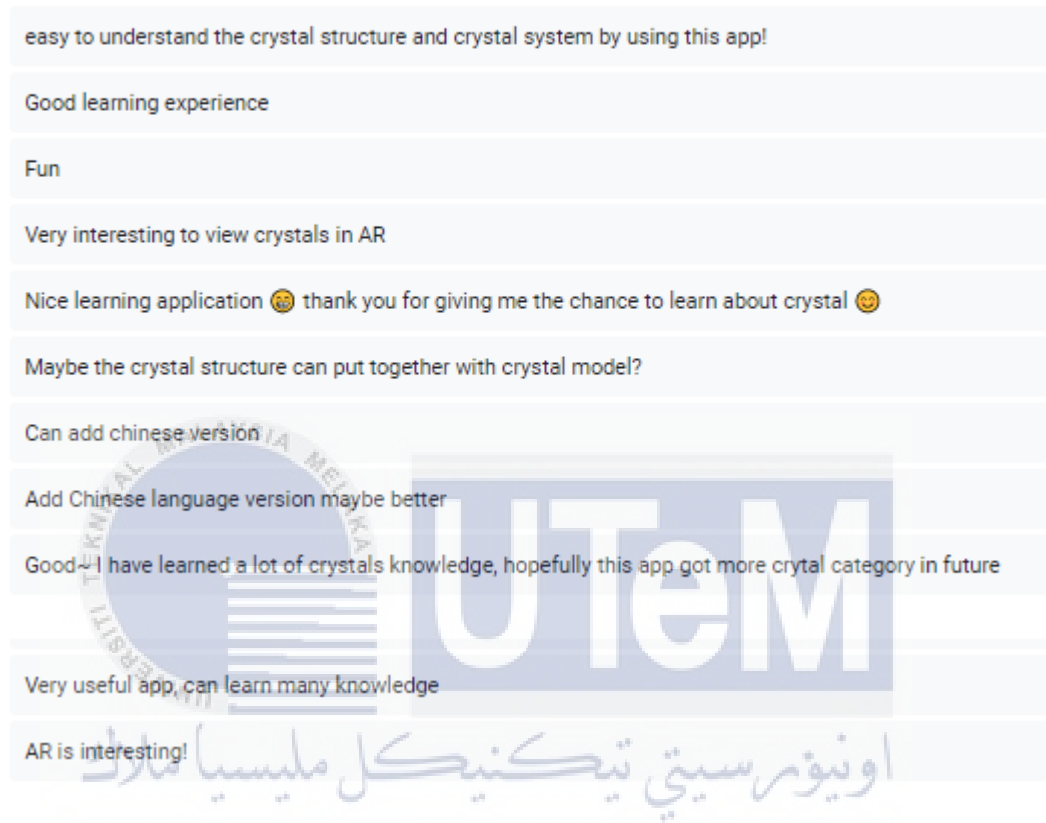

Figure 6.13: Feedback and Comment for Crystal AR Application Received from End User

There are 11 responses received from the end user for the feedback and comment about the Crystal AR application. Most of the respondents are giving a positive feedback towards the Crystal AR application. Besides, there are two suggestions from the respondents to improve the application such as build the Chinese version of Crystal AR and integrate the crystal structure model with crystal model.

In conclusion, the pre-test and post-test results have proved that the Crystal AR application is more effective than conventional learning material in learning crystals. The functionality, content, learnability and interface design of Crystal AR application is better than conventional learning material (PDF).

6.6   Conclusion

The purpose of the testing phase is to evaluate the user acceptance and effectiveness of augmented reality in learning the crystals compared to conventional learning methods. Besides, the testing also aim to evaluate the functionality, content, learnability and interface design of the Crystal AR application. The expert test result has proved that the content of Crystal AR application is suitable for the user to learn crystal's knowledge. The pre-test and post-test results have proved that learning crystals by using augmented reality is effective than conventional learning methods. From the result of end user acceptance test, the functionality, content, learnability and interface design of Crystal AR application is better than conventional learning material. The result showed that the user acceptance of augmented reality in learning the crystals is high.

CHAPTER 7: CONCLUSION

7.1 Observation on Weaknesses and Strengths

There are some weaknesses and strengths of Crystal AR project that had been identified during the testing phase will be discussed and concluded in this chapter.

7.1.1 Weaknesses

Firstly, the weakness of the Crystal AR application is only support for android mobile devices with minimum Android version 4.4 'KitKat' (API level 19). This is due to the project is built and develop by using Unity based on android platform. Furthermore, the suggestions from the experts are the number of crystals can be increased and the crystals models should be improved. Besides, the end user respondents also give some valuable feedback and suggestion. Their suggestions are to build Chinese version for the Crystal AR application and the crystal's structure model can be merged with the crystal model.

7.1.2 Strengths

The strength of the Crystal AR application is integrates the functionality of crystals and crystal's chemical knowledge. The strength enables the users to learn and know both of the knowledge easily because most of the existing system only consists one of the information. In addition, the strength of Crystal AR application is using the marker-less augmented reality technology. The AR technology enhances the learning experience of user and sped up the learning process. The users can interact with the 3D models and learn the crystal's knowledge in interactive way. Next, the users can learn and recognize the type of crystals through the visualization of crystal models. Furthermore, the users can learn the crystals knowledge in anytime

and anywhere because Crystal AR application does not need internet connection or any marker to activate the AR learning experience.

7.2   Prepositions for Improvement

Based on the advices and suggestions from evaluator, the testing should including the alpha testing to evaluate the technical issues of Crystal AR application. The alpha testing is aim to identify the bugs and errors of the application before releasing to public. Hence, alpha testing is considered as one of the crucial improvement for the project in future. Furthermore, the beta testing as well as the end user testing in the project should be done in two separate groups. The first group is involved in the pre-test and the other group is required to done the post-test.

Besides, based on the weaknesses of application mentioned above, some improvements can be made to enhance the project. The first available improvement is to develop the Crystal AR application that supports IOS mobile devices. Then, the number of the crystals can be increased and the color and lustre of the crystal's models can be improved. The Crystal AR application can have other language version such as Chinese version that was suggested by the end user. In addition, the crystal's structure model can be merged with the crystal model. For example, when the user double clicks on the crystal model and the crystal's structure model will be showed on the screen.

7.3   Project Contribution

The development of Crystal AR application will be able to contribute to anyone who is interested to learn crystal's knowledge especially for those beginner crystals learners and chemistry students. Next, the project can help the public to learn the information and knowledge of crystal in effective and interactive way.

7.4   Conclusion

In a nutshell, the outcome of the project is successful and meets all the objectives. The Crystal AR application fulfills all the requirements that enable the user to learn crystal's chemical knowledge and functionality of crystals (2 in 1) in

interesting and effective way. Finally, the project is completely developed within the expected time and came to an end.

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APPENDIX A

Development of Mobile Application On learning Crystals Through Augmented Reality (FYP)

Hi, I am ONG HUI JIE, year 3 student from University Technical Malaysia Malacca (UTeM). I am surveying for my final year project (FYP) which is development of mobile application on learning crystals through augmented reality. I hope you can spend some time to help me fill in the survey form. Your response is much appreciated, thank you.

* Required

Do you know about crystals? *

○ Yes

○ No

Do you have any knowledge related to crystals? (healing function, chemical structure and etc.) *

○ Yes

○ No

From where you learn/know about crystals' knowledge? *

○ Website

○ Book

○ Mobile Application

○ Other: _____

Do you face any problem when learning crystals' knowledge? *

○ Yes

○ No

What kind of problem had you face when learning crystals' knowledge? *

☐ Source to find is limited

☐ Hard to understand the structure of crystals

☐ Learning process is dull and lack of interactive

☐ Hard to find complete information about crystals (background+ chemical knowledge + function)

☐ Other: _____

Do you know about mobile AR learning?

○ Yes

○ No

Do you try any mobile AR learning before?

○ Yes

○ No

Are you interested in learning crystals through AR mobile application?

○ Yes

○ No

Are you interested to learn crystals' structure and crystals' system through visualization of 3D models?

○ Yes

○ No

Do you think learning crystals through AR mobile application is effective?

○ Yes

○ No

APPENDIX B

Pre-Test (PDF)

Please choose the correct answer.

* Required

Your Name : *

Your answer

What is the color of Citrine? *   1 point

○ White

○ Yellow

○ Red

Which one is Amazonite? *   1 point

○ a

○ b

○ c

What is the crystal system of Tiger's Eyes? *　　　1 point

○ Isometric

○ Trigonal

○ Orthorhombic

Which crystal is not in beryl (Be3Al2(SiO3)6) group? *　　　1 point

○ a. Emerald

○ Rose Quartz

○ Aquamarine

Which crystal is help for "Health"? *　　　1 point

○ Peridot

○ Rose Quartz

○ Rhodochrosite

Which one is the chemical structure of fluorite? *　　　1 point
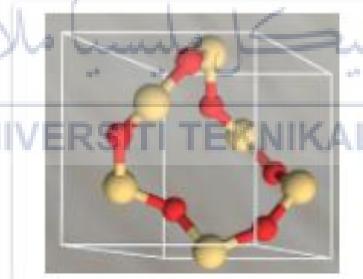
○ SiO2
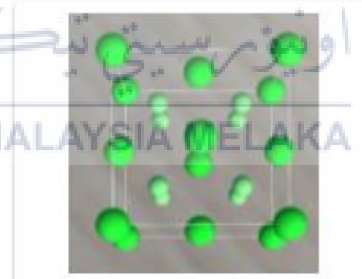
○ CaF2
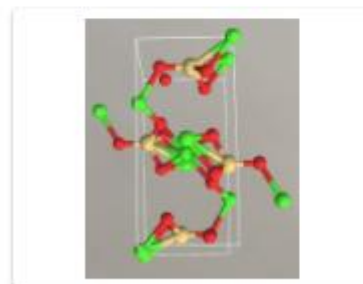
○ Mg2SiO4

Garnet is help to regulate blood circulation in body. * 1 point

○ True

○ False

Rhodochrosite is red/pink in colour, with vitreous lustre and have concentric/zigzag pattern. * 1 point

○ True

○ False

The crystal system of Aquamarine is trigonal. * 1 point

○ True

○ False

Choose the correct one. * 1 point

○ a. Love - Peridot, Clear Quartz

○ b. Study - Amethyst, Clear Quartz

○ c. Beauty — Garnet, Citrine

○ Other:
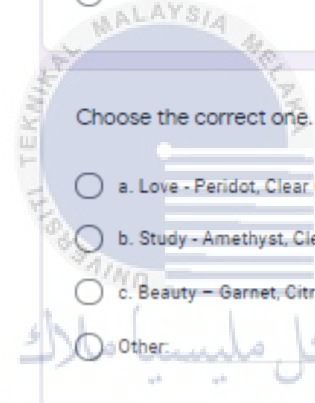
APPENDIX C

POST-TEST

PLEASE SELECT THE CORRECT ANSWER.

* Required

NAME

Your answer

What is the color of Garnet? *   1 point

◯ Blue

◯ Yellow

◯ Red

Which one is Rose Quartz?   1 point

◯ a

◯ b

◯ c

What is the crystal system of Amethyst? * 1 point

○ Trigonal

○ orthorhombic

○ Triclinic

Which crystal is not in Silicon dioxide (SiO2) group? * 1 point

○ Citrine

○ Clear Quartz

○ Peridot

Which crystal is help in "Love"? * 1 point

○ Fluorite

○ Clear Quartz

○ Rose Quartz

Which one is the chemical structure of Peridot? * 1 point
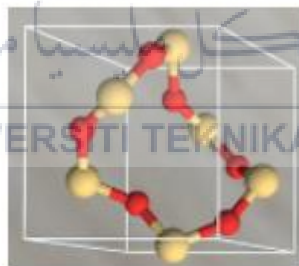
○ SiO2
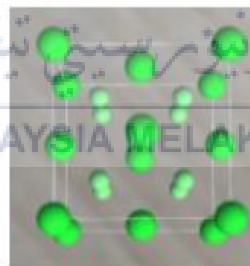
○ CaF2
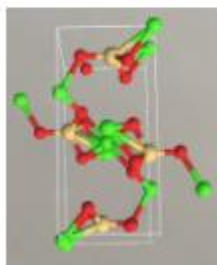
○ Mg2SiO4

Aquamarine is help to improve communication skill. *   1 point

◯ True

◯ False

Clear Quartz is white in colour and with vitreous lustre. *   1 point

◯ True

◯ False

The crystal system of Citrine is trigonal.   1 point

◯ True

◯ False

Choose the correct one. *   1 point

◯ a. Health - Clear Quartz, Rhodochrosite

◯ b. Study - Aquamarine, Rose Quartz

◯ c. Protective - Fluorite, Tiger's Eyes

APPENDIX D

User Acceptance Test (End User)

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

* Required

Functionality

The learning material is suitable to learn crystals' knowledge. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

The learning material can function well after downloaded. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

The learning material is easy to access the learning content. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

The learning material is easy to use. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

Content

The information and learning content is clear. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

The information and learning content is understandable. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

The information and learning content is attractive. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

The information and learning content is complete and useful. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

Learnability

The learning experience is fun and interesting. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

The learning material is easy to understand. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

The learning material is easy to learn and memorize the crystal's knowledge. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

The learning process is sped up. *

	1	2	3	4	5
PDF	◯	◯	◯	◯	◯
Crystal AR	◯	◯	◯	◯	◯

Interface Design

The interface design is attractive and easy to understand. *

	1	2	3	4	5
PDF	◯	◯	◯	◯	◯
Crystal AR	◯	◯	◯	◯	◯

The interface design is beautiful and comfortable. *

	1	2	3	4	5
PDF	◯	◯	◯	◯	◯
Crystal AR	◯	◯	◯	◯	◯

The font and text of learning material is readable and recognizable. *

	1	2	3	4	5
PDF	◯	◯	◯	◯	◯
Crystal AR	◯	◯	◯	◯	◯

The color used in the learning material is attractive. *

	1	2	3	4	5
PDF	○	○	○	○	○
Crystal AR	○	○	○	○	○

Feedback and Comment for Crystal AR application

Your answer

APPENDIX E

NAME: Lee Ser Yuen	SIGNATURE:

Please tick (/) to answer the question.

	Scale	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		1	2	3	4	5
A)	**FUNCTIONALITY OF APPLICATION**					
1	The application is suitable as a learning platform for the user to learn crystal's knowledge.					/
2	The application's instruction is clear to guide the user how to use the application to learn crystal's knowledge.					/
3	The AR technology that applied in the application is functional.				/	
4	The visualization of crystals' model, crystal's structure and crystal's information is useable.				/	
B)	**CONTENT OF APPLICATION**					
1	The content of application is understandable.					/
2	The information of the crystals is correct and matched.				/	
3	The categories of the crystals are correct and complete.				/	
4	The 3D crystal models and crystal structure models are recognizable.				/	
5	The 3D crystal models in the application look like the real crystals.				/	

6	The color and the surface of the 3D crystal models are correct and matched.				/	
7	The content in the application is delivered effectively to user.				/	
C)	**LEARNABILITY OF APPLICATION**					
1	The content of application is easy to learn and understand.				/	
2	The 3D model enables the user to visualize and recognize the crystals.				/	
3	The content of the application is suitable for the public to learn crystals' knowledge.				/	
4	The application is more effective than traditional learning methods to learn crystals' knowledge.					/
D)	**INTERFACE DESIGN OF APPLICACTION**					
1	The interface design of application is suitable.				/	
2	The interface design of application is attractive.				/	
3	The font and colors of application is readable and recognizable.				/	
4	The interface design of application is consistence and comfortable.					/
E)	**FEEDBACK AND COMMENT**					
	Good application for beginner to learn about Crystals. **Can add more crystals in future.**					

NAME: Gan Koyi		SIGNATURE: Koyi				
Please tick (/) to answer the question.						
	Scale	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
		1	**2**	**3**	**4**	**5**
A)	**FUNCTIONALITY OF APPLICATION**					
1	The application is suitable as a learning platform for the user to learn crystal's knowledge.					/
2	The application's instruction is clear to guide the user how to use the application to learn crystal's knowledge.					/
3	The AR technology that applied in the application is functional.					/
4	The visualization of crystals' model, crystal's structure and crystal's information is useable.					/
B)	**CONTENT OF APPLICATION**					
1	The content of application is understandable.					/
2	The information of the crystals is correct and matched.				/	
3	The categories of the crystals are correct and complete.			/		
4	The 3D crystal models and crystal structure models are recognizable.					/
5	The 3D crystal models in the application look like the real crystals.				/	

6	The color and the surface of the 3D crystal models are correct and matched.				/	
7	The content in the application is delivered effectively to user.					/
C)	**LEARNABILITY OF APPLICATION**					
1	The content of application is easy to learn and understand.					/
2	The 3D model enables the user to visualize and recognize the crystals.				/	
3	The content of the application is suitable for the public to learn crystals' knowledge.			/		
4	The application is more effective than traditional learning methods to learn crystals' knowledge.				/	
D)	**INTERFACE DESIGN OF APPLICACTION**					
1	The interface design of application is suitable.				/	
2	The interface design of application is attractive.					/
3	The font and colors of application is readable and recognizable.					/
4	The interface design of application is consistence and comfortable.				/	
E)	**FEEDBACK AND COMMENT**					

	Scale	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		1	2	3	4	5

NAME: Carrie Wong Yee Yin

SIGNATURE:

Please tick (/) to answer the question.

	Scale	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		1	2	3	4	5
A)	**FUNCTIONALITY OF APPLICATION**					
1	The application is suitable as a learning platform for the user to learn crystal's knowledge.					/
2	The application's instruction is clear to guide the user how to use the application to learn crystal's knowledge.				/	
3	The AR technology that applied in the application is functional.					/
4	The visualization of crystals' model, crystal's structure and crystal's information is useable.					/
B)	**CONTENT OF APPLICATION**					
1	The content of application is understandable.					/
2	The information of the crystals is correct and matched.				/	
3	The categories of the crystals are correct and complete.				/	
4	The 3D crystal models and crystal structure models are recognizable.				/	
5	The 3D crystal models in the application look like the real				/	

	crystals.					
6	The color and the surface of the 3D crystal models are correct and matched.				/	
7	The content in the application is delivered effectively to user.				/	
C)	**LEARNABILITY OF APPLICATION**					
1	The content of application is easy to learn and understand.				/	
2	The 3D model enables the user to visualize and recognize the crystals.					/
3	The content of the application is suitable for the public to learn crystals' knowledge.					/
4	The application is more effective than traditional learning methods to learn crystals' knowledge.				/	
D)	**INTERFACE DESIGN OF APPLICACTION**					
1	The interface design of application is suitable.				/	
2	The interface design of application is attractive.					/
3	The font and colors of application is readable and recognizable.					/
4	The interface design of application is consistence and comfortable.				/	
E)	**FEEDBACK AND COMMENT** Crystal model can be improved.					

NAME: AMBER LIU LI PING		SIGNATURE:

Please tick (/) to answer the question.

	Scale	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		1	2	3	4	5
A)	**FUNCTIONALITY OF APPLICATION**					
1	The application is suitable as a learning platform for the user to learn crystal's knowledge.					/
2	The application's instruction is clear to guide the user how to use the application to learn crystal's knowledge.				/	
3	The AR technology that applied in the application is functional.				/	
4	The visualization of crystals' model, crystal's structure and crystal's information is useable.					/
B)	**CONTENT OF APPLICATION**					
1	The content of application is understandable.					/
2	The information of the crystals is correct and matched.				/	
3	The categories of the crystals are correct and complete.				/	
4	The 3D crystal models and crystal structure models are recognizable.				/	

5	The 3D crystal models in the application look like the real crystals.			/		
6	The color and the surface of the 3D crystal models are correct and matched.				/	
7	The content in the application is delivered effectively to user.					/
C)	**LEARNABILITY OF APPLICATION**					
1	The content of application is easy to learn and understand.					/
2	The 3D model enables the user to visualize and recognize the crystals.					/
3	The content of the application is suitable for the public to learn crystals' knowledge.					/
4	The application is more effective than traditional learning methods to learn crystals' knowledge.					/
D)	**INTERFACE DESIGN OF APPLICACTION**					
1	The interface design of application is suitable.					/
2	The interface design of application is attractive.					/
3	The font and colors of application is readable and recognizable.					/
4	The interface design of application is consistence and comfortable.					/
E)	**FEEDBACK AND COMMENT** There is room for improvement for the colour and lustre of crystals.					

NAME: LIM KAH YEE		SIGNATURE: *KYEE*				
Please tick (/) to answer the question.						
	Scale	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
		1	**2**	**3**	**4**	**5**
A)	**FUNCTIONALITY OF APPLICATION**					
1	The application is suitable as a learning platform for the user to learn crystal's knowledge.					✓
2	The application's instruction is clear to guide the user how to use the application to learn crystal's knowledge.					✓
3	The AR technology that applied in the application is functional.					✓
4	The visualization of crystals' model, crystal's structure and crystal's information is useable.					✓
B)	**CONTENT OF APPLICATION**					
1	The content of application is understandable.					✓
2	The information of the crystals is correct and matched.				✓	
3	The categories of the crystals are correct and complete.				✓	
4	The 3D crystal models and crystal structure models are recognizable.					✓
5	The 3D crystal models in the application look like the real crystals.					✓

6	The color and the surface of the 3D crystal models are correct and matched.					✓
7	The content in the application is delivered effectively to user.					✓
C)	**LEARNABILITY OF APPLICATION**					
1	The content of application is easy to learn and understand.					✓
2	The 3D model enables the user to visualize and recognize the crystals.					✓
3	The content of the application is suitable for the public to learn crystals' knowledge.				✓	
4	The application is more effective than traditional learning methods to learn crystals' knowledge.				✓	
D)	**INTERFACE DESIGN OF APPLICACTION**					
1	The interface design of application is suitable.				✓	
2	The interface design of application is attractive.			✓		
3	The font and colors of application is readable and recognizable.					✓
4	The interface design of application is consistence and comfortable.				✓	
E)	**FEEDBACK AND COMMENT** Good Crystal Learning App!					

APPENDIX F

NAME	Tan Ser Yuen
AGE	37
OCCUPATION / POSITION	Senior Gemologist [GG(GIA)]
EXPERIENCES	More Than 10 Years in Gem and Crystals Fields
	Crystal & Mineral Exhibition Penang (2019)
	Gemstone Consultancy Seminar (2019)
	Singapore Jewellery & Gem Fair (2018)
	Jadeite Seminar (2018)
EDUCATION	B.SC.(HONS) Geology (2008)
	Graduate Gemologist From Gemmological Association of Australia(GAA) (2009-2013)
	GG.(GIA) (now)
	Accredited Australian-Trained Gemologist in Malaysia (now)

NAME	Gan Koyi
AGE	25
OCCUPATION / POSITION	Crystal Shop Owner (2018-now)
EDUCATION	Complete Crystal and Quartz Course AGL(2020)
EXPERIENCES	5 years

NAME	Carrie Wong Yee Yin
AGE	28
OCCUPATION / POSITION	Junior Gemologist
EDUCATION	Bachelor of Science with Honours (Geology) (UMS)
EXPERIENCES	Junior Gemology Workshop Basic Gemological Courses

NAME	Amber Liu Li Ping
AGE	26
OCCUPATION / POSITION	Junior Gemologist
EDUCATION	Bachelor of Science(BSc) in Applied Geology (UM) Gem Research Asia Lab Course (GRA lab)
EXPERIENCES	Basic Gemological Courses Gemstone Exhibition Kuala Lumpur Junior Gemology Workshop

NAME	Lim Kah Yee
AGE	23
OCCUPATION / POSITION	Trainee Gemologist
EDUCATION	Bachelor of Science (Hons) (Applied Geology) (Curtin University)
EXPERIENCES	-