Citra Journal of Computer Science and Technology

Journal homepage:
https://citralestari.my/index.php/cjcst/index
ISSN: 3093-7108

Development of a Virtual Reality (VR) Periodic Inspections of Domestic Air Conditioners

Muhammad Nooradli Mohd Yazed[1,*], Usuloudin Hamzah[1] , Affero Ismail[1] ,Tee Tze Kiong[1] , Rizky Ema Wulansari[2]

[1] Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[2] Faculty of Engineering, Universitas Negeri Padang, Jalan Prof. Dr. Hamka, Air Tawar Padang, Kota Padang, Sumatera Barat, Indonesia

ARTICLE INFO

Article history:
Received 26 February 2025
Received in revised form 14 March 2025
Accepted 17 May 2025
Available online 16 June 2025

Keywords:
VR; RAC Periodic Inspections; domestic air conditioners; learning aid

ABSTRACT

The development of Virtual Reality (VR) technology has become increasingly relevant in education, particularly in Technical and Vocational Education and Training (TVET). However, the use of VR as a teaching aid (ABM) for periodic inspections of domestic air conditioners remains limited. Conventional learning methods rely on theoretical instruction and physical equipment, which can be costly and pose safety risks. To address this issue, this study aims to develop a VR-based application titled Periodic Inspection of Domestic Air Conditioning to enhance student learning in the Refrigeration and Air Conditioning program at the Faculty of Technical and Vocational Education (FPTV), Universiti Tun Hussein Onn Malaysia (UTHM). The research follows the Hybrid ADDIE Model, comprising five phases: analysis, design, development, implementation, and evaluation. The VR application provides an interactive 360° virtual environment with three-dimensional (3D) objects, allowing students to explore, analyze, and practice periodic inspection procedures in a simulated setting. The Constructivist Learning Theory is integrated to facilitate active learning and engagement. Evaluation was conducted through expert reviews involving four interface specialists and three content specialists. The results indicate that the VR application is effective in terms of content accuracy, interface design, and user interaction. Experts highlighted the application's potential for improving students' understanding of periodic inspection procedures while minimizing risks associated with real-world training. In conclusion, this study contributes to the advancement of VR-based learning tools in technical education, offering an innovative and cost-effective solution for practical training in air conditioning maintenance. The findings suggest that integrating VR technology in education can enhance learning experiences, increase safety, and reduce training costs.

* *Corresponding author.*
E-mail address: adlyrander@gmail.com

https://doi.org/10.37934/cjcst.1.1.6479

1. Introduction

The integration of Virtual Reality (VR) technology in education has garnered significant global attention due to its potential to enhance learning experiences through immersive and interactive environments. VR technology provides learners with a simulated and engaging learning experience, making it a valuable tool across various educational domains, including technical and vocational training [12]. While the adoption of VR in education is widely recognized, particularly in Western countries, its implementation in regions such as China has been relatively slower due to technological infrastructure limitations and pedagogical adaptation challenges [14]. Despite these obstacles, VR continues to evolve, demonstrating a positive impact on knowledge acquisition and skill development, particularly in fields that require practical, hands-on learning [10].

In the Refrigeration and Air Conditioning (RAC) industry, periodic inspections of domestic air conditioners are essential for maintaining efficiency, safety, and longevity. However, traditional training methods for air conditioning maintenance rely heavily on physical demonstrations and hands-on practice, which can be costly, resource-intensive, and pose safety risks. The integration of VR-based learning applications offers a cost-effective and safer alternative, allowing students to simulate periodic inspections in a controlled virtual environment. This approach reduces dependency on physical equipment while ensuring experiential learning [5].

In addition to its technological advantages, VR-based learning also aligns with modern pedagogical frameworks, including the emphasis on holistic graduate development in Technical and Vocational Education and Training (TVET) programs. According to Mohamad *et al*., [11], emotional intelligence and entrepreneurial competencies play a crucial role in TVET education, enhancing students' ability to adapt to industry demands. A well-designed VR training module can integrate problem-solving scenarios, self-paced learning, and collaborative exercises, fostering both technical and soft skills necessary for future entrepreneurial and professional success.

Furthermore, the effectiveness of vocational training depends not only on innovative teaching aids but also on educators' competencies and instructional methods. Ismail *et al*., [8] highlighted that TVET teacher training programs must incorporate national core standards, ensuring that instructors are equipped with relevant knowledge and methodologies. The adoption of VR in RAC training supports this initiative by standardizing training procedures, reducing inconsistencies in skills development, and providing an accessible and scalable solution for TVET educators.

This study focuses on the development of a VR application for periodic inspections of domestic air conditioners, designed to provide students with an interactive 360° virtual experience. Through this application, students can explore, analyze, and practice air conditioning maintenance procedures in a realistic and risk-free environment. By integrating Constructivist Learning Theory, the VR application fosters active learning, enhancing students' technical skills, critical thinking, and decision making abilities in air conditioning inspections. This approach aligns with modern educational trends that emphasize technology-driven, skill-based learning in TVET programs [4].

Despite the potential benefits of VR in vocational education, its application in RAC training, particularly for periodic inspections of domestic air conditioners, remains underexplored. Existing studies have focused on VR in other sectors, but the application of VR specifically for HVAC systems, especially for maintenance and periodic inspections, has been limited. The research gap lies in the need for a VR solution that not only provides a hands-on learning experience but also addresses the unique challenges faced by RAC training, such as high costs, safety risks, and the need for scalable solutions. This study aims to bridge this gap by developing a VR-based application designed for periodic inspections of domestic air conditioners, ultimately enhancing the quality, accessibility, and effectiveness of RAC education.

1.1 Research Background

The adoption of VR technology as a teaching aid (ABM) in education is gaining increasing attention in Malaysia, particularly in TVET programs. However, its implementation remains limited and is still in the early stages of integration into the educational curriculum. Traditional teaching methods in vocational education, especially in RAC training, often rely on physical equipment and classroom based theoretical instruction, which may not fully engage students in practical learning experiences [12]. One of the key challenges in adopting VR-based learning in RAC training is the lack of interactivity in existing digital learning tools. Many institutions still rely on static presentations, such as PowerPoint slides, videos, or text-based materials, which fail to provide an immersive and interactive learning experience [3]. VR technology offers an alternative by creating realistic simulations where students can engage with 3D interactive environments, enhancing their understanding of periodic inspections of domestic air conditioners [10].

Another major issue in RAC training is the high cost of equipment and maintenance. Traditional vocational training requires physical air conditioning systems for hands-on practice, which leads to significant financial investments in equipment, spare parts, and operational maintenance Furthermore, working with real air conditioning units involves safety risks, including potential exposure to refrigerants, electrical hazards, and mechanical failures [5]. VR-based training solutions provide an opportunity to reduce costs by enabling students to practice periodic inspections in a virtual setting, eliminating equipment wear and tear while ensuring a safe and controlled learning environment [7].

Additionally, VR simulations facilitate the teaching of dynamic concepts, such as airflow measurement, refrigerant pressure testing, and temperature analysis, which are crucial for periodic inspections of domestic air conditioners. By utilizing animation and visualization techniques, instructors can enhance students' comprehension of complex HVAC (Heating, Ventilation, and Air Conditioning) systems, leading to improved skill acquisition and retention [9]. As technological advancements continue to shape modern education, the integration of VR-based learning applications in RAC training offers an innovative pedagogical approach to improving student engagement, knowledge retention, and hands-on skills. This study explores the development of a VR application for periodic inspections of domestic air conditioners, aiming to enhance learning efficiency, safety, and technical competencies among students at FPTV, UTHM.

1.2 Problem Statement

Based on the background provided, one of the main challenges in education related to the periodic inspections of domestic air conditioners is the limited use of VR technology as a teaching aid. Current teaching methods primarily rely on traditional multimedia presentations, videos, and theoretical instruction, which lack the interactivity and immersion needed for effective skill acquisition. These methods fail to fully engage students in hands-on learning, which is critical for developing practical skills in the RAC field. Additionally, the high cost of physical air conditioning equipment required for hands-on training places a financial burden on educational institutions and students. Furthermore, safety risks related to handling refrigerants, electrical components, and mechanical systems pose significant challenges, further restricting students' opportunities for practical exposure.

The lack of innovation in integrating VR technology into RAC training, along with limited institutional investment in digital learning solutions, has hindered its adoption in educational settings. As a result, there is a clear need for the development and implementation of a VR-based

learning application. Such an application would enable students to safely and interactively engage in the periodic inspections of air conditioners, addressing both the cost and safety concerns while enhancing learning outcomes. VR offers an immersive environment where students can interact with air conditioning components without the inherent risks of working with real-world equipment, all while reducing the need for costly physical tools.

Moreover, technological advancements have opened many opportunities for new learning methods, transforming teaching techniques and making education more engaging and interactive [1]. However, the lack of detailed studies comparing the costs and benefits of VRbased training versus traditional methods has limited widespread adoption. A cost-benefit analysis comparing VR training with traditional hands-on training would provide valuable insights into its practicality and efficiency. This analysis could demonstrate how VR training not only reduces financial burdens on institutions by minimizing the need for expensive physical equipment but also enhances learning effectiveness through immersive and interactive content. This would strengthen the case for adopting VR in educational settings, specifically in technical and vocational training programs like RAC.

1.3 Objectives

Three (3) main objectives of the study have been identified by the developer, and they are as follows: i. Virtual reality (VR) design of periodic inspection of domestic air conditioning. ii. Develop virtual reality (VR) periodic inspections of domestic air conditioners. iii. Testing the functionality of the virtual reality (VR) development of periodic inspections of domestic air conditioning. 2. Methodology To develop a VR application for periodic inspections of domestic air conditioners, the developer has adopted a Hybrid ADDIE methodology. This approach combines the traditional Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model with agile principles to enhance flexibility and adaptability in instructional design. By integrating agile elements, the Hybrid ADDIE model addresses the dynamic needs of modern learning environments, ensuring a more iterative and collaborative development process. This methodology is particularly effective in creating immersive VR learning experiences, as it allows for continuous feedback and refinement throughout the development stages. The adoption of this hybrid approach aims to optimize the educational impact of the VR application, providing learners with an engaging and effective tool for mastering air conditioner maintenance procedures. Figure 1 shows the Hybrid ADDIE Model Phases used in the development of the VR application.

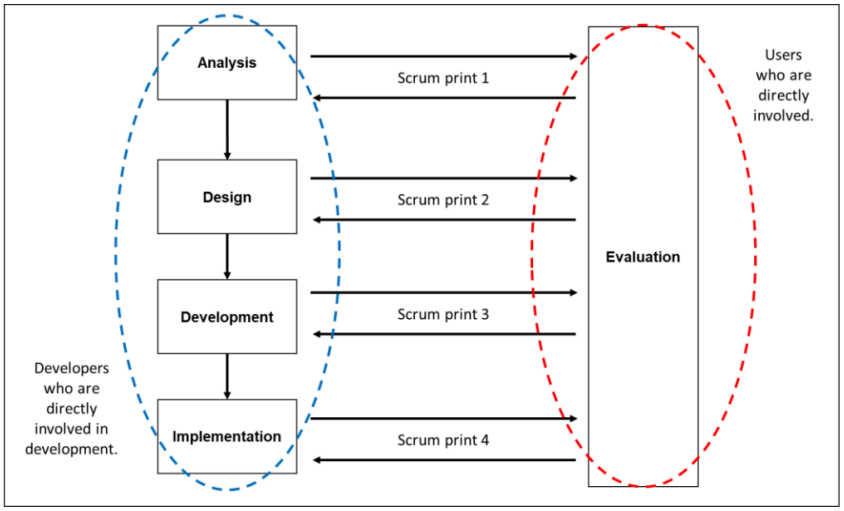


Fig. 1. Phases of the Hybrid ADDIE Model [13]

2.1 Analysis Phase

The requirements analysis phase is used to identify multimedia software construction requirements. This analysis stage is the most critical stage because this stage determines the overall capability of the software being built. User analysis, learning environment analysis as well as content and goals need to be determined first before the design and planning phase is implemented. Through this phase, it involves many aspects including user analysis, objective analysis and environment and learning analysis.

2.2 Design Phase

After analyzing the requirements, the developer moves to the design phase. Here, they focus on creating a user-friendly and visually appealing interface. They carefully planned the layout and navigation of the page in the VR application periodic inspection of the domestic air conditioner. Appropriate storyboards and navigation buttons were used to provide an overview of the developed page. The element that will be emphasized is the use of multimedia elements such as text, graphics, audio, video, and animation, additional elements such as VR elements and 3D model elements that are capable of solving students' problems. Throughout this phase, the usability aspect of the application is also given importance to ensure a user experience that is smooth and safe.

2.2.1 Content design

Content design is essential in developing VR applications. It includes learning materials and the selection of learning theories. This application uses constructivist learning theory. It also incorporates basic techniques from periodic inspections of domestic air conditioners. Users understand the concept of periodic inspection of domestic air conditioning in the VR application based on the book 'Training Manual for Refrigeration and Air Conditioning Service Technicians' which serves as a basic guide. Through this content design phase, it contains a section of the main VR page where the user interacts directly in the virtual environment. Interaction design Interaction design is a product journey that puts complete control over the user. Furthermore, the interaction design will determine where and how control power will be given to the user. On the main menu display, users can make choices and select the desired content and can be reached according to the user's wishes. Developers

use a hierarchical structure because it can be implemented by using different pages to organize information or functions in a hierarchical order. Pages such as Introduction, User Manual and VR Pages are placed in different hierarchical orders according to their level of information or importance. Users can access these pages in stages, where each page may have sub menus or more specific additional information. The developer sets the navigation like function, order, size of the buttons used in this developed VR application. The purpose is to make it easier for users to reach each page independently while using this VR application.

2.2.3 Interface design and multimedia presentation elements

Interface design is the phase in which developers create VR applications. User-friendly interface design, intuitive and suitable for VR environments. Researchers need to choose the right type of UI elements for interaction in a VR environment such as virtual buttons, navigation menus, clear instructions and easily accessible information. this VR application development realm, the use of high-quality 3D visualization with a 360^{o} viewing angle to display the components of the air conditioning system in detail in a virtual environment or room. In addition, the integration of relevant audio elements such as voice prompts or additional information sent by voice to enhance the user experience. It is important to make the design attractive so that the user remains interested and motivated to use the VR application.

2.3 Development Phase

In this development phase, the next process is to start the application development process by determining the process, hardware and software that will be used in the development of multimedia elements, 3D modeling sketches, graphic illustrations, programming code drafting, and VR application development. The software involved is Unity, Blender, Adobe Illustrator, and PICO Developer Center. Next, the developer begins the development phase of the initial draft of the interface that has been designed and agreed upon. The process starts with 3D object modeling design, graphic background design with 360^{o} viewpoint, navigation and others. Therefore, in this phase, the prototype of this VR application is built. The prototype to be developed is similar to the actual product. The developer has developed a VR application related to the topic of periodic inspection of domestic air conditioners that contains multimedia elements designed and intended to be displayed on this VR application. Accordingly, this phase will integrate the elements found in the learning framework based on multimedia elements for the development of VR applications. This VR application will be developed using multimedia authoring tools.

2.4 Implementation Phase

The implementation phase in VR development encompasses the process of transforming the design into a functional VR experience that users can interact with. This phase involves software development, hardware setup, and the integration of VR content into the appropriate platform or application. Once the development phase is completed, the implementation phase focuses on ensuring that the VR experience works as intended. This includes fixing any defects or dysfunctions identified during functional testing, addressing usability issues, and optimizing the experience for different user scenarios. During the implementation, special attention is given to the integration of interactive features, ensuring that the VR application runs smoothly on the designated hardware and operating systems. This phase also includes preparing the user interface (UI), refining user

interactions, and ensuring the virtual environment is engaging and educational. If the VR application is designed for a specific hardware setup, such as VR headsets, adjustments will be made to ensure compatibility and an optimal experience for the user.

2.4.1 Addressing technical limitations

It is important to recognize that VR technology, despite its potential, comes with several technical limitations. These include hardware requirements (VR headsets and motion controllers), software compatibility issues, and user access to necessary devices. For example, VR applications often require high-performance computers or dedicated VR headsets that may not be accessible to all students or institutions. Additionally, users may face difficulties adapting to VR environments, especially if they have not used similar technology before. To resolve these limitations, institutions can explore cost-effective VR hardware options, or consider alternative VR solutions that are compatible with less powerful devices. Moreover, providing adequate training and support for users to help them acclimatize to VR technology will enhance the user experience. Another potential solution is the development of VR applications that are optimized for mobile VR platforms, which may offer a more affordable and accessible option for students and institutions with limited resources. Additionally, some users may be resistant to adopting VR technology, either due to unfamiliarity or concerns about motion sickness and discomfort. To overcome this, user-friendly interfaces, short immersion periods, and gradual onboarding tutorials can help ease users into the technology, making the learning process more approachable. By addressing these potential limitations, the implementation phase can ensure that the VR application remains accessible, functional, and effective in delivering its intended learning outcomes.

2.5 Evaluation Phase

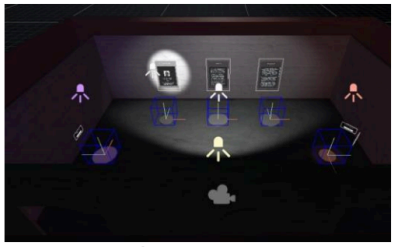
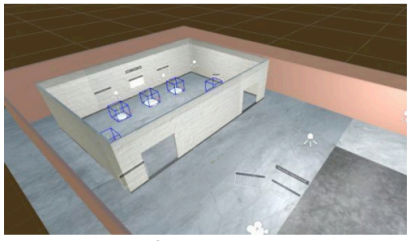
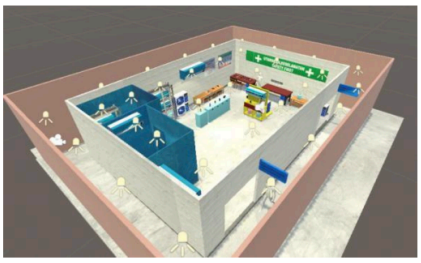
This phase occurs after each phase ends. The importance of this phase is to ensure whether the objectives are achieved or not in the phase or any changes need to be implemented. Users will be involved in the evaluation phase which involves the analysis phase and the evaluation phase after the implementation phase. The final phase of the evaluation will involve a usability testing process. The suggested Scrum Sprint classification in all phases found in the Hybrid ADDIE Model is as in Table 1.

Table 1
Scrum class in Hybrid ADDIE Model Phase

No	Phase	Scrum Print
1.	Collecting Requirements Analysis Assessment	Scrum Print 1
2.	Analysis Design Assessment	Scrum Print 2
3.	Design Development Evaluation (Functionality)	Scrum Print 3
4.	Evaluation (Usability)	Scrum Print 4

2.6 The interface for the development of a Virtual Reality (VR) Periodic Inspections of Domestic Air Conditioners is shown in Table 2.

Table 2
VR application interface

Interface	Description
 **Fig2. Main Menu Display**	• contains three main option buttons in this VR application namely introduction, user manual, VR page. • users can interact with a 360° virtual environment that is walking, touching, grasping, and choosing with the use of VR headsets and VR controllers. • the user will be in one column and force the user to walk to the select page button to select the next page.
 **Fig3. View Introduction Page**	• contains several things, such as the introduction of the VR application, the objective of the VR application, and the profile of the developer who developed this VR application. • users can interact with a 360° virtual environment that is walking, touching, grasping, selecting, and scrolling with the use of VR headsets and VR controllers. • the user will be in a room and force the user to walk towards the statement canvas to get information about this VR application.
 **Fig4. User Manual Page View**	• contains user guides to use this VR application such as walking, holding and more. • contains several things, such as a video guide to the use of the three main button parts, namely the joystick, trigger, and grab. • the user will be in a room and force the user to walk towards the video canvas to get information about the use and interaction of this VR application.
 **Fig5. Virtual Reality (VR) Page View**	• game pages or activities that will be carried out to perform periodic inspection measures of domestic air conditioning. • contains various components and equipment that have been arranged in one laboratory room. • users can interact with a 360° virtual environment that is walking, touching, grasping, selecting, and scrolling with the use of VR headsets and VR controllers.

3. Results and Discussion

Research results obtained from content design experts, as well as interface and interaction design. Four experts from the lecturers of the Creative Multimedia program, FPTV provide feedback from aspects of interface and interaction design. Additionally, three experts from the Refrigeration and Air Conditioning program lecturers, FPTV gave feedback from the content design aspect. Experts are selected based on their teaching experience and expertise in their area of specialization. Through

the testing and evaluation process carried out, developers can measure the functionality of the VR application for the periodic inspection of domestic air conditioning from the aspect of content design, as well as interface and interaction design. Table 3 and table 4 are demographics for content design specialists, as well as interface and interaction design.

Table 3
Demographics experts in content creation design

Detail	Expert 1	Expert 2	Expert 3
Gender	Male	Male	Male
Age	31-40 years	31-40 years	31-40 years
Education level	Doctor of Philosophy	Doctor of Philosophy	Doctor of Philosophy
Working period	25 years	14 years	10 years
Specialization	Heating, ventilation, and Air conditioning (HVAC)	Heating, ventilation, and Air conditioning (HVAC)	Heating, ventilation, and Air conditioning (HVAC)

Table 4
Demographics experts in User Interface (IU) and Interaction Design

Detail	Expert 1	Expert 2	Expert 3	Expert 4
Gender	Female	Female	Male	Female
Age	41-50 years	41-50 years	31-40 years	31-40 years
Education level	Doctor of Philosophy	Doctor of Philosophy	Doctor of Philosophy	Doctor of Philosophy
Working period	17 years	20 years	16 years	8 years
Specialization	Creative multimedia	Instructional design	Information and communication technology	Educational technology

3.1 Content Expert Assessment Analysis

In the Content Design Assessment form, 23 statements were developed to evaluate the functionality of the product in terms of content design. The data obtained was analyzed and presented using frequency values and percentages of acceptance, as shown in table 5. The results of the expert assessment regarding the content design aspect can be found in table 5.

Table 5
The results of expert assessment in content design

Item	Statement	Frequency		Acceptance
Split Unit Air Conditioning:		Yes	No	(%)
1.	The graphic design of the domestic air conditioner 3D model of the indoor unit is realistic	3	0	100
2.	The 3D graphic model design of the outdoor domestic air conditioning unit is realistic	3	0	100
Air Conditioning Inspection Equipment:				
3.	The 3D graphic model design of the manifold gauge set is realistic	3	0	100
4.	The 3D graphic model design of the manifold gauge set is realistic.	3	0	100
5.	The 3D graphic model design of the anemometer is realistic.	3	0	100
6.	The 3D graphic model design of the ammeter is realistic.	3	0	100
Steps for Periodic Inspection of Domestic Air Conditioning Displayed are Correct:				

7. Inspection of the condition of the domestic air conditioning unit (indoor & outdoor) is in good condition.	3	0	100
8. Inspection of the air filter of the indoor domestic air conditioning unit is clean.	3	0	100
9. Inspection of the ducts in the domestic air conditioning unit shows no leakage.	3	0	100
10. Inspection of the condition of domestic air conditioning components is in good condition	3	0	100
11. Inspection of the room temperature condition is appropriate.	3	0	100
12. Inspection of the airspeed from the air conditioning unit is appropriate.	3	0	100
13. Inspection of the electrical current in the outdoor air conditioning unit is normal using an ammeter	3	0	100
14. Inspection of low air pressure in the air conditioning unit follows the correct specifications using a manifold gauge set.	3	0	100
15. Record the inspection results.	3	0	100
Information Displayed in the VR Application:			
16. The low air pressure value displayed is correct.	3	0	100
17. The displayed room temperature value is correct	3	0	100
18. The displayed air conditioner temperature value is correct	3	0	100
19. The name of the air conditioning inspection equipment displayed is correct.	3	0	100
20. The function of the air conditioning inspection equipment displayed is correct.	3	0	100
Domestic Air Conditioning System:			
21. The position of the split unit domestic air conditioner is correct	3	0	100
22. The position of the air conditioning filter for the indoor unit is correct	3	0	100
23. The connection of the low-pressure duct from the manifold gauge set to the outdoor air conditioner unit is correct	3	0	100

The evaluation of the content design of the developed VR application was carried out based on the items that had been developed, showing that the experts agreed that the content of the VR application was arranged according to suitability and that the content had met the objectives of the study. The content provided in this VR application is equipment for periodic inspection, domestic air conditioning system and periodic inspection steps on domestic air conditioning. All experts stated that the content provided is appropriate and can be used for students in the field of RAC to understand the context of periodic inspections of domestic air conditioning with VR simulation. Nevertheless, there are also views and comments from experts for improvement in terms of additional information and component details on domestic air conditioning. Overall, the results of the research findings of the three experts agree with all the content design items of the developed VR application.

3.2 Interface Expert Assessment Analysis

In the interface design section, there are 20 statements prepared by the researcher to test the functionality of the developed VR application from the interface design aspect. Data that has been analyzed and presented using frequency values and responses. Based on the feedback received from the interface design experts, they agree that this VR application coincides with the concept and target users for the field of Refrigeration and Air Conditioning. Overall, experts agree with the VR application

of periodic inspection of domestic air conditioning from the interface design aspect. Here are the findings from the data analysis that can be seen in table 6.

Table 6
The results of the interface expert assessment analysis

Item	Statement	Frequency		Acceptance
Virtual Reality (VR) Elements:		Yes	No	(%)
1.	The user's eye view angle for the user interface (UI) display in the VR application is 360°.	4	0	100
2.	The 3D hand objects (right and left) in the VR application are positioned accurately, just like in the real world.	4	0	100
Graphic Elements:				
3.	The use of environmental graphics in the laboratory space developed in the VR application is appropriate.	4	0	100
4.	The lighting in the laboratory room is appropriate.	4	0	100
5.	The arrangement of furniture in the laboratory room is neat.	4	0	100
6.	The arrangement of equipment in the laboratory room is neat.	4	0	100
3D Model Elements:				
7.	The 3D model of the indoor domestic air conditioning unit is displayed correctly.	4	0	100
8.	The 3D model of the outdoor domestic air conditioning unit is displayed correctly	4	0	100
9.	The 3D model of the manifold gauge set is displayed correctly	4	0	100
10.	The 3D model of the thermohygrometer is displayed correctly	4	0	100
11.	The 3D model of the anemometer is displayed correctly.	4	0	100
12.	The 3D model of the ammeter is displayed correctly	4	0	100
13.	The size of the 3D model in the VR application follows real-world dimensions.	4	0	100
14.	The 3D laboratory model design in the VR application is appropriate	4	0	100
Text Elements:				
15.	The font type used is clear.	4	0	100
16.	The text size displayed is readable.	4	0	100
17.	The text color used with the background color is appropriate	4	0	100
18.	The position of pop-up text is appropriate	4	0	100
19.	The text is center-aligned on the canvas.	4	0	100
Audio Elements:				
20.	The click sound effect on the numeric keypad is clearly heard by the user.	4	0	100

Based on the results of the analysis, four experts skilled in the field of Creative Multimedia gave positive and good feedback on the interface design aspects developed in this VR application. The experts agree that the use of VR elements, graphic elements, 3D model elements, text elements, and audio elements found in this VR application is suitable for the target user and the objective of the study. Experts have appreciated the quality and excellence of the graphic elements, 3D models, and text in the application. These elements are important to convey information clearly to users. In terms of views and comments, the good feedback from these experts shows that the design of the VR application interface has been confirmed in terms of compatibility with the target user and achieves the objectives of the study that have been set. Furthermore, there are 15 statements prepared by the researcher to test the functionality of this developed VR application from the aspect of interaction design. Data that has been analyzed and presented using frequency values and feedback. Based on the feedback received from interaction design experts, they agree that this VR application coincides with the concept and target users for the field of Refrigeration and Air Conditioning. Overall, the experts agreed on the VR application of periodic inspection of domestic air conditioning

from the aspect of interaction design. The following are the findings from the data analysis can be seen in table 7.

Table 7
The results of expert assessments in interaction design

Item	Statement	Frequency		Acceptance
VR Headset:		Yes	No	(%)
1. The VR application can be opened properly by the user		4	0	100
2. The user's eyes can interact well with the VR headset to view a 360° perspective in the VR application.		4	0	100
VR Controller Controls:				
3. The top button on the right controller, when moved left or right, functions to rotate the user's eye view 360° horizontally.		4	0	100
4. The top button on the right controller, when moved forward, functions as teleportation to a predetermined location.		4	0	100
5. The top button on the left controller, when moved in all directions (forward, backward, left, & right), functions as free movement in the laboratory space in the VR application.		4	0	100
6. The side buttons on both controllers (right & left) function as gripping objects that have been arranged		4	0	100
7. The bottom buttons on both controllers (right & left) function as selection buttons.				
3D Objects:				
8. The 3D model of the thermohygrometer can be grasped and moved well.		4	0	100
9. The 3D model of the anemometer can be grasped and moved well.		4	0	100
10. The 3D model of the ammeter can be grasped and moved well.		4	0	100
11. The 3D model of the manifold gauge set can be grasped and moved well.		4	0	100
Text				
12. The text canvas appears when the hand touches a programmed component.		4	0	100
13. The text canvas disappears when the hand no longer touches the programmed component.		4	0	100
14 The inspection step text display can be scrolled properly.		4	0	100
Audio:				
15. The click sound effect on the numeric keypad is heard when touched.		4	0	100

3.3 Reviews and Feedback from the Expert

Views and comments from experts are crucial in guiding researchers to make improvements to the VR application, ensuring it meets the necessary requirements for developing a VR application related to domestic air conditioning. Expert feedback plays a vital role in refining the content, interface, and interaction design, as well as enhancing the overall quality of the application. Moreover, such feedback helps the RAC program develop interactive teaching aids that differentiate it from others, benefiting both students and lecturers. To ensure the application's effectiveness, it is important to evaluate it through specific metrics that cover usability, engagement, content accuracy, and knowledge retention. The experts provided feedback on the VR application from the aspects of content design, as well as interface and interaction design, as shown in table 8 and table 9.

Table 8
Content design expert reviews and feedback

Expert		Reviews and Feedback
Expert 1	i	Interesting development. Can be improved by adding elements.
Expert 2	i	A very good study and can be improved for a more detailed method of maintenance or diagnosis of the aircond system
Expert 3	i	Indoor & outdoor units if possible, can show internal components.

Table 9
Interface and interaction design expert reviews and feedback

Expert		Reviews and Feedback
Expert 1	i.	VR development is very good and interesting.
	ii.	The product is very good and excellent.
	iii.	Congratulations, the product is very neat and suitable for the air conditioning laboratory environment
Expert 2	i.	Recommended for students to enter national and international competitions. Congratulations & well done.
Expert 3	i.	Very well developed product Can be commercialized and proposed for patenting. Congratulations
Expert 4	i.	No improvement for degree level. Product can be commercialized.
	ii.	The entire VR produced meets the interface design.
	iii.	The components in the air conditioning laboratory are compatible.
	iv.	The displayed text is clear.

The evaluation of the VR application is based on several key metrics, including usability, engagement, content accuracy, and knowledge retention. Usability refers to how easily users can interact with the VR application, focusing on the navigation and user interface. Experts assessed whether users can complete tasks within the VR environment without confusion or frustration. Engagement, on the other hand, measures how immersive and captivating the VR experience is. Experts evaluated the visual and auditory elements of the application, considering how well it draws users into the experience and whether it maintains their attention throughout the learning process. Content accuracy is another important metric, which involves gathering feedback on the relevance, clarity, and correctness of the technical content presented in the VR application. Experts reviewed whether the content aligns with current industry practices and if it effectively supports student learning in air conditioning maintenance. Knowledge retention was also assessed, focusing on how well the VR application helps users retain the skills and knowledge necessary for periodic inspections and maintenance procedures for domestic air conditioners. For instance, Expert 1 commented, "The VR development is interesting, but improvements can be made by adding more detailed elements." Expert 2, while acknowledging the solid design, noted, "Content accuracy and the interface design are solid, but the interaction experience could be enhanced by integrating indoor and outdoor unit components." These expert reviews provide valuable insights into both the strengths and areas for improvement in the VR application. They help guide the refinement process, ensuring that the VR-based learning tool becomes an effective and engaging resource for students, ultimately contributing to the advancement of technical education in the RAC field.

3.4 Discussion

This section addresses three research issues which is design suitability, development method, and expert evaluation of the basic VR periodic inspections of domestic air conditioners. The findings confirm that the application successfully addresses these research concerns.

3.4.1 Suitable design for a virtual reality (VR) periodic inspection of domestic air conditioning

In the development of VR applications for periodic inspections of domestic air conditioners, accurate design is key to providing an effective, informative, and engaging experience for users.

There are several aspects that need to be considered in the design of VR applications based on multimedia elements that can add to the user experience of VR technology. Among them is the design of the user interface (UI) should be simple, easy to understand, and intuitive in producing realistic 3D visuals. Users should be able to easily access and understand the controls and navigation in the VR environment without difficulty. In addition, the visualization or depiction of the domestic air conditioning system should be realistic and detailed. An effective VR design should allow users to interact with the air conditioning environment directly with textual guidance. Finally, the developers have ensured that the developed VR application can run smoothly and is compatible with various VR devices.

3.4.2 Development of a virtual reality (VR) periodic inspection of domestic air conditioning

The development of the VR application is planned to provide benefits to users, especially students and instructors in the field of Refrigeration and Air Conditioning, either as a teaching aid (ABM) for instructors while as a practical simulation exercise for regular inspections of domestic air conditioning for students. Constructivism theory can be applied to improve the user experience of the application by ensuring that the user's learning experience is not only focused on receiving information, but also on developing their own knowledge through active interaction with the VR simulation environment. For the development of 3D models of inspection equipment and domestic air conditioning components, Blender software is the right software to use because it provides features that are easy to understand and operate. While the Unity software is the software that is used to combine all the multimedia elements that have been edited, adding interaction and functionality either through the document package provided or programming writing, then made into an application for the VR platform by using a VR headset to play.

3.4.3 Expert assessment of the functionally of the virtual reality (VR) periodic inspection of domestic air conditioning

The evaluation of the design of the content, interface and interaction of the developed VR application was carried out based on the items that were developed, showing that the experts agreed that the content, interface and interaction of the VR application were arranged according to the appropriateness and content, as well as being able to interact between users and objects in VR has met the objectives of the study. All experts stated that the content provided is appropriate and can be used for students in the field of Refrigeration and Air Conditioning to understand the context of periodic inspections of domestic air conditioning with VR simulation. Experts have appreciated the quality and excellence of important elements such as graphic elements, 3D models, and text in VR applications that can convey information clearly to users. great user experience. In the section of

views and comments by experts, there are various good comments and congratulations on the success in developing this VR application. Overall, the positive evaluation from these experts shows that the interaction design aspects in VR applications have successfully met the needs of interaction between users and the VR simulation environment.

4. Conclusions

This study aimed to develop a VR application for the periodic inspection of domestic air conditioning, based on the Training Manual for Refrigeration and Air Conditioning Service Technicians. The developed VR application functions as an interactive teaching aid, enhancing both instructors' teaching efficiency and students' understanding through an engaging and immersive virtual environment. The findings suggest that the VR application effectively serves its purpose as a teaching tool in the field of Refrigeration and Air Conditioning (RAC). Expert evaluations on content design, interface design, and user interaction provided positive feedback, confirming the application's usability, effectiveness, and educational value. The positive results affirm that the VR application meets its objectives, demonstrating the potential of VR technology to enhance vocational education by offering a safer, more cost-effective, and interactive learning experience. However, to further refine the application, future iterations of the study could benefit from gathering feedback directly from the end-users (students). Collecting qualitative data on their learning experiences will provide deeper insights into the application's strengths and weaknesses, allowing for targeted improvements to better meet the needs of the students and instructors. This will help ensure that the VR application evolves into an even more effective and impactful tool for vocational education. Acknowledgement This research was funded by the Industry Grant (M174) under the Research Management Centre, Universiti Tun Hussein Onn Malaysia.

References

[1] Abidin, Muhamad Nazrul Zainol, Muhammad Helmi Norman, and Noorhayati Mohd Noor. "Keberkesanan penggunaan realiti maya dalam kurikulum pendidikan Malaysia." *Jurnal Dunia Pendidikan* 3, no. 1 (2021): 729-737.

[2] Budoya, Christian, Mussa Kissaka, and Joel Mtebe. "Instructional design enabled agile method using ADDIE model and feature driven development method." *International Journal of Education and Development using ICT* 15, no. 1 (2019).

[3] Chaudhary, Farkhunda Rasheed, and Sidra Khushnood. "Transforming science education through digital technology." *International Journal of Innovation in Teaching and Learning (IJITL)* 5, no. 2 (2019): 17-32. https://doi.org/10.35993/ijitl.v5i2.698

[4] Di Natale, Anna Flavia, Claudia Repetto, Giuseppe Riva, and Daniela Villani. "Immersive virtual reality in K-12 and higher education: A 10-year systematic review of empirical research." *British Journal of Educational Technology* 51, no. 6 (2020): 2006-2033. https://doi.org/10.1111/bjet.13030

[5] Gavish, Nirit, Teresa Gutiérrez, Sabine Webel, Jorge Rodríguez, Matteo Peveri, Uli Bockholt, and Franco Tecchia. "Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks." *Interactive Learning Environments* 23, no. 6 (2015): 778-798. https://doi.org/10.1080/10494820.2013.815221

[6] Gawlik-Kobylinska, Małgorzata. "Reconciling ADDIE and Agile instructional design models—case study." *New Trends and Issues Proceedings on Humanities and Social Sciences* 5, no. 3 (2018): 14-21. https://doi.org/10.18844/prosoc.v5i3.3906

[7] Grassini, Simone, and Karin Laumann. "Evaluating the use of virtual reality in work safety: A literature review." In *Proceedings of the 30th European safety and reliability conference and the 15th probabilistic safety assessment and management conference*, vol. 1. Springer, 2020. https://doi.org/10.3850/978-981-14-8593-0_3975-cd

[8] Ismail, Affero, Razali Hassan, Alias Masek, Norhasyimah Hamzah, Irwan Mahazir Ismail, and Tamil Selvan Subramaniam. "Implementation of vocational training into TVET's teacher program for national core standard." In *2016 IEEE 8th International Conference on Engineering Education (ICEED)*, pp. 28-31. IEEE, 2016. https://doi.org/10.1109/ICEED.2016.7856088

[9] Kamlin, Malini, and Tan Choon Keong. "Adaptasi video dalam pengajaran dan pembelajaran." *Malaysian Journal of Social Sciences and Humanities (MJSSH)* 5, no. 10 (2020): 105-112. https://doi.org/10.47405/mjssh.v5i10.508

[10] Makransky, Guido, and Gustav B. Petersen. "The cognitive affective model of immersive learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality." *Educational psychology review* 33, no. 3 (2021): 937-958. https://doi.org/10.1007/s10648-020-09586-2

[11]` Mohamad, Nurul Haerani, Badaruddin Ibrahim, Asri Selamat, Affero Ismail, and Zulida Abdul Kadir. "A protocol for development of holistic-entrepreneur graduates: Emotional intelligence perspectives." *Journal of Technical Education and Training* 13, no. 1 (2021): 35-43. https://doi.org/10.30880/jtet.2021.13.01.004

[12] Radianti, Jaziar, Tim A. Majchrzak, Jennifer Fromm, and Isabell Wohlgenannt. "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda." *Computers & education* 147 (2020): 103778. https://doi.org/10.1016/j.compedu.2019.103778

[13] Torrance, Megan. "Reconciling ADDIE and agile." *Learning Solutions Magazine* (2014).

[14] Zhang, Qian, Ke Wang, and Sheng Zhou. "Application and practice of vr virtual education platform in improving the quality and ability of college students." *IEEE Access* 8 (2020): 162830-162837. https://doi.org/10.1109/ACCESS.2020.3019262