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Development of Chemistry Lab Practical Application for Secondary Student in Virtual Reality: ChemisTry

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Abstract

Virtual Reality (VR) has emerged as a significant technological innovation in the age of globalization and technological advancement, offering users an immersive 3D experience within computer-generated environments. VR applications have found in various sectors, including medicine, video games, tourism, industry, and education. The existing applications for Chemistry practical labs that are available are yet to be implemented, especially in VR. Therefore, this project is proposed to develop a practical chemistry lab application to help students in secondary school practice doing their experiments. This project explores the development and significance of "ChemisTry," a VR application designed to assist secondary school students, particularly those in forms 4 and 5, in mastering their practical chemistry skills. This project uses the TRES-D methodology for its development. It covers experiment based on the syllabus from Kurikulum Standard Sekolah Menengah (KSSM). User acceptance testing for the ChemisTry application with 30 students from SMK Seri Gading, using TAM and SUS, yielded positive feedback, with 88.8% students strongly agree and agree with the statements. Overall, the application is deemed suitable for virtual Chemistry lab practical.

1. Introduction

In November 2020, the Ministry of Education Malaysia (MOE) released a verdict that says written paper 3 for Physics, Biology, and Chemistry will be terminated and changed to a practical exam where students must experiment physically[1]. This news has changed the overall sight of how the exam will be taken. The student with lab anxiety will have a hard time doing their experiment. Dinther, *et al.* [2] stated that employing the implementation of a virtual lab in a chemistry lab might be a possible solution to help the students improve their understanding and help them practice lab work beforehand. In contrast to reading just a static lab manual book, virtual reality (VR) can offer students a fully immersive, dynamic, and engaging learning experience that can help them understand the topic more and comprehend the notion of chemical reactions. Furthermore, everyone agrees that laboratory experiments and skills are crucial to the secondary school study of chemistry and science [3]. Nonetheless, the quantity of practical laboratory exercises that can be incorporated into the curriculum is frequently restricted by instructional resources [4]. Even though it is commonly known that receiving adequate hands-on laboratory instruction is necessary to acquire practical laboratory skills [3]. According Dinther et al [2], chemistry has been one of the most challenging subjects, and implementing virtual reality in chemistry class might be a possible solution to help the student improve their understanding. The use of VR technology has emerged as one of today's society's most significant technological advancements. By using computer modeling to replicate reality, VR allows people to interact with an immersive computer-generated environment [5]. There are three types of VR technology which are non-immersive VR, semi-immersive VR, and fully immersive VR. VR is all the rage these days, with a wide range of industries using it for business, entertainment, gaming, travel, health, and education.

Therefore, the implementation of VR in the Chemistry lab practical is proposed for development. This project aims to explore the implementation of VR in education, specifically in the context of Chemistry lab practical. The objectives of this project are (1) to design the ChemisTry application using the kinaesthetic learning approach, (2) to develop the ChemisTry application for chemistry lab practice by implementing fully immersive virtual reality, and (3) to perform functional and usability testing of the developed virtual reality application. The ChemisTry application is designed for secondary school students to help them practice their chemistry practical exam through a virtual reality environment. It serves as a virtual guide for students, enabling them to gain hands-on experience in doing Chemistry experiments. The fully immersive nature of VR allows students to visualize and interact with the materials and apparatuses of Chemistry experiments in a way that traditional methods cannot replicate. ChemisTry application contains two modules, which are the Practical Module and the Activity Module. The content of this ChemisTry application is based on the Chemistry textbook for Form 5, focusing on Chapter 1, Redox Equilibrium. ChemisTry application is developed as a fully immersive VR application that contains a chemistry lab module that helps the students to practice and understand their lab practical before entering their practical lab session. The content of this application is in the English language. By using the TRES-D methodology, a systematic and structured process is followed throughout the development process. In addition, the kinaesthetic learning approach has also been implemented in this application.

The rest of the paper is arranged as follows: Section 2 covers the domain of study, the technology used, and the result of the comparative analysis. Section 3 describes the TRES-D methodology that has been chosen to be used in this project, as well as the output of the analysis and design phases of this project. Furthermore, Section 4 discusses the results and discussion, while Section 5 presents the conclusion of the project.

2. Related Work

This section discusses the background of the study, the technology used, and the result of the comparative analysis.

2.1 Chemistry Subject for Secondary School

Chemistry subject is one of the core subjects in secondary school. According to the Ministry of Education (MOE), four elective science courses are in addition to the three main science courses in the curriculum, which are biology, chemistry, physics, and computer science [1]. Science is one of the basic topics at the elementary, lower, and higher secondary levels. The secondary school Chemistry curriculum's objectives are to give students information and abilities in chemistry and technology to help them solve problems and make decisions in their daily lives based on moral principles and scientific attitudes. The necessity for teachers to proactively adapt classes to each student's requirements has increased in recent years due to the growing variety of the student population, especially in the subject of chemistry [6], [7]. This has led educators, academics, and other stakeholders to investigate effective methods for students' continuous benefit. As stated in the Malaysian Education Blueprint 2013–2025, differentiated instruction (DI) has drawn attention in Malaysia to support the 21st-century learning strategy[8]. Although the method is not new, a lack of exposure and comprehension has prevented Malaysian teachers from implementing it widely.

2.2 Virtual Reality

The technology used to develop this proposed application is virtual reality (VR). VR is a simulated 3D visual experience that empowers users to engage with an immersive computer-generated environment, replicating reality through computer modeling [5]. VR is also an advanced technological innovation that has transformed how people interact with digital environments. It is defined as real-time interactive graphics utilizing three-dimensional models in conjunction with display technology that allows the viewer to manipulate objects directly within the model world and feel as though they are immersed in it [9]. The three types of VR are non-immersive VR, semi-immersive VR, and fully immersive VR. VR is the talk of the town nowadays, and its widespread application spans various fields, including gaming, entertainment, tourism, business, health, and education [10]. Putting new educational innovations into practice, making the most of their benefits to maximize learning, encouraging cooperative and collaborative learning, and helping students acquire the cognitive and new skills they will need.

2.3 Learning Approach

VARK learning style is a model of learning developed by Neil Fleming [11]. This model is based on various senses, which are visual, auditory, reading/writing, and kinesthetic. The kinaesthetic learning style is a measurement method that focuses on the combination of different sensory functions, emphasizing experience-based and practice-based learning [12]. According to Armstrong [13], students with this kind of intelligence have a tendency to move around, exhibit activity, are skilled at picking up new skills, have a tendency to think while they are moving, excel in specific sports, are likely to use movement as a memory aid, have good coordination and tempo awareness and are easily relaxed. Integrating VR apps into the classroom is an unmatched benefit for kinaesthetic learners since it turns abstract ideas into realistic, immersive experiences that promote retention and better understanding through active, hands-on learning. The kinaesthetic learning style approach from the VARK learning style has been used to develop the proposed application

2.4 Comparative Analysis

Comparative analyses were conducted on three related applications to the proposed system. The three applications are Unreal Chemist[14], Virtual Chemistry Lab[15], and CAVE™[16]], as shown in Fig. 1(a), (b), and (c), respectively. Table 1 shows the result of the comparative analysis.

The comparison being discussed is based on eight different features of the application such as is the technology used, the platform used, content, learning module, activity module, operating system, and payment charges. Based on Table 1, the first comparison that can be done is that the existing application either provides a not fully immersive VR or does not provide any at all, but the developed application does provide a a fully immersive VR. Next, the developed application provides two different modules, which are not provided in the existing application. ChemisTry application is available on desktop and is free of charge, unlike the other three existing applications. Furthermore, the ChemisTry application focuses on practical labs done in upper secondary school and focuses on Chapter 1, Redox Equilibrium, as the main practical lab exercise.

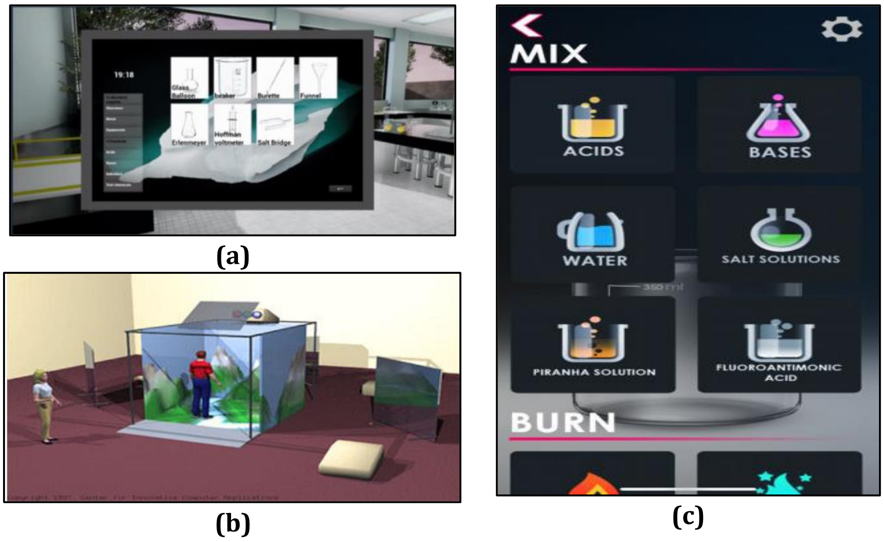

Fig. 1 (a) *Virtual Chemistry Lab*[15]*; **(b)** CAVE™*[16]*; **(c)** Unreal Chemist* [14]

Table 1 *Comparison between the existing applications and the developed application*

Features/ Applications	Unreal Chemist	Virtual Chemistry Lab	CAVE™	ChemisTry
Technology used	Not provided	Non-immersive VR	Semi-immersive VR	Fully immersive VR
Platform used	Mobile	Desktop	CAVE™	Desktop
Content	Focusing on mixing chemicals and burning salts	Chemistry experiment	Chemistry atoms	Practical lab, Chapter 1: Redox Equilibrium

Table 1: (cont)

Features/ Applications	Unreal Chemist	Virtual Chemistry Lab	CAVE™	ChemisTry
Syllabus	General	General (Focused on Experiment)	General (Focused on Atoms)	Based on Kurikulum Standard Sekolah Menengah (KSSM)
Learning module	Provide 2 learning modules on mixing chemicals and burning salts	Not provided	Provide learning module chemistry atoms	Provides a Practical module of practical lab
Activity module	Not provided	Provide an activity in the context of an experiment	Not provided	Provide an activity module using the escape room as the concept
Operating system	iOS 11.0 or later	Windows 7 64-bit or higher	Linux or Windows	Android-based
Payment charges	Free download, In-app purchases	Paid content	Paid	Free of charge

3. Methodology

The ChemisTry learning application has been developed using the TRES-D methodology [17], as depicted in Fig. 2. This is because VR application development is the focus of the TRES-D methodology and for its comprehensive coverage of the development process. The six phases of this methodology are the initial requirement phase, understand requirement phase, concept design phase, iterative design phase, building and implementation phase, and deployment and maintenance phase. The iterative design process contains two more subphases, abstract design and presentation design. Table 14 in Appendix A provides a summary of the output of the six phases of the TRES-D methodology

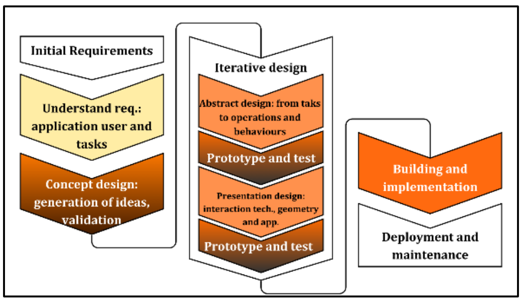

Fig. 2 *TRES-D Methodology* [17]

3.1 Initial Requirement Phase

In this first phase, the initial requirements needed for the development of the ChemisTry learning application are determined. This phase involved reviewing existing applications, interviews with Subject Matter Experts (SME), and a questionnaire from the target user, form 4 and 5 students from SMK Seri Gading, Batu Pahat, Johor which was conducted through Google Forms. An interview session was conducted with the SME, Mrs Norisfarina binti Ismail, who is teaching Chemistry at SMK Bongawan and has 24 years of experience in teaching Chemistry. A total of 20 respondents were participating in this questionnaire. As a result, an initial requirement checklist has been created, as shown in Table 2. Meanwhile, Table 3 shows the user analysis extracted from an interview with SME.

Table 2 *Initial requirement checklist*

Item	Description
Type of application	Learning application
Objectives	• to design the ChemisTry application using the kinaesthetic learning approach, • to develop the ChemisTry application for chemistry lab practice by implementing fully immersive virtual reality, and • to perform functional and usability testing of the developed virtual reality application.
Target platform	Android-based
Target device	Oculus Meta Quest
Target users	Secondary School Student (Form 4 and 5)
Content	Chemistry subject focuses on practical lab
Technology used	Virtual Reality (VR)

Table 3 *User Analysis*

Stakeholder category	Role in product	Design implication	Action needed
Subject Matter Expert (SME) Mrs Norisfarina binti Ismail	Content consultant expert in Chemistry subject	Less use of words, simple sentences	Use more icon-based buttons. Use simple sentences for users to understand the content easily
		Easy to navigate, user friendly	Use the start, play, next, previous and home buttons to navigate the user to relative pages.
		Content is based on secondary school student syllabus.	Follow the KSSM syllabus, and the content must use Chapter 1: Redox Equilibrium from the Form 5 syllabus.
		Time-limited experiment	Add a timer inside the application when they are doing the experiment

3.2 Understand Requirement Phase

In this phase, the structure of the application to be developed was analyzed. Fig 3 shows system flowchart for the application. Table 4 and Table 5 show the functional and non-functional requirements of the developed application. The navigation structure, flowchart for each module, and application module diagram are shown in Appendix B – F.

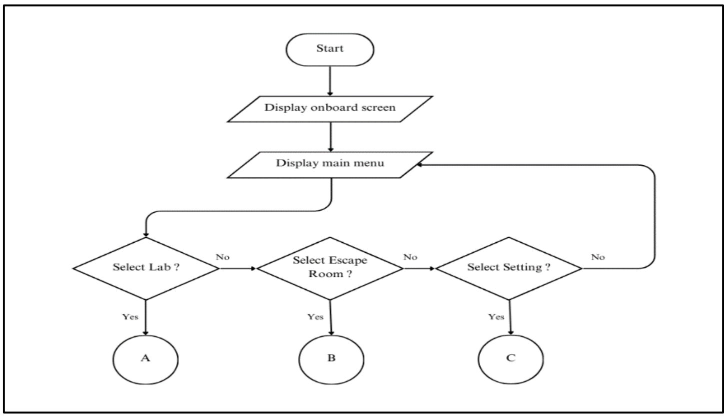

Fig. 3 *System Flowchart*

Table 4 *Functional requirements*

Functional requirements	Module/ Scene	Description
Autonomous system activities	Practical Module	The sound and music should play when the users enter the Practical Module.
	Activity Module	The sound and music should play when the users enter the Activity Module.
Learning/ practice content	Practical Module	The application should allow users to learn four different types of experiments.
	Activity Module	The application should allow users to play escape rooms.
User interaction	Onboard Interface	The application should allow users to click on the Start button to go to the main menu page.
	Main Menu	The application should allow users to select the Practical Module, Activity Module, and Setting buttons.
	Practical Module	The application should allow users to select four different experiments they want.
	Activity Module	The application should allow users to input the answer to the question.

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Table 5 *Nonfunctional requirements*

Non-functional requirements	Description
Performance	The applications should be able to perform and load all the modules and pages. The average time the application took to respond is 2 seconds.
Legal	Users should only be able to view the content of the application and are not able to edit or modify the content.
Usability	Users should be able to access the application everywhere, and anywhere they want if they have the hardware required for the application to run.
Operational	The application should be able to operate on Meta Quest devices with an Android-based platform.

3.3 Concept Design Phase

The third phase of the TRES-D methodology is to determine the concept design for the project. With the data gathered, different solutions were designed to assist with the development of this project. One of the primary objectives of the concept design stage is to define the tasks that users will be able to perform within the ChemisTry application. This includes identifying the specific actions or operations that users need to carry out to achieve their objectives while using the application. In this application, the tasks are based on an interview with an SME, a questionnaire from the target user, and an application review. Several activities pertaining to user interactions is found and integrated into the developed application during the concept design stage.

3.4 Iterative Design Phase

The fourth phase of the TRES-D methodology is the iterative design. There are two main subphases for this phase, which are abstract design and presentation design. User feedback was gathered after completing the abstract design and presentation design for future improvements. A detailed explanation of abstract design and presentation design is explained in sections 3.4.1 and 3.4.2.

3.4.1 Abstract Design

In this phase, plans of the virtual environment were created, showing where things are located and how to get around as illustrated in Fig 4. In addition, the objects' behaviors and their responses to user input were identified as tabulated in Table 6 and Fig 5 shows the menu button of Oculus Meta Quest 2. Each task will have its individual operations which are functions that can be applied to specific objects.

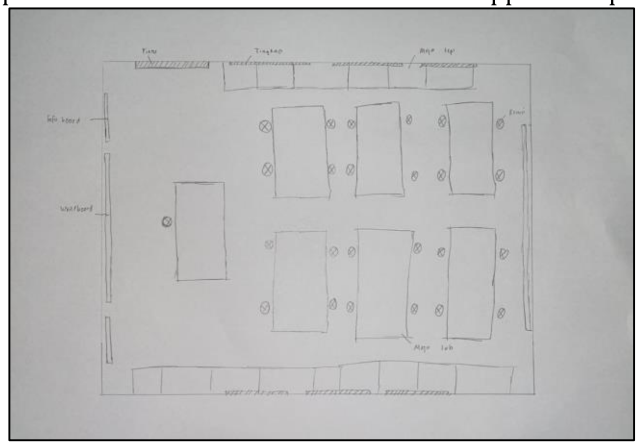


Fig 4 *Chemistry lab room plan*

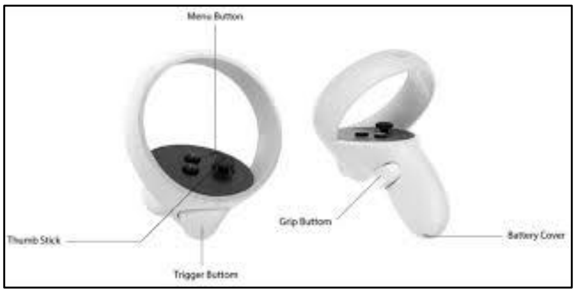


Fig 5 *Controller button of Oculus Meta Quest 2*

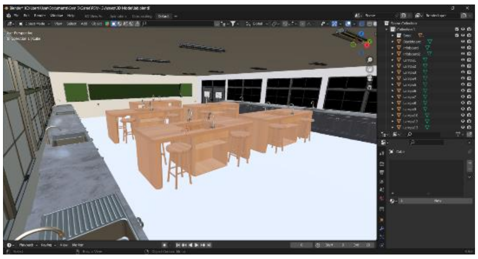
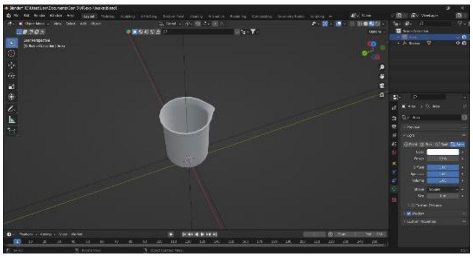
Table 6 *Controller button*

Button	Description
Right Controller	
Trigger button	Use to make a selection on the UI interface Use to point at any object in order to grab the object
Grip button	Use to grab and move objects
Joystick	Use to move around the VR environment
Left Controller	
Trigger button	Use to make a selection on the UI interface Use to point at any object in order to grab the object
Grip button	Use to grab and move objects
Joystick	Use to make head and camera gaze rotation

3.4.2 Presentation Design

In this phase, the visual and interactive aspects of the application were analyzed. The low-level dialogue was initialized by choosing the interaction styles for every operational group. Each operation's necessary information is then converted into one or more fundamental interaction tasks. These tasks were linked to specific interaction techniques, and the behavior of the techniques is then defined in terms of actions performed by the input device. Appendix G presents the interface design of the ChemisTry application. Table 7 shows the 3D model during the modeling object development process.

Table 7 *3D Modeling of Asset Development*

Model	Development	Description
Chemistry Lab		The 3D models of the Chemistry lab room are modelled and textures in Blender software. Each of the models is imported to unity to be integrated with VR function.
Lab Table		The 3D models of the Chemistry lab room are modelled and textures in Blender software. Each of the models is imported to unity to be integrated with VR function.
Experiment Apparatus (Beaker)		The 3D models of the Chemistry lab room are modelled and textures in Blender software. Each of the models is imported to unity to be integrated with VR function.

3.6 Building and Implementation Phase

In this phase, the first thing to do is select the suitable development tools for the development of the VR application. After the development software is decided, the 3D models designed through Blender software will be integrated into the Unity software to ensure proper scaling and alignment. In this phase, the main functions of the application are also developed. The application has two modules, the Lab Experiment and Activity modules. User interactions are implemented using VR controllers and other input methods. In this part, the navigation of how users select objects and interact with the VR environment is determined through programming and scripting. The C# script is used to do the programming for the user interaction implementation. Thorough testing and debugging are carried out to find and fix any problems, and testing input is used to inform incremental improvements to the user interface and overall experience. Before testing, an APK file must be built. First, ensure the necessary SDKs and plugins are installed, then enable Virtual Reality Support in the Player settings, and build the project for Android using the Build Settings window.

The testing phase is the last phase that involves functional testing, user acceptance testing, performance testing, and bug fixing. In functional testing, the buttons and features of the completed application are tested. Two types of user testing will be conducted, which are the Technology Acceptance Model (TAM) and the System Usability Scale (SUS). If bugs and improvements are discovered during the testing, bug fixing will be conducted to resolve the problem. Once the bugs are resolved and the application is performing well, it will be tested on the target user for user acceptance testing. Table 8 shows the button design The ChemisTry application was developed using Unity 3D as the main platform and Visual Studio Code as the code editor, with scripts and code written fully in C# language. Best practices and coding conventions were followed throughout the development process to ensure maintainable and clean code. Table 8 shows the button design while Table 9 shows the snippet of the C# script for three functions.

Table 8 *Button design*

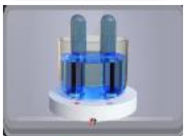
Button	Description
	• Start button navigates the user to the main menu.
	• Labelled button for Practical Module will bring the user to the Practical Module
	• Labelled button for Activity Module will bring the user to the Activity Module
	• The application should be able to operate on Meta Quest devices with an Android-based platform.
	• Experiment 1 button will bring the user to the Experiment 1 page
	• Experiment 2 button will bring the user to the Experiment 2 page
	• Experiment 3 button will bring the user to the Experiment 3 page
	• Home button navigates the user back to the main menu
	• Close button allows the user to close the information pop-up
	• Next button navigates the user to the next page
	• Previous button navigates the user to the previous page

Table 9 *C# Snippet Script using Visual Studio Code*

Functions	C# Script	Description

XR Grab Interactable	public partial class XRGrabInteractable : XRBaseInteractable
	{
	const float k_DefaultTighteningAmount = 0.5f;
	const float k_DefaultSmoothingAmount = 5f;
	const float k_VelocityDamping = 1f;
	const float k_VelocityScale = 1f;
	const float k_AngularVelocityDamping = 1f;
	const float k_AngularVelocityScale = 1f;
	const int k_ThrowSmoothingFrameCount = 20;
	const float k_DefaultAttachEaseInTime = 0.15f;
	const float k_DefaultThrowSmoothingDuration = 0.25f;
	const float k_DefaultThrowVelocityScale = 1.5f;
	const float k_DefaultThrowAngularVelocityScale = 1f;
	const float k DeltaTimeThreshold = 0.001f:
		The code snippet for XR Grab Interactable enables users to grab, pick up, hold, move, and interact with objects within the virtual environment using the VR controllers.

Answer Prompt	public void ans(bool answer)
	{
	if (answer)
	{
	rightanswer.SetActive(false);
	rightanswer.SetActive(true);
	}
	else
	{
	wronganswer.SetActive(false);
	wronganswer.SetActive(true);
	tryAgainButton.gameObject.SetActive(true);
	}
	}
		The code snippet for the answer prompt whenever the users input a correct or incorrect answer. The answer prompt script is designed to provide immediate feedback to users based on their interactions and inputs within the virtual environment

Change Single Panel	public class ChangeSinglePanel : MonoBehaviour
	{
	public GameObject panelmenu;
	public GameObject panelinstruction;
	void Start()
	{
	panelmenu.SetActive(false);
	panelinstruction.SetActive(true);
	}
		The code snippet for Change Single Panel, changing a single panel script to another panel or closing the panel whenever the user clicks on the next button or close button.

3.7 Deployment and Maintenance Phase

The final phase focuses more on the deployment and maintenance of the ChemisTry application. The application is packaged and deployed to the target platform, such as virtual reality headsets (Oculus Meta Quest), for users to access and use the application. Processes for ongoing maintenance and support are set up to address any problems, and ensure the smooth operation of the application.

4. Result and Discussion

This section discusses the testing and evaluation of the application. Application functionality testing and user acceptance testing have been conducted to ensure the application functions well and achieves the user experience. In functional testing, the buttons and features of the completed application were tested. If bugs and improvements are discovered during the testing, bug fixing will be conducted to resolve the problem. Once the bugs are resolved and the application is performing well, it will be tested on the target user for user acceptance testing. Table 10 and Table 11 show the functional testing results for both the buttons and the interaction involved inside the application.

Table 10 *Functional testing results for button*

Buttons	Expected Result	Actual Result
Start button	Navigate to the Main Menu	Works well as expected
Lab button	Navigate to the Practical Module	Works well as expected
Escape button	Navigate to the Activity Module	Works well as expected
Setting button	Navigate to the Setting	Works well as expected
Experiment 1 button	Navigate to the Experiment 1	Works well as expected

Table 10: (cont)

Buttons	Expected Result	Actual Result
Experiment 2 button	Navigate to the Experiment 2	Works well as expected
Experiment 3 button	Navigate to the Experiment 3	Works well as expected
Home button	Navigate user back to the Main Menu	Works well as expected
Close button	Close the panel instruction	Works well as expected
Next button	Navigates the user to the next page	Works well as expected
Previous button	Navigates the user to the previous page	Works well as expected
Reset button	Reset the question	Works well as expected

Table 11 *Functional testing results for interaction*

Interactions	Expected Result	Actual Result
Experiment session	Stable experiment session	Works well as expected
Escape room session	Stable escape room session	Works well as expected
Object grabbable	Able to grab the object	Works well as expected
Move the object	Able to move the object	Works well as expected
Rotate the object	Able to rotate the object	Works well as expected
Instructional prompt	Can display the panel instruction	Works well as expected
Correct answer	Show the input answer is correct	Works well as expected
Incorrect answer	Show the input answer is incorrect	Works well as expected

Meanwhile, user acceptance testing was conducted on 30 students of SMK Seri Gading, Batu Pahat, Johor. Two types of user testing were performed, which are the Technology Acceptance Model (TAM) [18] and the System Usability Scale (SUS) [19]. The questions for TAM are listed in Table 12. Fig 6 to Fig 9 show the analysis of perceived of usefulness (PU), perceived ease of use (EU), user satisfaction (US), and attribute of usability (AU), respectively. A Likert scale from 1 to 5 represents "Strongly Disagree" and Strongly Agree" are utilized.

Table 12 *Technology Acceptance Model (TAM)*

Construct	Evaluation variables	Measured items
Perceived of Usefulness (PU)	Information	PU1: I found that most of the 3D models of the lab apparatus are similar with the real one. PU2: I found that the content of the application is similar with Chemistry form 5 textbook. PU3: I found that this application is useful in helping me practice my lab practical experiment.
Perceived Ease of Use (EU)	Usability	EU1: I found it easy to navigate through inside virtual environment. EU2: I found that all the buttons inside the application are simple and easy to understand. EU3: I found it easy to learn how to use this application.
User Satisfaction (US)	Overall performance	US1: I feel very confident in using this application to practice Chemistry lab practical. US2: I found that the buttons are compatible with its function. US3: I completely satisfied in using the VR application on practicing my Chemistry lab practical.
Attribute of Usability (AU)	Functionality	AU1: The VR session is very stable. AU2: The functions in this application are well integrated. AU3: I think that I would like to use this application always.

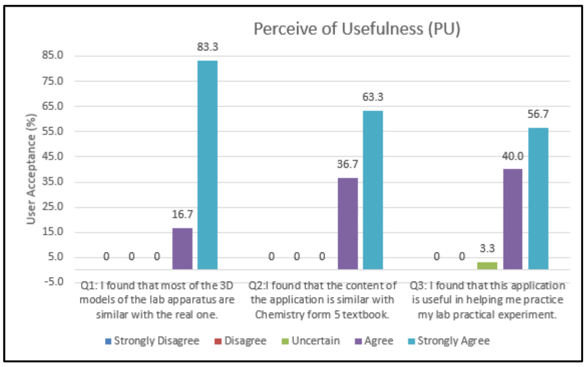


Fig 6 *Analysis of Perceived of Usefulness (PU)*

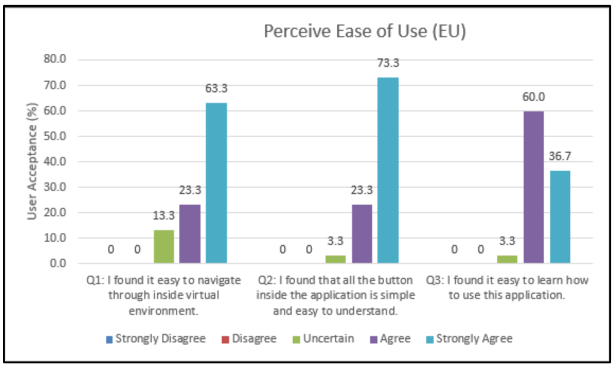


Fig 7 *Analysis of Perceived Ease of Use (EU)*

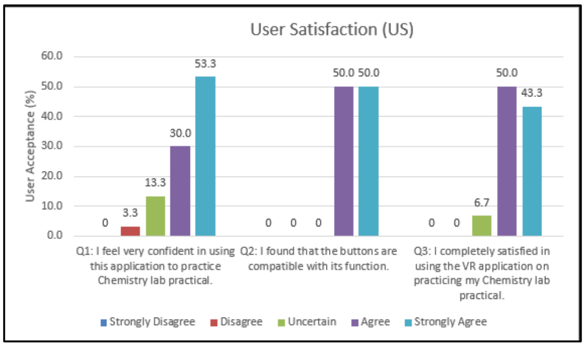


Fig 8 *Analysis of User Satisfaction (US)*

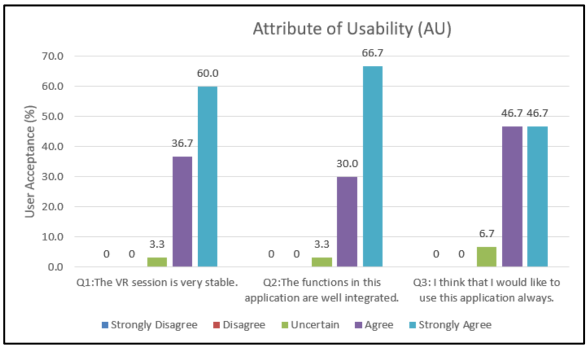


Fig 9 *Analysis of Attribute of Usability (AU)*

The respondent average scores for the user acceptance test are presented in Table 13. The formula used to obtain the usability test results is based on the SUS formula.

SUS formula:

Total score = (odd items score + even items score) x 2.5

$$\text{Average score} = \frac{\text{Total score}}{\text{Total respondent}}$$

Where:

Odd items (Q1, Q3, Q5, Q7, Q9) = contribution -5

Even items (Q2, Q4, Q6, Q8, Q10) = 25 – contribution

Therefore,

Average score =

$$\frac{90+75+82.5+87.5+97.5+97.5+92.5+92.5+82.5+100+100+52.5+85+100+90+85+82.5+90+90+87.5+92.5+90+87.5+90+87.5+87.5+100+90+87.5+92.5}{30}$$

= 88.8

Table 13 *System Usability Scale (SUS) Score*

Respondent	Score Item										Odd Items Score	Even Items Score	Total Score
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
R01	5	1	5	2	4	1	5	2	4	1	18	18	90
R02	4	2	4	2	4	2	4	2	4	2	15	15	75
R03	4	2	4	2	4	1	5	2	4	1	16	17	82.5
R04	4	1	5	2	4	2	5	1	5	2	18	17	87.5
R05	5	1	5	2	5	1	5	1	5	1	20	19	97.5
R06	5	2	5	1	5	1	5	1	5	1	20	19	97.5
R07	5	1	5	1	4	1	5	2	5	2	19	18	92.5
R08	5	1	4	2	5	1	5	2	5	1	19	18	92.5
R09	4	2	5	2	4	2	5	1	4	2	17	16	82.5
R10	5	1	5	1	5	1	5	1	5	1	20	20	100

Table 13: (cont)

Respondent	Score Item										Odd Items Score	Even Items Score	Total Score
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
R11	5	1	5	1	5	1	5	1	5	1	20	20	100
R12	3	2	4	1	5	3	1	5	2	3	10	11	52.5
R13	5	1	5	2	4	2	4	1	5	3	18	16	85
R14	5	1	5	1	5	1	5	1	5	1	20	20	100
R15	4	2	5	1	5	2	5	2	5	1	19	17	90
R16	5	1	5	2	5	2	3	1	4	2	17	17	85
R17	4	1	5	1	4	2	5	2	3	2	16	17	82.5
R18	4	1	5	1	5	2	4	1	5	2	18	18	90
R19	5	1	4	1	5	2	5	2	4	1	18	18	90
R20	5	2	4	1	5	2	4	1	5	2	18	17	87.5
R21	4	1	5	2	5	1	4	1	5	1	18	19	92.5
R22	5	1	5	2	5	1	4	1	4	2	18	18	90
R23	5	2	5	1	5	2	4	1	4	2	18	17	87.5
R24	5	2	4	1	4	2	5	1	5	1	18	18	90
R25	5	1	4	2	5	1	4	2	4	1	17	18	87.5
R26	5	1	4	2	4	1	5	1	4	2	17	18	87.5
R27	5	1	5	1	5	1	5	1	5	1	20	20	100
R28	5	1	4	2	5	1	4	1	4	1	17	19	90
R29	5	2	4	2	5	1	4	1	5	2	18	17	87.5
R30	5	1	4	2	5	1	5	1	4	1	18	19	92.5
												Average Score	**88.8**

The questionnaire of the SUS method consists of ten statements related to the usability of the developed application. The SUS score is determined by subtracting the score value from 25 for even-numbered items and 5 from the responses for odd-numbered statements. Subsequently, the total scores for every statement are multiplied by 2.5 and interpreted on a scale of 0 to 100.

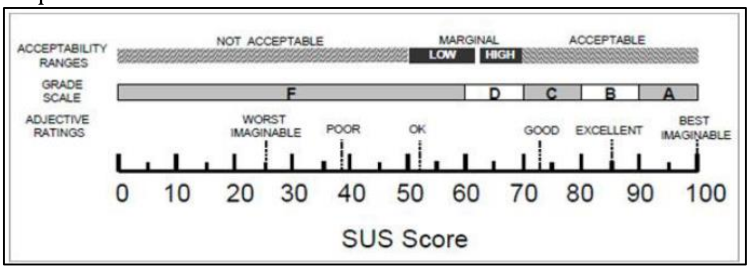


Fig 10 *System Usability Scale (SUS)* [19]

The average usability value score, as indicated by the SUS score scale, is 88.8, which falls within the "Excellent" category, as shown in Fig 10. This suggests that most users thought the application was satisfactory in terms of overall usability and functionality. It suggests that the application has done well regarding usability, design, and functioning.

5. Conclusion

To conclude, the ChemisTry application was successfully developed with two main modules, namely the Practical Module and the Activity Module. User acceptance has been conducted using two different methods, which are the Technology Acceptance Model (TAM) and the System Usability Scale (SUS). Besides, the feedback from the testing concludes that the ChemisTry application is easy to use and navigate through the virtual environment.

All three objectives set from the beginning of the project have been accomplished. The three objectives of this project were fully accomplished by developing the ChemisTry application using the TRES-D methodology. There are a few advantages that can be concluded from the application. First, the application used the same content from the Chemistry Form 5 textbook and followed the KSSM syllabus. Second, the application enables students to practice their lab practical outside their Teaching and Learning (PdP) session with their teacher. Besides that, the ChemisTry application offers a fully immersive VR experience where students can familiarize themselves with the real lab practical exam. Despite that, there are still limitations to the ChemisTry application, which is it only runs on Oculus Meta Quest devices and is not supported for all types of devices.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Halimah Nur Andi Azis, Noorhaniza Wahid;* ***data collection:*** *Halimah Nur Andi Azis, Noorhaniza Wahid;* ***analysis and interpretation of results:*** *Halimah Nur Andi Azis, Noorhaniza Wahid;* ***draft manuscript preparation:*** *Halimah Nur Andi Azis, Noorhaniza Wahid. All authors reviewed the results and approved the final version of the manuscript.*

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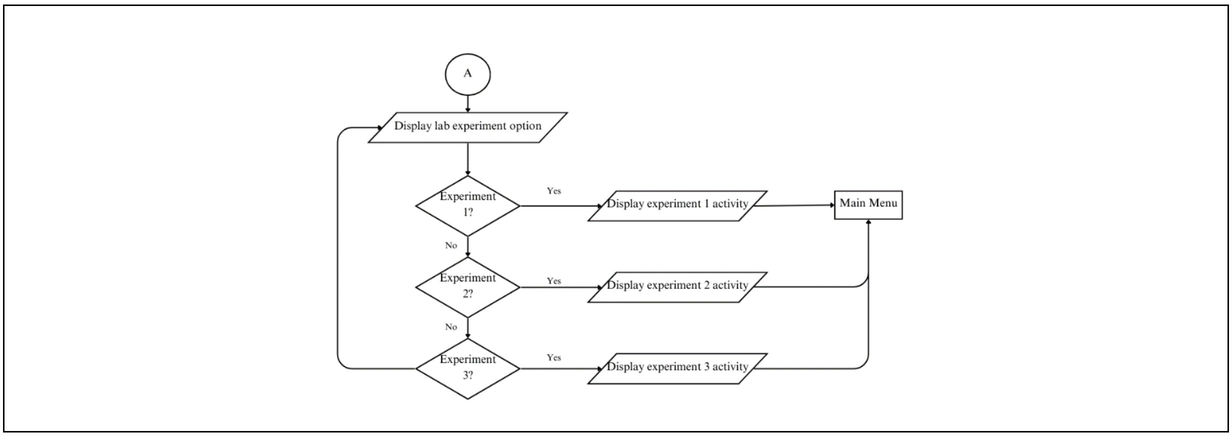
Appendix A: Summary of The Output of The Six Phases of the TRES-D Methodology

Table 7 *Application Development Workflow*

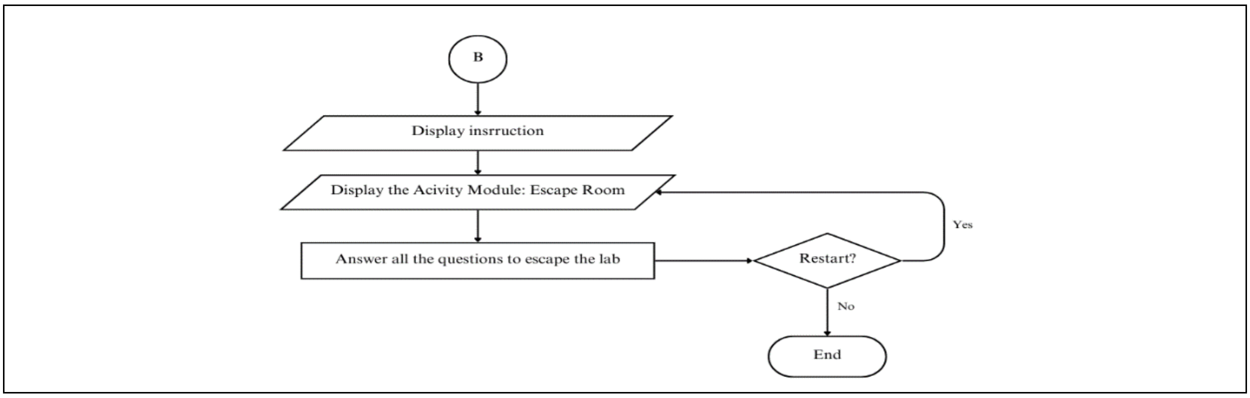
Phases	Activities	Outputs
Initial Requirement	• Define project scope and target platform • Identify the target user • Gather initial ideas by interviews with SME and questionnaire with target user	• The project title, problem statement, objectives, target platform and target user • Initial requirement checklist • User analysis
Understand Requirement	• Conduct user research • Define functional requirements • Identify hardware compatibility	• Obtain functional and non-functional requirements • Hardware and software requirements • Project scope
Concept Design	• Sketching design ideas • Storyboarding • Wireframing	• Storyboard • Wireframe • Rough project design (Button design)
Iterative Design	• Abstract design • Presentation design • Gather user feedback • Refinement	• 3D model • Chemistry lab room plan • Content • User feedback on the 3D model
Building and Implementation	• Select development tools • Asset integration • Interaction implementation • Optimization • Functional testing • User acceptance testing • Performance testing • Bug fixing	• Unity software for development • Integrate 3D model into Unity software • Implement interaction between user and 3D model using scripting and programming language • Identify and solve the problem found in the application • User acceptance of the functionality, usability, and

		performance of the application
Deployment and Maintenance	• Deploy to the target platform • Maintenance	• Application able to run in target platform • Problems fixing, bug fixing

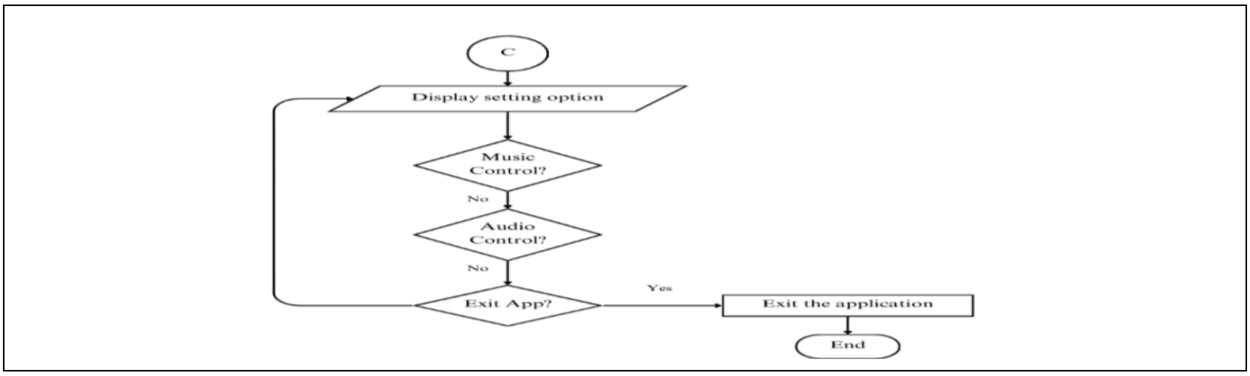
Appendix B: Flowchart of Practical Module



Appendix C: Flowchart of Activity Module



Appendix D: Flowchart of Setting Module



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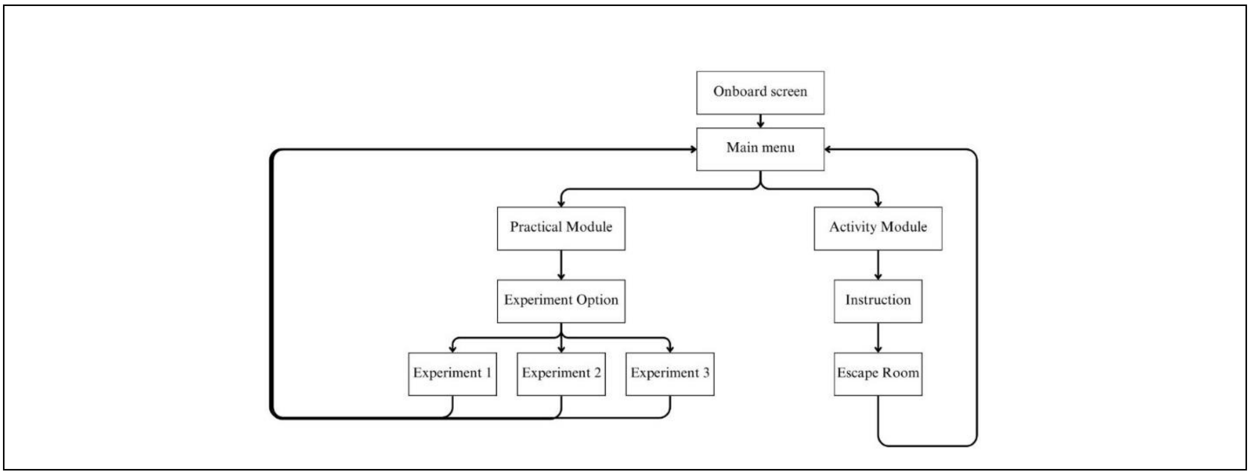
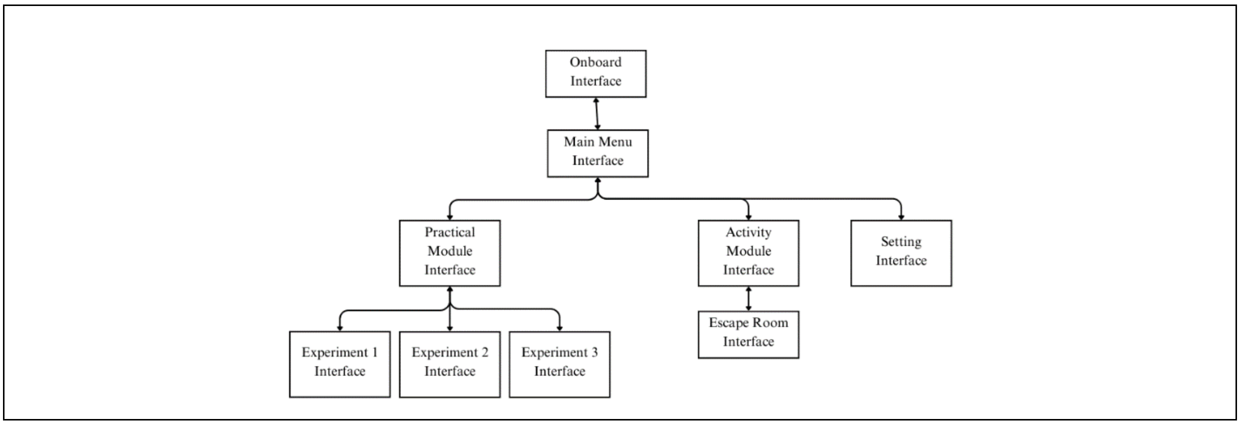
Appendix E: Application Module Diagram



Appendix F: Navigation Structure



Appendix G: Interface Design

Fig 4 *Onboard Interface*

Fig 4 *Main Menu Interface*

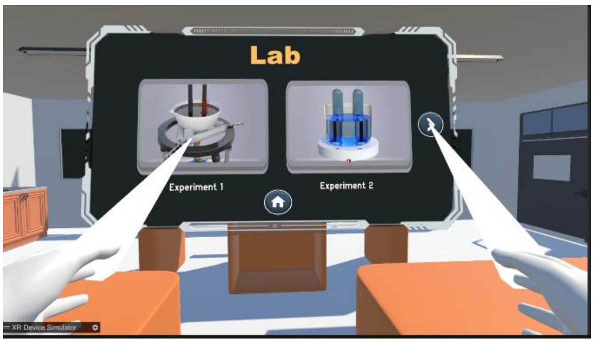
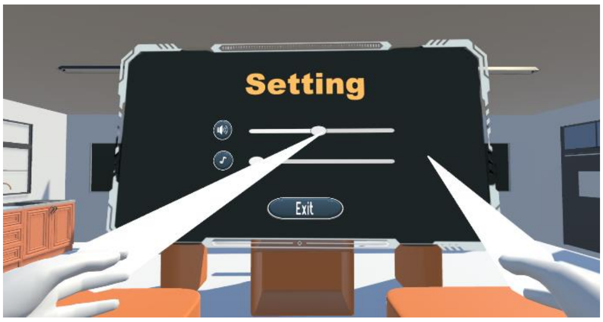
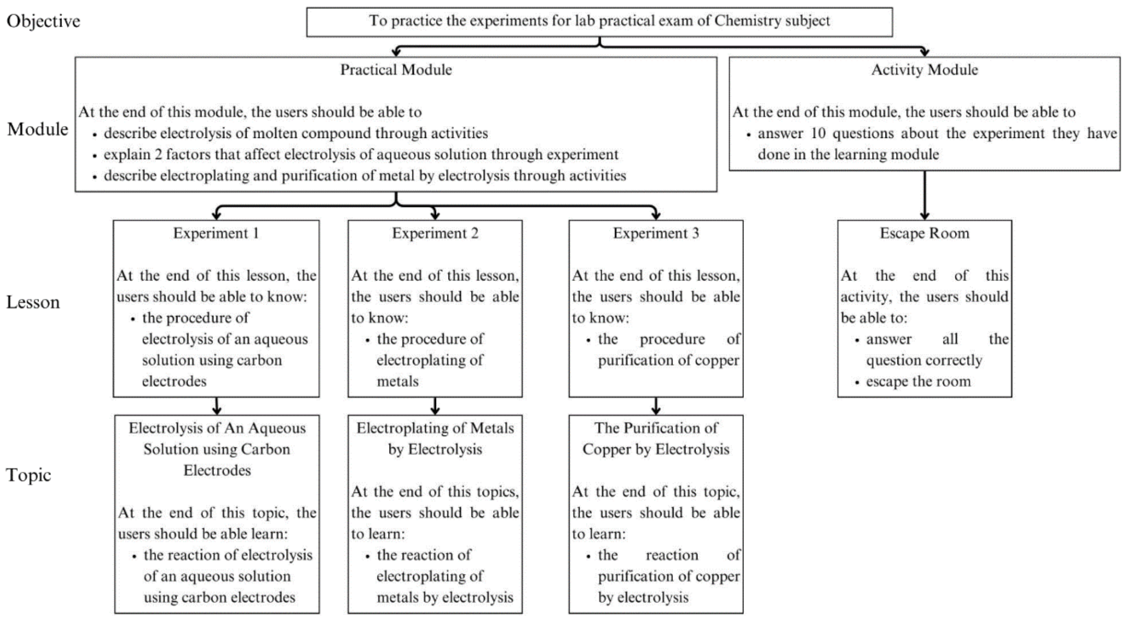


Fig 4 *Practical Module Interface*	**Fig 4** *Activity Module Interface*
 **Fig 4** *Experiment Interface*	 **Fig 4** *Setting Interface*

Appendix H: Content Structure



Appendix I: Testing Session