POLITEKNIK BANTING SELANGOR

VIRTUAL REALITY OF COMPOSITE TAP TEST

NAME	MATRIC NO.
AQIL MUQRI BIN MAHADI	**24DAM22F1021**
IZZUL HAZWAN BIN MOHD FAZLY	**24DAM22F1019**
NURFATEHAH BINTI MOHD NAZRY	**24DAM22F1016**
AFREINA BINTI MOHD AFANDI	**24DAM22F1033**

DEPARTMENT OF AIRCRAFT MAINTENANCE

NOVEMBER 2024

POLITEKNIK BANTING SELANGOR

VIRTUAL REALITY OF COMPOSITE TAP TEST

NAME	MATRIC NO.
AQIL MUQRI BIN MAHADI	**24DAM22F1021**
IZZUL HAZWAN BIN MOHD FAZLY	**24DAM22F1019**
NURFATEHAH BINTI MOHD NAZRY	**24DAM22F1016**
AFREINA BINTI MOHD AFANDI	**24DAM22F1033**

A REPORT SUBMITTED TO DEPARTMENT OF AIRCRAFT MAINTENANCE IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR A DIPLOMA ENGINEERING IN AIRCRAFT MAINTENANCE

SUPERVISOR:

MR. MOHAMMAD AZMIN BIN ZAINAL

REPORT ENDORSEMENT

This report is being submitted, reviewed, and endorsed to fulfill the conditions and requirements of report writing as specified.

Checked by:

Supervisor's Signature :

Supervisor's Stamp : MOHAMMAD AZMIN BIN ZAINAL
Ketua Program (PPPT DH44)
Jabatan Penyenggaraan Pesawat
Politeknik Banting Selangor

Date : 29th November 2024

Endorsed by:

Project Coordinator's Signature :

Project Coordinator's Stamp : KHAIRUL IZWAN BIN ISMAIL
Pensyarah
Jabatan Penyenggaraan Pesawat
Politeknik Banting Selangor

Date : 3rd December 2024

CERTIFICATION OF PROJECT ORIGINALITY & OWNERSHIP

VIRTUAL REALITY OF FLIGHT INSTRUMENT

SESSION: 1 2024/2025

NAME	MATRIC NO.
AQIL MUQRI BIN MAHADI	**24DAM22F1021**
IZZUL HAZWAN BIN MOHD FAZLY	**24DAM22F1019**
NURFATEHAH BINTI MOHD NAZRY	**24DAM22F1016**
AFREINA BINTI MOHD AFANDI	**24DAM22F1033**

"We hereby declare that this report is the result of our own work, except excerpts that we have outlined its sources and this project will be the ownership of polytechnic.

SIGNATURE: WRITER 1

(AQIL MUQRI)

SIGNATURE: WRITER 2

(IZZUL HAZWAN)

SIGNATURE: WRITER 3

(AFREINA)

SIGNATURE: WRITER 4

(NURFATEHAH)

Endorsed by,

____

(SUPERVISOR'S SIGNATURE)

MOHAMMAD AZMIN BIN ZAINAL
Ketua Program (PPPT DH44)
Jabatan Penyenggaraan Pesawat
Politeknik Banting Selangor

SUPERVISOR'S STAMP

DATE: 29th November 2024

ACKNOWLEDGEMENT

We would like to express our deepest gratitude to our supervisor, Mr. Mohammad Azmin Bin Zainal, for his invaluable guidance, support, and expertise throughout the completion of our final project thesis, titled Virtual Reality of Composite Tap Test (VRCTT). His extensive knowledge in the field and his unwavering commitment to our academic and professional growth have been instrumental in shaping this project. His encouragement and constructive feedback inspired us to explore and innovate, allowing us to gain a comprehensive understanding of both virtual reality applications and composite testing methodologies.

Mr. Mohammad Azmin's mentorship has been exceptional, fostering a learning environment where we were encouraged to think critically, analyze effectively, and work collaboratively. He was always approachable and willing to share his insights, which enriched our project with practical perspectives and in-depth theoretical knowledge. His patience, dedication, and passion for excellence have not only guided us academically but also taught us the importance of perseverance and attention to detail in engineering research.

Finally, we extend our sincere appreciation to Mr. Mohammad Azmin for his continuous support, from the initial concept development to the final stages of this thesis. His belief in our potential kept us motivated, even though challenging times. This thesis would not have been possible without his guidance, and we are truly grateful for his role in helping us achieve this milestone.

ABSTRACT

The development of Virtual Reality (VR) for composite repair represents a significant advancement in the field of maintenance and engineering. This innovation utilizes VR technology to simulate and enhance the process of repairing composite materials, which are commonly used in aerospace, automotive, and other high-performance applications. By integrating VR, technicians can receive immersive, interactive training, visualize complex repair procedures, and practice techniques in a risk-free environment. This approach not only improves the accuracy and efficiency of repairs but also reduces costs and downtime associated with traditional training methods. The development of VR in composite repair aims to advance skills, ensure high-quality repairs, and streamline maintenance processes through advanced digital tools and simulations.

The composite tap test is an essential non-destructive testing (NDT) method in aerospace for detecting defects such as delamination in composite materials. Traditional training methods can be costly and pose risks of damaging materials. Virtual reality (VR) has emerged as a promising tool for technical training, offering immersive environments to practice complex tasks safely. This project developed a VR-based training system for the composite tap test by simulating defect detection in composite materials. The system replicates the tapping process and generating realistic sound feedback to help users identify defects. Trainees can practice the technique in a controlled environment while receiving real-time performance feedback on accuracy and consistency.

Users trained with VR improved their defect detection skills and demonstrated greater confidence compared to traditional methods. Feedback also highlighted the system's ease of use and high engagement levels. The VR platform reduces the need for physical materials, cutting training costs and risks. VR composite tap test system offers a safe, effective, and cost-efficient solution for training NDT inspectors, with the potential to enhance training quality and reduce reliance on expensive and fragile physical components.

Keywords: Virtual Reality (VR), Composite Tap Test, Non-Destructive Test

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

VR	Virtual Reality
AR	Augmented Reality
NDT	Non-Destructive Testing
3D	Three Dimensions
OEM	Original Equipment Manufacturer
CAAM	Civil Aviation Authority of Malaysia
CFRP	Carbon Fiber Reinforced Polymers
GFRP	Glass Fiber-Reinforced Epoxy
AFRP	Aramid Fiber Reinforced Polymers
CAD	Computer Aided Design
HMD	Head-mounted Display
XR	Extended Reality
MR	Mixed Reality

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The aerospace, automotive, maritime, and construction industries have all seen significant changes according to the excellent properties of composite materials, which include their high strength-to-weight ratio, resistance to corrosion, and design flexibility. Because they enable the creation of lighter, more fuel-efficient aircraft designs, composite materials are crucial to the modern aircraft building industry. Yet understanding about composite materials still presents many challenges for engineers, students, and professionals in the aerospace industry.

Figure 1.1: Training Composite Aircraft (Sciencedirect.com, Nov 2013)

One of the primary challenges of understanding composite materials is their complicated and versatile characteristics. Compared to traditional materials like metals and alloys, composites are composed of multiple components, such as fibers, matrices, and additives, each of which has distinct properties and behaviors. Understanding how these elements interact and impact the overall performance of composite materials requires a strong knowledge of materials science, material structure, and production techniques. Following this, instructors and students usually struggle to understand the fundamental concepts that explain composite materials, which can lead to misunderstanding and knowledge deficits.

One of the biggest obstacles to understanding composite materials is the lack of available instructional materials and opportunities for practical training. Composites are relatively new materials with quickly developing technologies and applications, in contrast to classic materials like metals, which have been well researched and documented over decades. As a result, there is a lack of detailed textbooks, course materials, and lab exercises designed especially for students of all levels studying composite materials. As well, especially in academic institutions with limited funding or infrastructure, access to specialized tools and facilities for creating, evaluating, and assessing composite materials may be restricted.

However, with the introduction of Virtual Reality (VR) and Augmented Reality (AR) technology, aircraft maintenance has undergone significant transformation. VR introduces technicians in a simulated environment in which they can visualise complex aircraft structures in three dimensions, allowing for more effective training and pre-repair planning. Instead, AR overlays digital information on physical planes, providing real-time guidance and data visualisation during repair tasks, improving the process and reducing errors.

The integration of VR and AR technologies with innovative repair technologies and aircraft composites represents a paradigm shift towards a more flexible, sustainable and technologically advanced future for aviation maintenance and operations as the aviation industry continues to evolve.

We have been taught the Material & Hardware course in Semester 2 and the Non-Destructive Testing (NDT) course in Semester 4 as part of the Diploma in Aircraft Maintenance Engineering program at Politeknik Banting Selangor (PBS). These programs provide a strong foundation for understanding the properties of composite materials and the techniques for their inspection and repair. With the incorporation of VR and AR, students benefit from a practical, hands-on approach to troubleshooting, maintenance, and repair of composite materials, preparing them to effectively address challenges in modern aircraft design and maintenance.

1.2 PROBLEM STATEMENTS

Problem Statement 1:

<u>Difficult to understand an aircraft's composite structure in conventional method</u>

We have conducted a survey of 98 participants of PBS students, industry etc. 98 respondents have answered as per the details below. Based on the survey, respondents struggled to understand the complex structure of aircraft composite materials using conventional methods, often due to the high costs associated with obtaining specialized training or equipment. This lack of understanding affects their ability to understand important concepts, which could delay progress in the field.

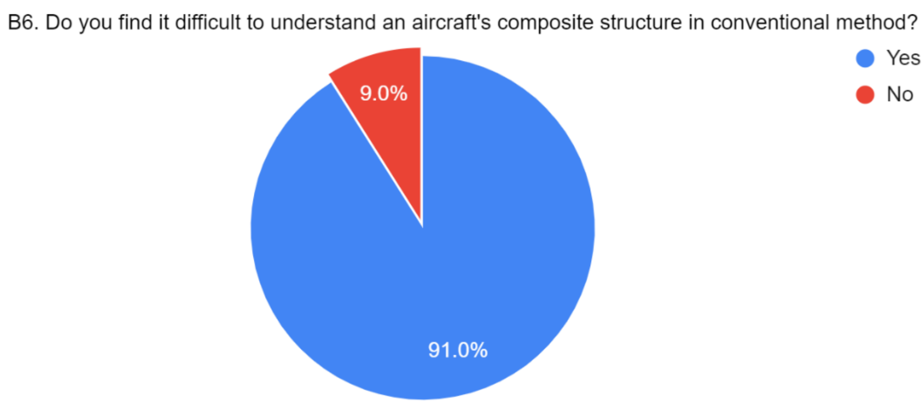


Figure 1.2: Respondents' Understanding of Aircraft's Composite Structure in Conventional Methods

Problem Statement 2:

<u>Having difficulties in identifying of composite repair</u>

Respondents across the education and industrial sectors face significant challenges in identifying composite repairs due to the complexity of composite materials and a lack proper training and resources. This difficulty not only impacts learning outcomes, but it leads to practical challenges in the timely and effective maintenance of composite structures in industries.

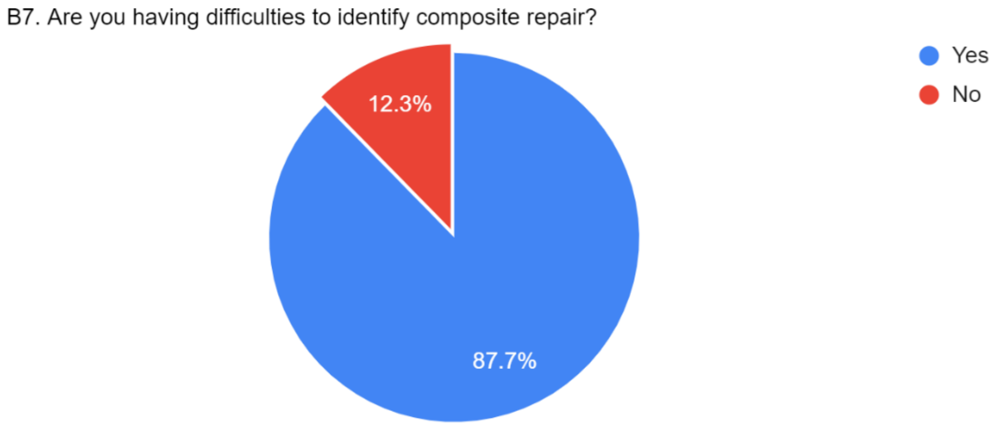


Figure 1.3: Respondents' Ability to Identify of Composite Repairs

Problem Statement 3:

<u>Having difficulties determining the operation of composite repair</u>

Respondents having difficulty determining the operation of composite repair due to a lack of provided techniques could cause confusion. Furthermore, each type of damage might require specific repair processes and materials, such as delamination and Fiber breaking, making it difficult to determine the appropriate repair operation.

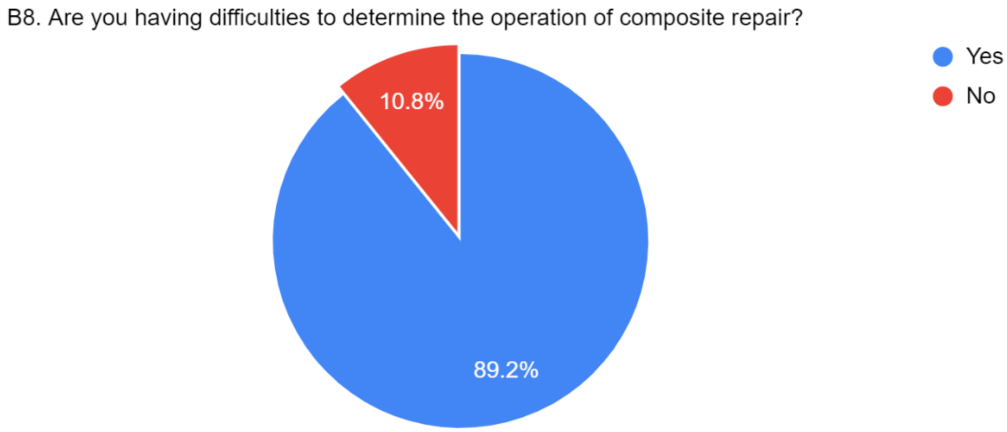


Figure 1.4: Respondents' Understanding of the Operation of Composite Repair

1.3 PROJECT OBJECTIVES

1.3.1 General Project Objectives

The project objectives are:

Objective 1:

To design an interactive VR environment for aircraft composite and repair

Design and create a customized virtual reality (VR) environment tailored specifically for understanding the structure and repair of aircraft composites. This VR environment will be interactive, allowing users to simulate composite repairs commonly encountered in aviation.

Objective 2:

To develop and integrate the VR simulation of composite tap test

Create an interactive VR simulation that mimics the process of performing composite tap tests on aircraft materials. This simulation will allow users to practice identifying defects in composites by simulating real-world scenarios commonly encountered in aviation maintenance.

Objective 3:

To evaluate the effectiveness of VR training for improving aircraft composite understanding and repair skills

The evaluation of the project will focus on measuring the improvement of the user's ability to understand the composite structure of the aircraft, identify repair needs and determine repair procedures after using the VR environment. This evaluation will provide evidence of the effectiveness of VR solutions in improving learning outcomes and addressing identified challenges.

1.3.2 Specific Individual Project Objectives

1.3.2.1 Product Structure

The following simply describes the goals of creating a product structure for a virtual reality (VR) application specifically designed for composite tap test:

- To design software frameworks that incorporate interactive models, training modules, and tools for performance assessment in composite repair scenarios.
- To develop a hardware system that provides immersive visuals and facilitates practical training experiences through environmental tracking and realistic interactions.
- To demonstrate the effectiveness of the VR application in providing immersive composite repair training through real-time interactions.

1.3.2.2 Product Mechanisms

A product mechanism is the functional components and interaction of a product or system. People are increasingly turning to virtual reality (VR) as an educational medium since it provides an immersive environment where learners can interact with 3D simulations. To guide the development process effectively, product mechanisms for VR learning centered on composite materials need to have well-defined objectives.

1. To design an interactive Virtual Reality game for learning that simulates the composite tap test inspection for aircraft maintenance applications.

2. To develop a Virtual Reality of Composite Tap Test (VRCTT) that includes realistic environment, accurate sounds and interactive features to improve user understanding and learning outcomes.

3. To demonstrate the VRCTT as an effective learning solution by showing its functionality and its effectiveness in improving users' knowledge of composite tap test procedure.

1.3.2.3 Software/ Programming

Here are some specific individual project objectives for our Final Year Project on the development of Virtual Reality of Composite Tap Test (VRCTT) using Unity:

1. To design a Unity development environment for Virtual Reality (VR) with intuitive user interfaces that enable seamless interaction through hand tracking or controller-based inputs.

2. To develop a VR-compatible setup using the Valve Index for optimal functionality, along with accurately scaled 3D models of aircraft components and composite materials for integration into the Unity environment.

Figure 1.5: Aircraft 3D Model (Researchgate.com, Nov 2019)

3. To evaluate the functionality, usability, and effectiveness of the interactive VR interface in simulating the Composite Tap Test, as well as the accuracy of the virtual representation and interaction of aircraft parts and tools within the VR environment.

1.3.2.4 Accessories & Finishing

The specific project objectives are:

1. To design the Composite Repair Techniques:

- When repairing composite materials in aircraft, various techniques are employed based on OEM manuals.
- One common method is bonded repair, where a composite repair patch is adhesively co-bonded around the damaged area of the aircraft exterior.
- Understanding these repair techniques is essential for successful composite repair projects.

2. To develop the Automation in Aircraft Repair:

- Automation plays a significant role in efficient composite repair:
- High-resolution metrology measures the actual 3D shape of in-service parts.
- Automatic non-destructive testing (NDT) locates and assesses composite part damage.
- Implementing automation can improve accuracy, reduce costs, and enhance repair quality.

3. To demonstrate the Augmented Reality (AR) and Mixed Reality:

- Beyond virtual reality (VR), augmented reality (AR) and mixed reality play crucial roles in composites design and manufacturing.
- AR applications superimpose actual data onto virtual models:
- For instance, ply images from an automatic inspection system can be overlaid on a 3D digital model, showing deviations from nominal ply boundaries and Fiber orientation.
- Technicians equipped with AR glasses can visualize under-surface laminate damage accurately located on actual components.
- These technologies bridge the gap between the virtual world of design and simulation and the real-world of composites manufacturing and repair.

Figure 1.6: Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) (Uni.agency, 29 Dec 2023)

1.4 PURPOSE OF PRODUCT

The purpose of this product is to provide immersive, hands-on training experience for individuals involved in aircraft maintenance. It enables users to practice and refine their skills in performing composite tap tests, a crucial procedure for detecting structural issues in composite materials. By simulating real-world scenarios, VRCTT allows users to interact with virtual aircraft components, improving their ability to identify defects and make informed repair decisions. This technology enhances training by offering a safe, cost-effective, and repeatable environment, making complex repair tasks more accessible and better understood without the need for physical aircraft components.

1.5 SCOPE OF PROJECT

1.5.1 General Project Scopes

For our final year project, we focused on creating solutions to help students and professionals better understand and use composite repair techniques. By developing a VR-based training system, our project aims to offer students an immersive learning experience, enabling them to understand complex repair processes more effectively. Furthermore, we aim to provide technicians and engineers in industrial settings with practical and cost-effective tools to improve their skills in composite repair. Through VR technology, our project aims to develop an interactive platform that simulates real-world repair scenarios, ultimately improving learning outcomes and operational efficiency. By undertaking this project, we aim to contribute to the advancement of knowledge and skills in the aerospace and composites industry, equipping future professionals with the expertise needed for their careers.

1.5.2 Specific Individual Scope

1.5.2.1 Product Structure

The purpose of a project centered on the creation of VRCTT is to utilize virtual reality technology to improve training and simulation for composite repair workers. It includes several stages and concerns. This is an overview of the scope:

- Conceptualization and Design

  The virtual training environment's purposes, characteristics, and general structure are outlined throughout the ideation and design stages of the VR composite repair project. This entails figuring out the main learning objectives, which include knowing how to fix composites, understanding the characteristics of materials, and adhering to safety regulations. The aim is to provide a virtual workshop environment that replicates practical situations, such fixing transport or airplane parts. In order to effectively communicate repair processes and best practices, the design process will concentrate on developing interactive lessons, guided exercises, and immersive simulations. We want to give trainees a hands-on learning experience that encourages engagement, continuation, and skill development in composite repair processes by taking advantage of VR technology.

- Content Development

  For the VRCTT project, content development includes building 3D models, interactive guides, and simulation scenarios that reflect the difficulties and tasks of actual repairs. In order to create 3D models of composite materials, broken parts, repair tools, and other equipment needed for different repair processes, we will design these items. Performance and realism will be prioritized in the development of these models, guaranteeing precise interaction and representation in the virtual world. To educate repair methods, processes, and safety precautions, interactive tutorials and guided exercises will be created. These will guide learners through each step of the process and offer feedback on how well they performed.

1.5.2.2 Product Mechanisms

A product mechanism is the functional components and interaction of a product or system. It includes the moving parts, links, and related components that allow a product to carry out certain activities or functions. To reach the objective, the process of developing a product mechanism for VR learning includes designing and implementing a system that allows for effective learning experiences in virtual reality. The product mechanism involves selecting and configuring the required hardware components. This comprises VR headsets, motion controllers, and any other devices required for the learning objectives. VR headsets come in a variety of models. These headsets often have built-in visuals, lenses, sensors for movement and audio systems. Motion tracking systems capture the user's gestures in real time, letting them navigate and interact with the virtual environment. Furthermore, the starting point of the product mechanism is to create VR software that matches the learning objectives. This involves the creation of interactive simulations, the surrounding area, and scenarios to engage students and improve outcomes for learning. To provide an immersive and successful educational experience, the application must include features such as 3D modelling, physics simulations, interactivity, and user feedback systems. Effective instructional design also plays an important role in structuring virtual reality learning experiences. This includes creating learning objectives, effectively arranging content, which includes interactive features, and creating evaluations to track the progress of learners.

1.5.2.3 Software/ Programming

Our final year project is going to be a VR-based training system for aircraft composite tap test. The scope of our project is to develop a fully interactive educational environment that promotes deeper understanding of complex repair methods. This project aims to benefit students by providing a realistic simulation environment in which they can practice and improve their knowledge. Additionally, by using this VR platform, engineers and technicians in the aerospace industry can improve their skills in composite repair, which will ultimately improve operational efficiency and lower training costs.

By using Unity programming, we are responsible for developing the software aspect of the VR training system. This includes developing interactive simulations of repair scenarios, applying user interfaces for navigation and interaction, and optimizing performance for smooth user experience. Through the project's scope, I aim to make a difference to the advancement of VR technology in education and industry training, particularly in the aerospace and composites sector.

Figure 1.7: Unity Development Platform (Cantercrow.com, 7 Oct 2024)

1.5.2.4 Accessories & Finishing

First, this VR will be focusing on education due to some people don't have any ideas about how to do composite repair. The VR composite repair will show steps and tutorial about composite repair on aircraft by referring to the Civil Aviation Guidance Material 8106 (CAGM – 8106) from CAAM which is about Design of Repair (CAAM Part 21 Subpart M). This VR will show the steps about doing composite repair. The design will conclude with one small aircraft and the workplace will be in a hangar. Our target will be for the students' knowledge about composite repair. We hope this VR composite repair can enhance students and our client's knowledge more information about composite repair.

Figure 1.8: Civil Aviation Guidance Material 8106 (CAGM – 8106) Design of Repair (CAAM Part 21 Subpart M) (CAAM.gov.my, 1 Oct 2021)

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL LITERATURE REVIEW

2.1.1 Demand in Aviation

Composite materials are currently widely used in the aviation industry due to their excellent strength-to-weight ratio. The resin-to-reinforcement material ratio enhances a composite's strength. Considering there are so many resins and reinforcement materials available, formulations can be developed to meet any strength requirements.

Furthermore, composite materials are lighter in weight, less corrosive, and less susceptible to fatigue failure, which leads to higher long-term cost savings and less maintenance. Although they are cost-effective in the long run, they are more expensive to repair when required. There are also some concerns about their repair. For instance, composites use resins that are flammable at 150 degrees Fahrenheit, which requires fire safety procedures. Burning complex composites releases hazardous microparticles and fumes into the atmosphere, causing severe health risks.

For that issue, regular inspections are required to detect any signs of damage or wear early on, and that includes training personnel on proper composite material handling procedures. This prevents damage during maintenance or repair procedures by not dropping or handling components improperly.

2.1.2 Type of Virtual Reality

VIRTUAL REALITY	EXPLAINATION
Non-Immersive Virtual Reality  **Figure 2.1: Non-Immersive Virtual Reality (RexTheme.com, n.d.)**	Non-immersive virtual reality is a virtual experience offered via computer in which you can regulate some characters or actions within the software, but the surroundings do not interact with you directly. It does not provide the sensation of being completely immersed in the virtual world.
Fully Immersive Virtual Reality  **Figure 2.2: Fully Immersive Virtual Reality (Linkedin.com, 11 Oct 2023)**	Fully immersive virtual reality offers real interaction in the virtual world. Using VR headsets and motion tracking, users can experience a complete sensation of presence in a virtual world. Users can communicate and interact with the virtual environment as if they were in the real world.
Semi-Immersive Virtual Reality  **Figure 2.3: Semi-Immersive Virtual Reality (WrittenTomorrow.com, 2 Mar 2022)**	Semi-immersive virtual reality is a combination of non-immersive and fully immersive virtual reality. It can be device- or web-based. It generally includes a high-resolution screen and tracking technologies, yet the user may still perceive their physical environment.

Augmented Reality  **Figure 2.4: Augmented Reality (RockwellAutomation.com, n.d.)**	Augmented reality is an interactive experience that augments the real environment with computer-generated perception data. Rather than immerse you in a virtual world, a virtual creature is introduced into the actual world using any device. It can give a user a more intense, immersive experience than they would otherwise have, which increases their enjoyment or understanding.
Mixed-Reality  **Figure 2.5: Mixed-Reality (Nsflow.com, n.d.)**	Mixed reality (MR) is a newly developed technology that combines virtual reality (VR) and augmented reality (AR) to create imaginative environments in which actual and digital objects coexist and interact in real time. It goes beyond basic overlays (as in augmented reality) to anchor and integrate digital elements into the user's actual surroundings, resulting in greater immersion and engaging interactions.

Table 2.1 Type of Virtual Reality

2.1.3 VR Technology Implementation

One of the greatest attractions of virtual reality technology is its ability to show design evaluators representations created in computer 3D environments at any scale without requiring physical objects [20]. This can improve systematic procedures, increase process effectiveness, save costs, and reduce the amount of time needed to physically demonstrate and explain the product design in detail. Unlike CAD, VR lacks a physical component and enables users to experience, interact, and take actions with it just like they would with an actual product. VR can be utilized, in summary, as

- A source of inspiration prior to producing visualizations
- A tool for modelling, prototyping, visualizing, and sketching while creating design representations.
- Following the creation of the design representations, a presentation, demonstration, experience, usability evaluation, and ergonomic evaluation tool
- A platform for teamwork both before and after design representations are created.

Furthermore, the more difficult, complicated, and expensive the set-ups are, the more helpful it is to adopt VR to explore and discover viable alternatives in engineering design. Technological development and compatibility provide challenges in the development and implementation of VR solutions. Under these situations, the low-resolution VR headsets will make it harder to make decisions and defend product design proposals.

2.1.4 Evolution for Virtual Reality

VR technology has advanced significantly since its early days with stereoscopic visuals in the 1800s. VR provides an immersive and engaging 3D experience that extends beyond the actual world. The concept of virtual reality emerged in the mid-20th century, with pioneering works such as Morton Heilig's Sensorama (1957) and Ivan Sutherland's "Ultimate Display" concept (1965), which laid the framework for immersive experiences. The earliest mechanistic virtual reality prototypes (e.g., Sensorama) allowed us to view stereoscopic 3D images accompanied by stereo sound, smells, as well as wind effect - set the foundation.[17] The first attempts at building immersive virtual environments occurred in the 1970s and 1980s with projects such as the Aspen Movie Map and the Sword of Damocles, a VR head-mounted display (HMD) developed by Ivan Sutherland and his student Bob Sproull.

Figure 2.6: Sega VR headset in 1993 (Meta.com, n.d.)

The 2010s experienced an increase of interest in VR, fueled by advances in computational power, display technology, and motion tracking. Companies such as Oculus and HTC Vive produced high-quality VR headsets that incorporated excellent visuals and motion tracking technologies. The launch of consumer-friendly VR headsets like the Oculus Rift, HTC Vive, and PlayStation VR in 2016 brought VR closer to mainstream adoption until now. Nowadays, VR is growing beyond gaming and entertainment to other industries such as healthcare, education, and architecture. Medical practitioners employ virtual reality for simulations and procedures, educators for immersive learning experiences, and architects for design visualization.

2.2 SPECIFIC LITERATURE REVIEW

2.2.1 Product Structure

Figure 2.7: Person using VR (Shutterstock.com, n.d.)

In general, virtual reality (VR) is made up of two components which are software and hardware. Hardware includes things like controllers, headsets, and sensors. To produce a smooth VR experience, researchers frequently stress how crucial it is to figure out how these elements interact and combine [15]. Enhancing user engagement through VR requires a smooth experience. Users can fully immerse themselves in the virtual environment, increasing their presence and creating a more immersive experience when the hardware and software components function together flawlessly. Users may become more satisfied as a result and be more eager to explore and interact with the VR content.

Figure 2.8: Oculus Quest 2 (Walmart.com, n.d.)

Our product lineup offers an extraordinary gaming experience by combining the most advanced software and technology in a single unit. Fundamentally, the Oculus Quest 2 VR headset is the basis of immersion, providing users with an individual's experience and high-fidelity images that let them in to virtual worlds [18]. Quest 2's ergonomic hand controllers, accurate tracking sensors, and user-friendly interaction features make sure that players are fully immersed in the virtual world, encouraging a sense of presence and engagement that has never been seen before.

The idea for our research software is powered by the powerful Unity game engine, which enhances the hardware capabilities of Oculus Quest 2. Our development team can create engaging virtual environments, complex gameplay mechanisms, and immersive experiences that deeply connect with players because of Unity's adaptability and large feature set. We set out on a creative and innovative adventure, utilizing Unity's powerful scripting capabilities, huge asset store, and user-friendly interface to realize our vision for game entertainment with unmatched accuracy and depth.

The use of the C++ programming language in software development gives our project an extra level of complexity and optimization. The foundation of C++ is used for vital functions like native software creation, performance optimization, and low-level programming details, which guarantees that our gaming experience runs smoothly and efficiently on the Oculus Quest 2 platform. By utilizing C++, we can optimize all aspects of our game, ranging from physics simulations to graphics lines, thereby expanding the scope of virtual reality possibilities.

Figure 2.9: Coding C++ (Myloview.com, n.d.)

Our product structure is systematically divided into important stages, each of which is necessary to achieve our goal of creating engaging gaming experiences [16]. We specify the fundamental gameplay mechanics, story points, and creative direction that will change the player's journey through the virtual environment starting with the idea of the game design. Scene development is the next phase, when we use Unity's extensive toolkit to create beautiful settings, add dynamic elements to them, and give them life with detailed animations and effects.

2.2.2 Product Mechanism

The product mechanism for virtual reality (VR) includes the underlying systems, processes, and components that allow for the creation, distribution, and optimization of VR experiences. The mechanism is what enables your product or service work. It is the reason for how your product or service provides the benefit, promise, or impact.

2.2.2.1 Types of Hardware

The product mechanism includes creating and producing hardware components that enable consumers to have immersive and responsive VR experiences. This includes factors like display resolution, field of view, tracking accuracy, comfort, and ergonomics.

2.2.2.1.1 Motion Controllers

Figure 2.10: Motion Controller (HP.com, 8 Oct 2019)

Motion controllers are physical devices that enable users to interact with mixed reality. Motion controllers provide many ways for users to interact with virtual objects and environments. This might include buttons, triggers, thumb sticks, touch-sensitive surfaces, and gesture recognition capability. Motion controllers offer exact positioning and smooth interaction with digital objects, making them preferred over gestures. The design and ergonomics of motion controllers are essential to user comfort and usability during extended VR sessions. Controllers are often designed to be lightweight, ergonomic, and easy to handle, with features like adjustable straps, ergonomic grips, and strategically positioned buttons and triggers to reduce hand fatigue and enhance comfort during use.

2.2.2.1.2 HTC Vive XR Elite

Figure 2.11: HTC Vive XR Elite (Vive.com, n.d.)

HTC designed and manufactured the VIVE XR Elite, an extended reality (XR) headset. The headset combines virtual reality (VR) and mixed reality (MR) functions. The features of high-resolution screens (1920x1920 px) and color passthrough, and its modular design promises a portable user experience. This device offers a range of software features designed to enhance the productivity of knowledge workers.[19] Hand-tracking is included in the Vive XR Elite, allowing for a whole new dimension of MR scenarios such as playing games with characters running on your living space, having real-time overlays with numerous virtual screens, and still being able to use your physical keyboard and mouse. The HTC Vive XR Elite enhances XR capabilities by improving display quality, tracking accuracy, ergonomics, and integration with augmented reality technologies. XR technology has a wide range of uses, including gaming, entertainment, education, training, and simulation.

2.2.2.1.3 Oculus Quest 2

Figure 2.12: Oculus Quest 2 (Meta.com, n.d.)

The Oculus Quest 2 is a standalone virtual reality (VR) headset produced by Oculus, a division of Facebook Reality Labs. It's lighter and slightly smaller than its predecessor. While its battery life is just 2-3 hours and users are required to log in using a Facebook account, the headset remains at the cutting-edge of VR technology. Oculus Quest works by itself, without a wireless connection. It is an adaptable device for both entertainment and education that immerses the user in a virtual environment. The Oculus Quest, a low-cost VR headset, can be used to reliably measure, but also challenge, a person's ability to maintain their balance.[21]

2.2.2.1.4 Valve Index

Figure 2.13: Valve Index (Macromart.co.uk, n.d.)

The Valve Index headset provides amazing visuals on a high-resolution display. This device uses off-ear audio technology to deliver excellent sound. The headset is built for comfort, enabling extended VR sessions without discomfort. Valve index controllers enable natural interactions and high-fidelity hand presence. They are ergonomically engineered to provide long-term comfort during gameplay. The Valve Index system contains Base Stations 2.0, which allow for exact tracking of your movements in any room. These base stations offer an uninterrupted and realistic VR experience.

2.2.3 Software / Programming

2.2.3.1 Type of Software

2.2.3.1.1 Unreal Engine

Figure 2.14: Unreal Engine (Bairesdev.com, n.d.)

Unreal Engine, also known as UE, is a video game development tool from the video game and software development company Epic Games. With this tool, developers have the ability to build a simulation, edit videos or sound, and render animations. Devs have used it to build some of the most popular games on today's market as well [22]. Oculus Rift, HTC Vive, PlayStation VR and other VR platforms are just a few of the platforms supported by Unreal Engine making it a popular choice for VR projects among developers.

2.2.3.1.2 Oculus Medium

Figure 2.15: Oculus Medium (Roadtovr.com, n.d.)

Oculus Medium is a digital sculpting tool which leverages Touch’s high quality motion tracking to allow free-form creation that focuses on manipulation of mass, rather than the production of brush strokes (like we find with titles like Tilt Brush and Quill). Medium is very much a tool rather than a game, but its ease of use means even the non-artistic can toy around with it, and maybe discover they’re a little more creative than once thought [23]. With the software's selection of sculpting tools and brushes, designers and artists can create intricate and precisely detailed virtual objects. Oculus Medium's user-friendly interface and immersive sculpting experience have made it extremely popular among digital artists and designers. Models can be exported in several formats for use with different 3D platforms and applications.

2.2.3.1.3 Blender 4.0

Figure 2.16: Blender 4.0 (Blender.org, n.d.)

Blender is the free and open source 3D creation suite. It supports the entirety of the 3D pipeline—modeling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation [24]. It can be used to create content for VR applications even if it is not specifically VR software. Blender offers an extensive feature set that includes powerful rendering engines (Cycles and Eevee), a robust set of modelling tools, rigging and animation tools, and simulation capabilities (such as fluid and fabric simulation). Blender users can create VR content by creating 3D models, environments and animations. This can then be integrated into VR applications created with other software or exported to VR platforms using the appropriate file format. For both amateur and professional content creators interested in VR development, Blender is a popular choice due to its vibrant community and extensive documentation.

2.2.3.1.4 Unity

Figure 2.17: Unity (PubNub.com, n.d.)

Unity is a platform for creating and operating interactive, real-time 3D games and other content. It provides developers with comprehensive tools and features to build games for various platforms, including PCs, consoles, mobile devices, and virtual reality [25]. Unity offers a user-friendly interface and a variety of features to design, develop and deploy VR applications across multiple platforms, including Oculus Rift, HTC Vive, Windows Mixed Reality and others. It supports multiple programming languages, including C#, JavaScript, and Boo, allowing developers to choose the language they're most comfortable with for scripting interactions and game logic. The Unity asset store provides many pre-made assets, scripts and plugins that can speed up development and enhance the VR experience with features such as realistic physics, audio effects and special effects.

2.2.4 Accessory & Finishing

The VR's accessory and finishing will be the design in the game that we will produce. For the game environment, we will do the in the hangar workshop and there's a small aircraft which is a Learjet 45. For the gameplay we are going to do a tap test inspection. We will do a free movement which can make the player walk around the aircraft and do the tap test inspection following the task that we will put and a checkpoint of place that will be inspected. We will be adding the sound of the real tap test inspection to make the player feel like a real tap test inspection and there's certain checkpoint will be elimination which when do the tap test it will make the other sound from the original sound. After finishing all the checkpoints, the player must submit a report of the inspection.

Figure 2.18: Learjet 45 (PrivateJetCentral.flights, n.d.)

Figure 2.19: Tap Testing Tool (henchmanusa.com, n.d)

2.3 REVIEW OF RECENT RESEARCH / RELATED PRODUCTS

2.3.1 Related Patent Product

2.3.1.1 Japan Airline (JAL) Innovation Lab

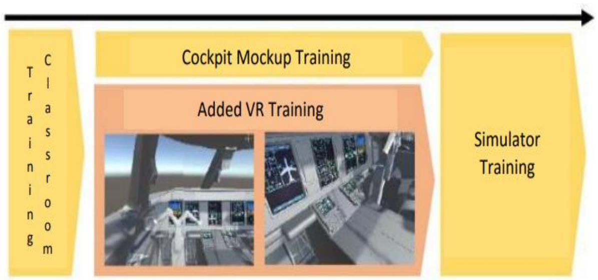
No.	Patented Product	Product Summary
1	 **Figure 2.20: Japan Airline (JAL) Innovation Lab**	**Product Name:** Japan Airline (JAL) Innovation Lab **Published Dates:** August 2, 2019 **Developer:** Japan Airline and Toshiba System Technology Corp. **Description:** Enhance maintenance engineers' skills on Embraer E170 and E190 aircraft. The program simulates realistic engine run-up scenarios, cockpit indicators, and sounds, addressing reduced hands-on opportunities due to aircraft reliability improvements.

Table 2.2: Japan Airline (JAL) Innovation Lab

2.3.1.2 VR Maintenance Training

No	Patented Product	Product Summary
1	 **Figure 2.21: Propeller inspection and repair by HQSoftware**	**Product name:** VR Maintenance Training by HQSoftware **Published date:** 14 August 2023 **Developer:** HQSoftware **Description:** Focuses on maintenance tasks such as inspections on propeller. This product includes collaborative tools, engagement, knowledge and its enhancing training.

Table 2.3: VR Maintenance Training

2.3.1.3 Airport Ground Handling Simulator VR

No	Patented Product	Product Summary
1	 **Figure 2.22: Airport Ground Handling Simulator VR (Meta.com, 14 April 2023)**	**Product Name:** Airport Ground Handling Simulator VR **Published Date:** 14 April 2023 **Developer:** AVIAR B.V. **Description:** This is an Early Access consumer version of the professional VR training software developed by AVIAR and used by major airports and ground handlers to train ground staff. In this VR simulation, you take on the role of a ground crew member, performing various tasks during an aircraft turnaround process with high realism, detailed scenarios, and a serious approach. [26]

Table 2.4: Airport Ground Handling Simulator VR

2.3.1.4 Virtual Maintenance Trainer

No	Patented Product	Product Summary
1	**Figure 2.23: Virtual Maintenance Trainer by L3HARRIS**	**Product Name:** Virtual Maintenance Trainer (VMT) **Published Date:** 2024 **Developer:** L3Harris Technologies **Description:** The Virtual Maintenance Trainer is a simulation-based training tool for aircraft maintenance. It allows technicians to explore virtual flight decks and aircraft systems, practice troubleshooting, and conduct simulated tests. Designed to enhance safety, efficiency, and cost-effectiveness, it supports various maintenance and training certifications like EASA Part 66. Features include an instructor operating station, virtual flight decks, and computer-based training modules. [27]

Table 2.5: Virtual Maintenance Trainer

2.3.2 Recent Market Products

2.3.2.1 Microsoft Flight Simulator

No	Market Product	Product summary
1.	 **Figure 2.24: Flight Simulator VR (Xbox.com, n.d.)**	**Product Name:** Microsoft Flight Simulator **Published dates**: December 22, 2020. **Developer**: Asobo Studio **Description**: Utilises modern technologies to deliver a remarkably authentic and realistic flying experience. Professionals in aviation use the simulator for training as well as flight lovers.

Table 2.6: Microsoft Flight Simulator in Virtual Reality

A widely known and very advanced flight simulation program is Microsoft Flight Simulator. Utilizing the latest technologies, Asobo Studio's creation, published by Xbox Game Studios, offers a remarkably realistic and immersive flying experience. Three main objectives that guided the development of Microsoft Flight Simulation are accuracy, authenticity of flight, and realism.

2.3.2.2 Aircraft De-Icing VR Training

No.	Market Product	Product Summary
1.	 **Figure 2.25: De-icing Training Sensus VR (VirtualRealityMarketing.com, n.d.)**	**Product Name:** Sensus Virtual Reality De-icing Training **Published Date:** 27 September 2022 **Developer:** Insulation Netforms **Description:** The Sensus VR tool offers two modes: guided training with visual options and assessment mode without hints, which tests the trainee's knowledge and decision-making abilities. This simulation improves practical training by providing repetitive practice without the costs and limits of real-world de-icing operations.

Table 2.7: Aircraft De-Icing VR Training

2.3.2.3 VR Aircraft Inspection

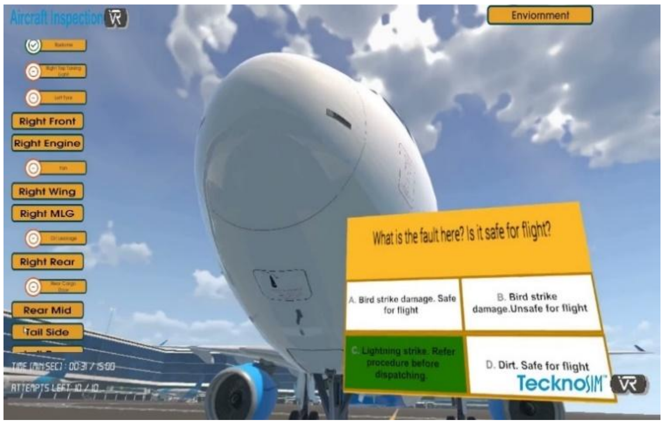
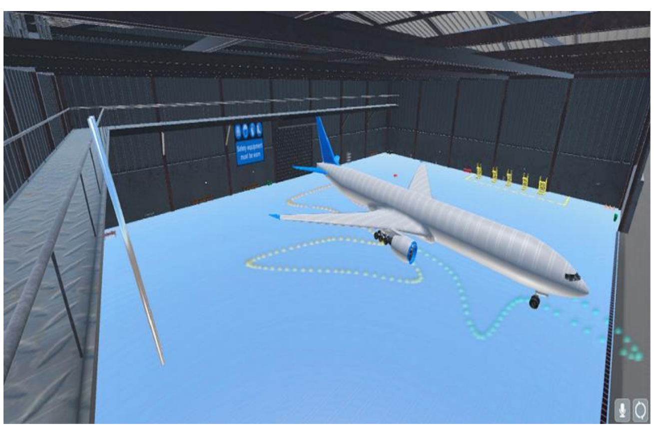
No	Market Product	Product Summary
1	 **Figure 2.26: TecknoSIM VR Aircraft Inspection (Tecknotrove.com, 6 Apr 2021)**	**Product Name:** TecknoSIM VR Aircraft Inspection **Published Date:** 27 July 2020 **Developer:** Tecknotrove **Description:** TecknoSIM VR aircraft inspection is an effective tool designed to train ground handling staff on a faster turnaround time. The module has been introduced for training on pre-arrival, arrival, and pre-departure checks. The training also helps to manage and mitigate risks at airports. [10]
2	 **Figure 2.27: VR Aircraft Maintenance Training (SP.edu.sg, 25 Feb 2021)**	**Product Name:** VR Aircraft Maintenance Training **Published Date:** 25 February 2021 **Developer:** Singapore Polytechnic **Description:** This student-developed project with SIA Engineering Company simulates aircraft walk-around checks to help trainees identify defects on an aircraft. This environment provides trainees with practice at their convenience without any negative consequences to the actual aircraft and hangar. [11]

Table 2.8: VR Aircraft Inspection

2.3.2.4 VR Boeing 737 Next Gen Thrust Reverser Opening Procedure

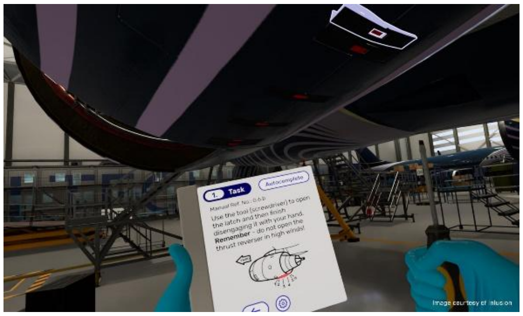
No	Market Product	Product Summary
1.	 **Figure 2.28: VR Boeing 737 Next Gen Thrust Reverser Opening Procedure (Inlu.net, 20 Sep 2019)**	**Product Name: VR Boeing 737 Next Gen Thrust Reverser Opening Procedure** **Published dates**: 20 September 2019 **Developer**: Inlusion Netforms **Description**: Develop to ensure that users comply with the process specified by the aircraft repair manual. The objective is to minimize maintenance errors, enhance aviation safety, and lower training costs by providing a realistic and immersive training environment.

Table 2.9: VR Boeing 737 Next Gen Thrust Reverser Opening Procedure

2.4 COMPARISON BETWEEN RECENT RESEARCH AND CURRENT PROJECT

2.4.1 VRCTT VS Microsoft Flight Simulator VS Patented Product

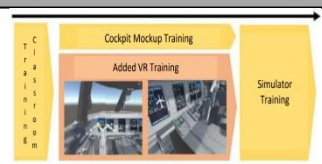
Product	Japan Airline (JAL) Innovation Lab (Patented Product)	Microsoft Flight Simulator (Current Product)	VRCTT (Our Product)
Design			
Content Type	Realistic 360° video-based VR training for pilots and cabin crew	Offers a comprehensive and highly realistic flying experience, with an emphasis on detail, accuracy, and immersion	Gaining practical knowledge for composite repair and recognizing issues that arise in the process
Scenarios	Flight safety drills, emergency handling, and operations training	Variety of flight situations, including landings and takeoffs, emergencies, and weather.	Various repair scenarios, including damage evaluation, material application, and repairing processes.
Simulated Environment	Aircraft cockpit, cabin scenarios in full VR	Global terrain rendering and integration of real-time weather data.	Simulation of workshop environments and real-world conditions affecting repairs.

Table 2.10: Comparison between VRCTT and Microsoft Flight Simulator and Patented Product

2.4.2 VRCTT VS Sensus VR De-icing Training VS VR Maintenance Training

Project	VR Maintenance Training (Patented Product)	Sensus VR De-Icing Training (Current Product)	VRCTT (Our Product)
Design			
Application	Developed to train in a simulated and immersive environment. Specifically for aviation operation like ground support equipment (GSE) training.	Understand deicing fluid varieties, application methods, timing, and safety standards to avoid ice accumulation on aircraft.	Highlights practical skills in identifying damage and deciding on acceptable repair procedures.
Content	Handling six types of ground support equipment (GSE), practicing maintenance procedures following safety standards and problem-solving quiz.	Operation of deicing equipment, fluid application procedures, weather evaluations, safety guidelines, and adherence to regulations	Precise repair instructions, properties of the material, damage testing, and safety precautions.
Technology & Interaction	Used Unity and integrated with Learning Management Systems (LMS) for real-time performance tracking.	Creates realistic deicing scenarios by simulating airport environs, aircraft, and weather conditions using virtual reality.	Uses VR simulation to generate accurate repair scenarios, which frequently include tools and material in the field.

Table 2.11: Comparison between VRCTT, Sensus VR De-icing Training and VR Maintenance Training

2.4.3 Airport Ground Handling Simulator VR VS TecknoSIM VR Aircraft Inspection VS VRCTT

Product	Airport Ground Handling Simulator VR (Patented Product)	TecknoSIM VR Aircraft Inspection (Current Product)	VRCTT (Our Product)
Design			
Purpose	To train users in airport ground handling tasks with high realism and detail.	To visually inspect the aircraft for any signs of damage, wear, or anomalies.	To detect and repair defects in composite materials using tap testing for delamination and other issues.
Procedure	Perform tasks like ramp checks, marshalling, and equipment connections in various scenarios and conditions.	Walkthrough or fly-around simulation, visual examination of aircraft surfaces for damage or wear.	Simulated tap testing on composite surfaces, listening to sound variations to detect defects.
Applications	Training ground crew for aircraft turnaround processes, improving operational efficiency and safety.	General aircraft inspections, routine maintenance checks, pre-flight checks.	Repair and maintenance of composite materials in aircraft, focused inspections of known or suspected problem areas.

Table 2.13: Comparison between Airport Ground Handling Simulator VR, TecknoSIM VR Aircraft Inspection and VRCTT

2.4.4 Virtual Maintenance Trainer VS VR Boeing 737 Next Gen Thrust Reverser Opening Procedure VS VRCTT

Product	Virtual Maintenance Trainer (Patented Product)	VR Boeing 737 Next Gen Thrust Reverser Opening Procedure (Current Product)	VRCTT (Our Product)
Design			
Application	Used for aircraft maintenance training to improve technical proficiency, safety, and operational readiness.	The objective is to train technicians on each procedure involved in safely opening and closing the thrust reverser on a Boeing 737 Next Generation aircraft, ensuring that they adhere to the proper safety standards and procedures.	The project focuses on training users to repair composite structures in aircraft. This involves damage identification procedures and an understanding of composite repair processes.
Content	Includes virtual flight decks, aircraft systems simulations, an instructor station, and interactive training modules aligned with certifications like EASA Part 66.	Focuses on the thrust reverser, particularly the system mechanical procedures, safety inspections, and operational specificity.	Highlights hands-on skills for composite material repair, such as inspection.
Scenarios & Variability	The tool offers diverse scenarios simulating real-life maintenance tasks, emergencies, and operational tests, allowing variability in equipment types, system faults, and maintenance environments for comprehensive skill-building.	Follows an exact procedure; however, there may be variances, such as identifying common challenges or dealing with unexpected problems.	Consist of a wide range of damage conditions, from minor surface breakages to major structural damage.

Table 2.14: Comparison between Virtual Maintenance Trainer VS VR Boeing 737 Next Gen Thrust Reverser Opening Procedure VS VRCTT

CHAPTER 3

RESEARCH METHODOLOGY

3.1 PROJECT BRIEFING & RISK ASSESSMENT

3.1.1 Utilization of Polytechnic's Facilities

Polytechnics frequently offer practical, hands-on learning settings that are perfect for practicing and teaching maintenance methods. Students and instructors who are directly involved in aircraft maintenance studies might provide insightful input on your VRCTT project if you use polytechnics as a testing basis or even as first target markets. These organizations already have a technical focus and can offer valuable insights that will enable the VRCTT system be further improved and better suited to training needs in the real world.

3.1.2 Project Collaboration & Transfer of Technology

The VRCTT project was developed in a collaboration with Otaiz Solution and Asia Digital Engineering (ADE), using its technical expertise in virtual reality technology. This collaboration includes information, skills, and technology to develop and improve the system's operation and ensuring it meets real-world training requirements.

1. **Information**

   Our team, Otaiz Solution and ADE collaborated through ongoing discussions and technical talks in order to exchange information. Here, we discuss about essential data such as tap test procedures, safety precautions and programming skills to develop VR environment and tap test simulation in Unity.

2. **Collaborative Development and Testing**

   This phase includes planning, implementation and testing product. Otaiz Solution also offer technical expertise to VR development which to improve VRCTT functionality and effectiveness.

3. **Technology Transfer**

   The collaboration allowed the transfer of advanced VR software development skills to our group. This involved using Unity as a development platform while developing technological means to simulate accurate tap test sounds. Through this transfer, our team gained the capability to enhance and maintain the VRCTT system.

   Asia Digital Engineering (ADE) supported this project and have provided valuable feedback on the VRCTT. ADE validated VRCTT potential to improve composite inspection training by recommending it as learning tool that make learning more engaging and effective.

3.2 OVERALL PROJECT GANTT CHART

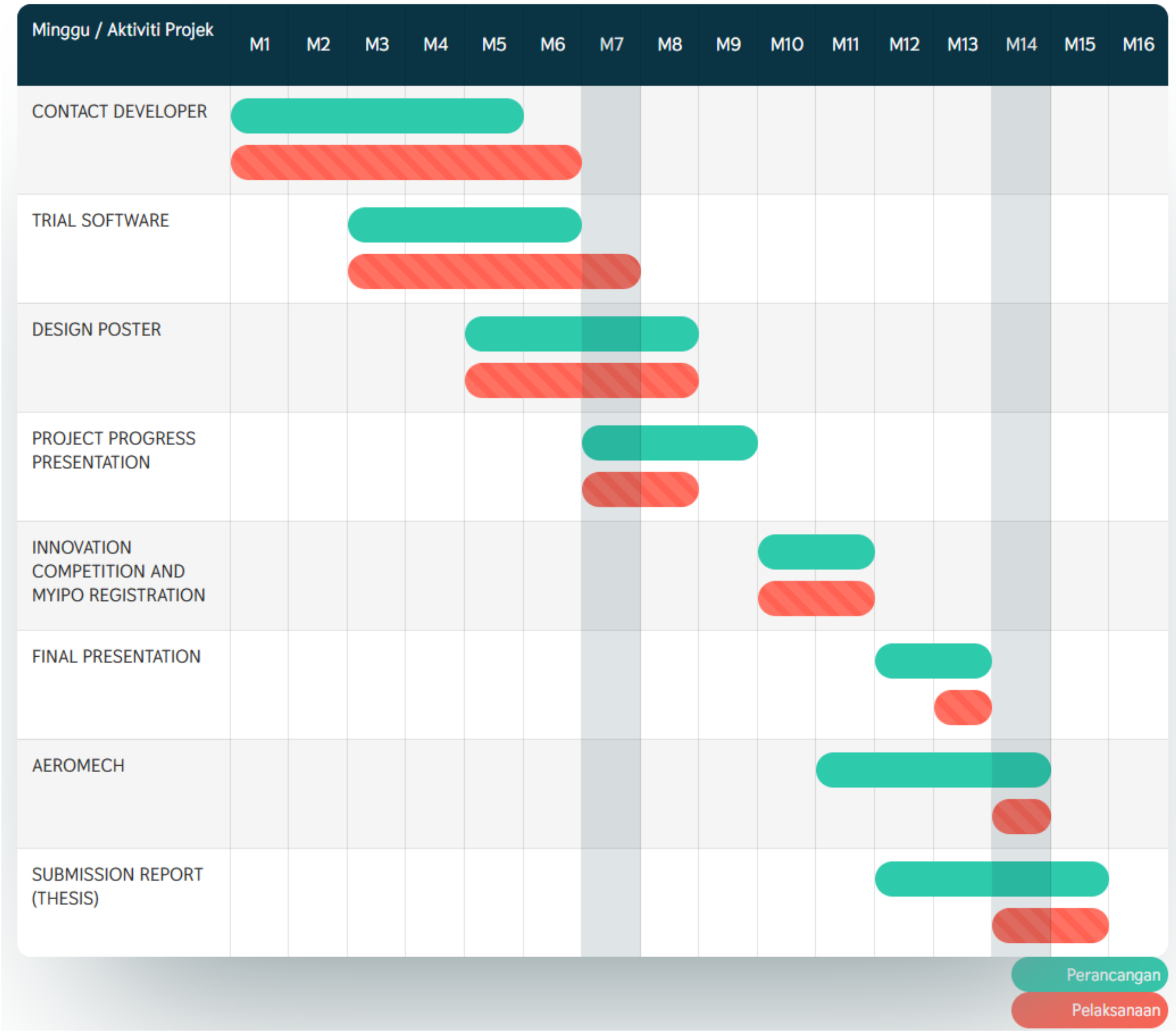


Figure 3.1: Gantt Chart

3.3 PROJECT FLOW CHART

3.3.1 Overall Project Flow Chart

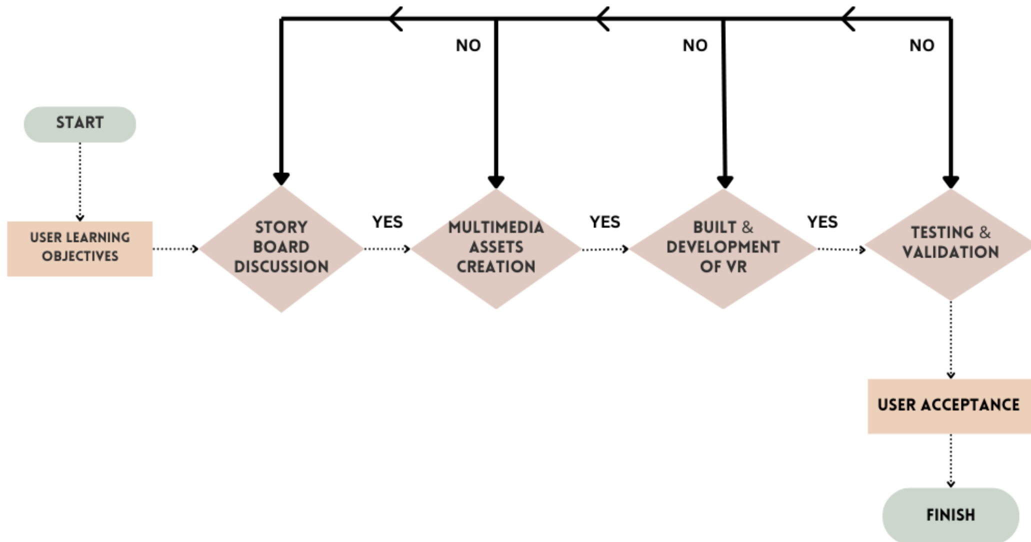


Figure 3.2: VRCTT Flowchart

3.3.2 SPECIFICS PROJECT DESIGN FLOWCHART/ FRAMEWORK

3.3.2.1 Product Structure

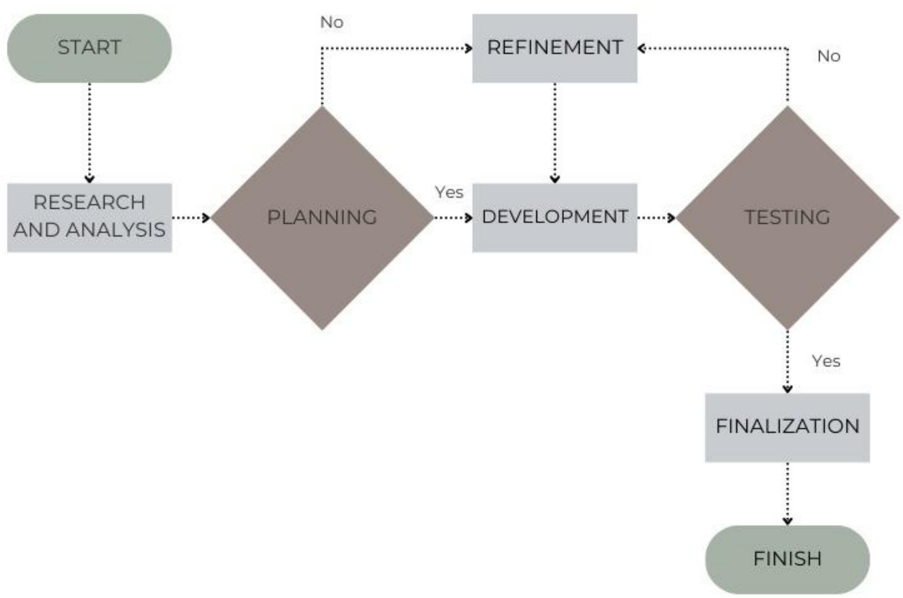


Figure 3.3: Product Structure Flowchart

3.3.2.2 Product Mechanism

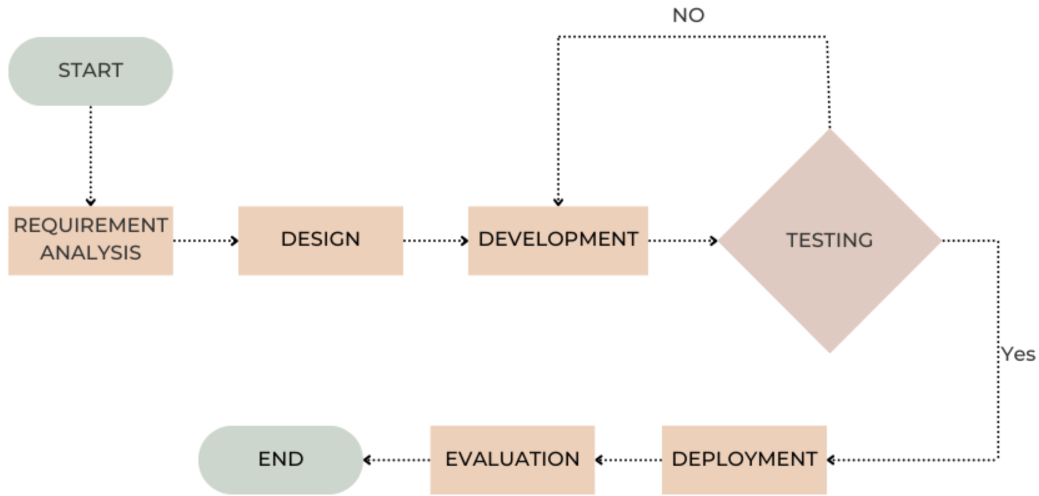


Figure 3.4: Product Mechanism Flowchart

3.3.2.3 Software / Programming

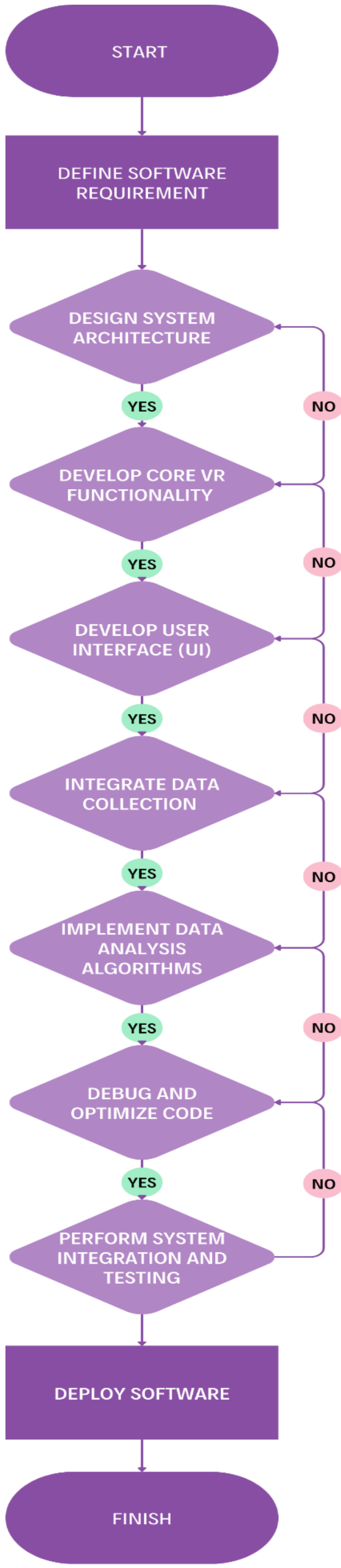


Figure 3.5: Software/ Programming Flowchart

3.3.2.4 Accessories & Finishing

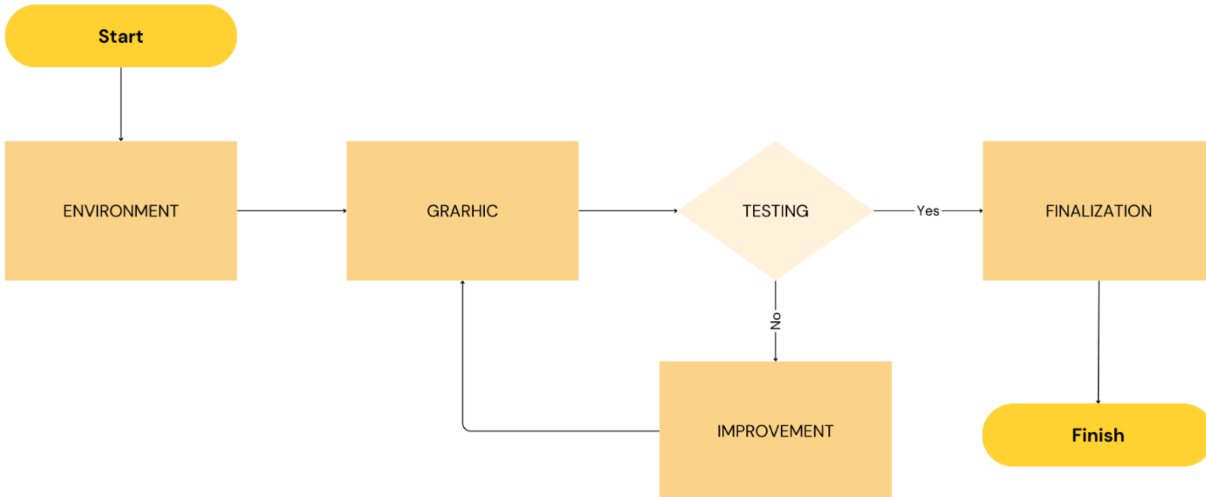


Figure 3.6: Accessories & Finishing Flowchart

3.4 DESIGN ENGINEERING TOOLS

3.4.1 DESIGN REQUIREMENT ANALYSIS

3.4.1.1 Questionnaire Survey

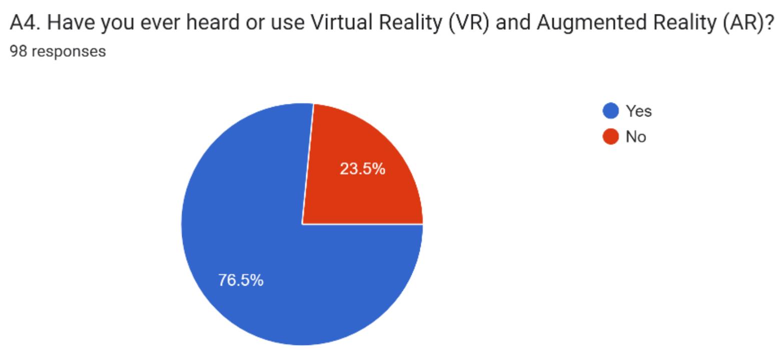


Figure 3.7: Respondents' Demographic

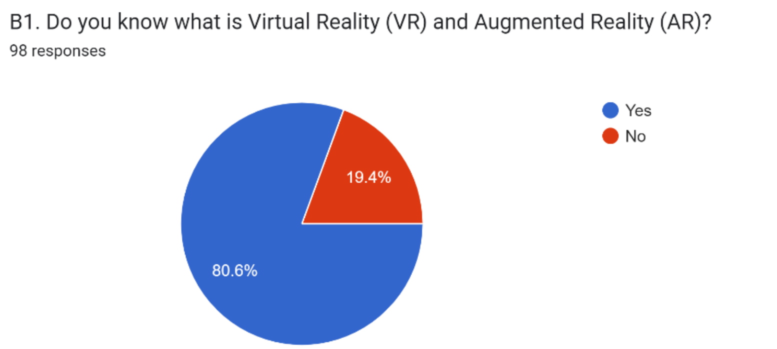


Figure 3.8: Respondents' VR and AR Knowledge

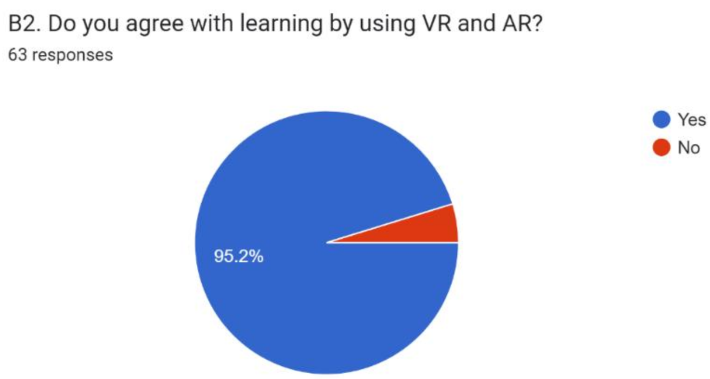


Figure 3.9: Respondents' Agreement on Learning with VR and AR

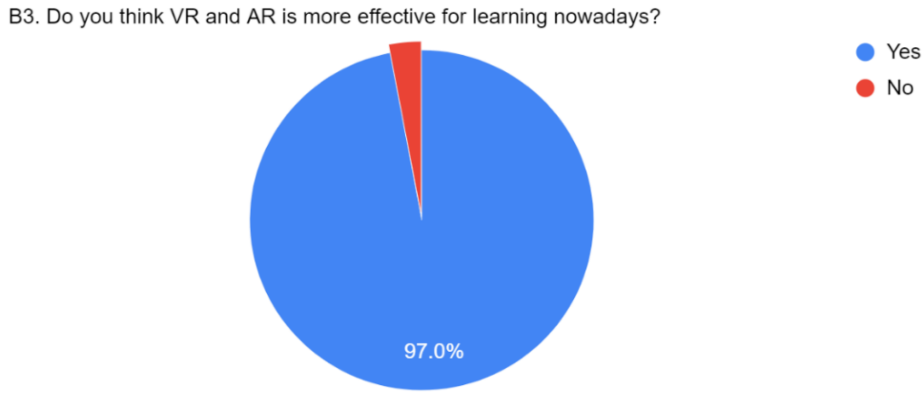


Figure 3.10: Respondents' Understanding of VR and AR Effectiveness

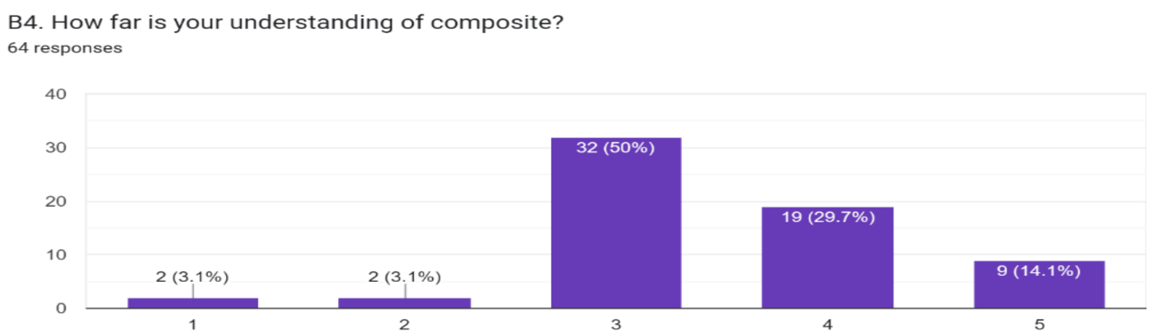


Figure 3.11: Respondents' Knowledge of Composite

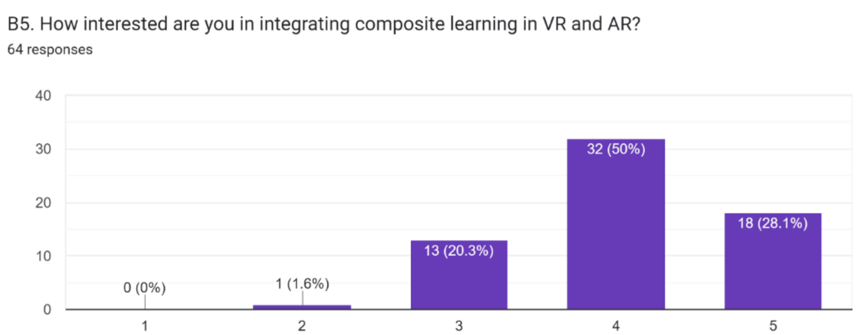


Figure 3.12: Respondents' Interest in Learning Composite with VR and AR

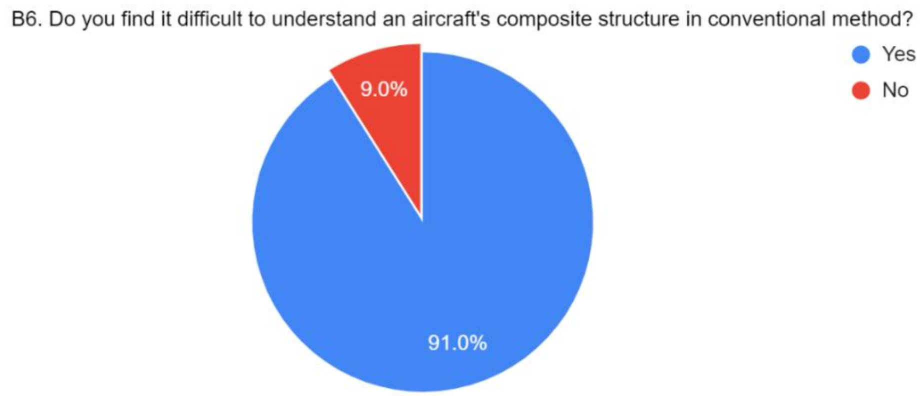


Figure 3.13: Respondents' Understanding of Composite in Conventional Methods

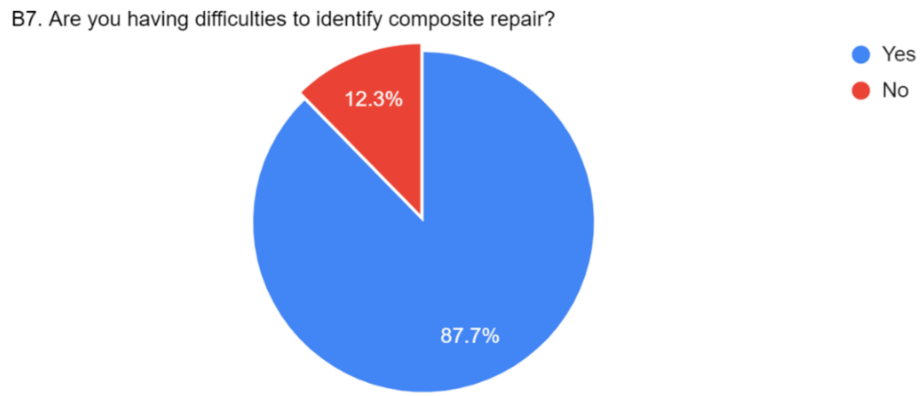


Figure 3.14: Respondents' Ability to Identify Composite Repairs

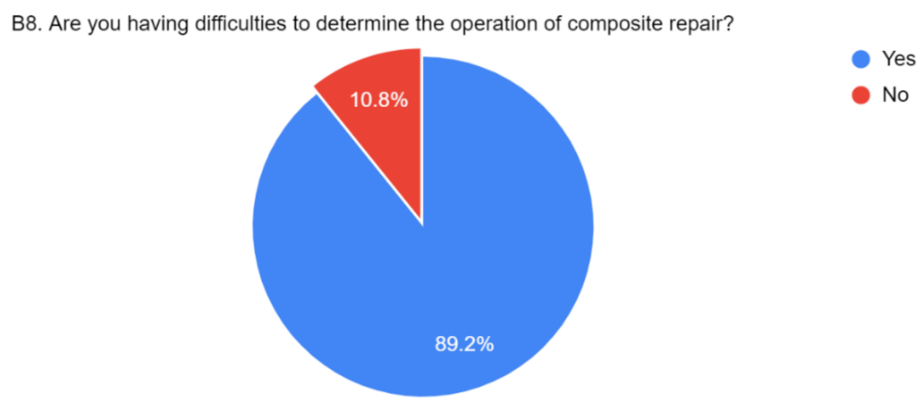


Figure 3.15: Respondents' Understanding of the Operation of Composite Repair

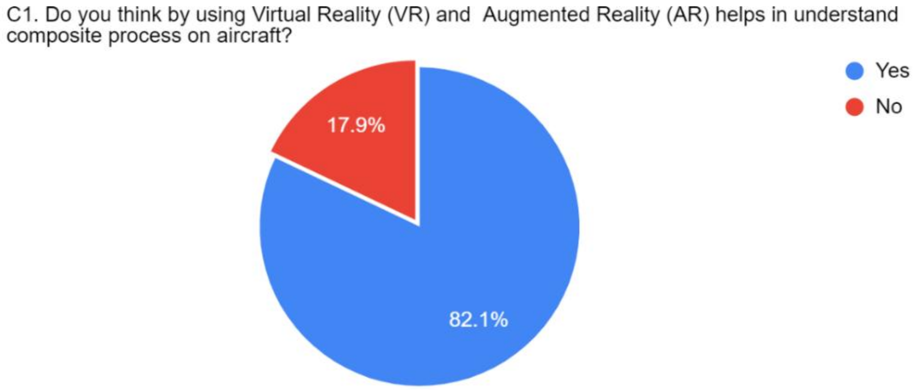


Figure 3.16: VR and AR Improve Understanding of Aircraft Composites Processes

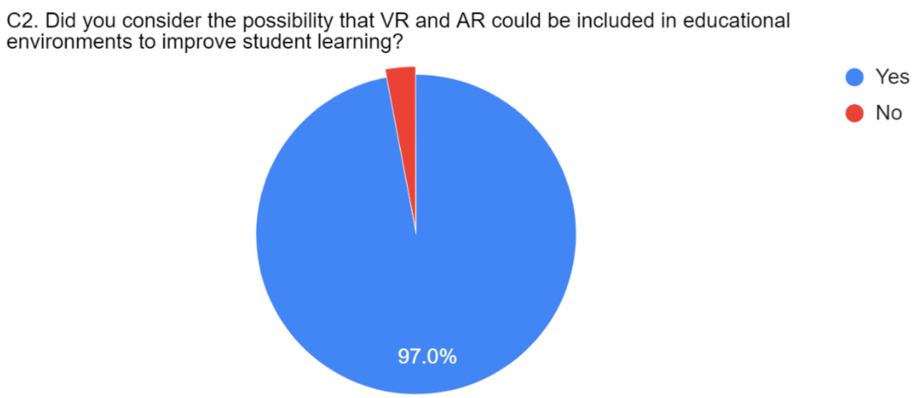


Figure 3.17: VR and AR Enhance Student Learning in Educational Settings

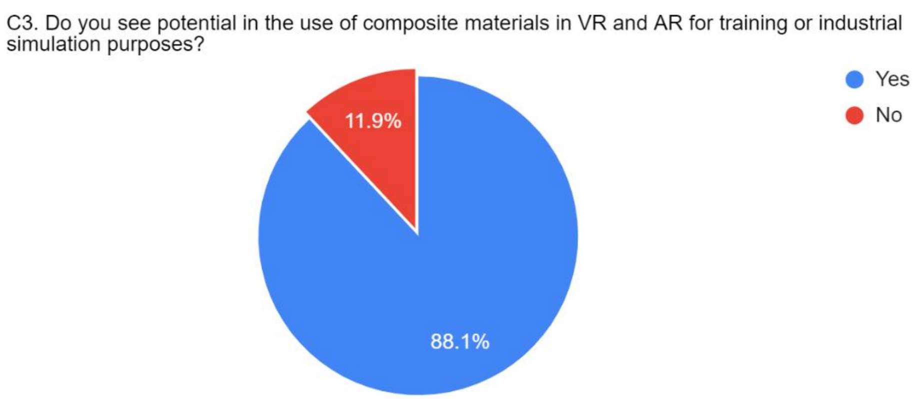


Figure 3.18: Composite Materials in VR and AR for Training and Industrial Simulation

3.4.1.2 Pareto Diagram

Conventional Method

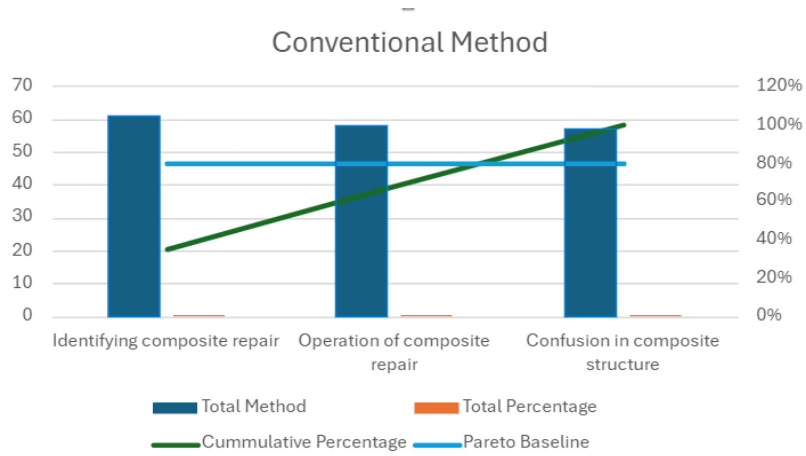


Figure 3.19: Pareto Diagram (Conventional Method)

According to the pareto diagram, most of our respondents have difficulty identifying composite repairs on aircraft, which results in a total method of 61 and a cumulative percentage of 40%. The difficulty in identifying composite repairs could be attributed to a lack of training and knowledge in composite materials and repair procedures. Respondents also have difficulty determining the operation of composite repair. This shows in the pareto diagram that the total method is 58 and the cumulative percentage is 68%. Understanding the operation is critical to ensuring the repaired components' effectiveness and safety. Lastly, a minority of our respondents, whose total method is 57 and their cumulative percentage is 100%, are facing problems understanding the composite structure of aircraft due to confusion. These challenges may cause delays in repairing damaged composite materials as well as quality issues, since misunderstandings about composite repair procedures can result in insufficient repairs.

Impact of VR

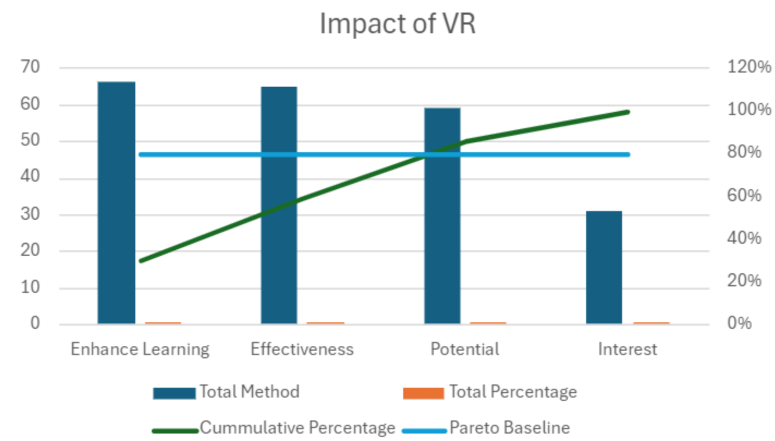


Figure 3.20: Pareto Diagram (Impact of VR)

Referring to this pareto diagram, it shows that most respondents agree that VR enhances learning. We can see that the result of the total method is 66, and the cumulative percentage is 30%. This could be because the VR can precisely imitate varied composite repair situations, such as different types of damage and surface conditions. Next, many of our respondents also agree that VR is an effective way of understanding composite structures. It shows in the pareto data that the total method of effectiveness is the second highest. Some of our respondents agree that VR's immersive and interactive nature has the potential for enhancing learning in composite structures. This results in a pareto diagram with 56 total methods and a cumulative percentage of 86%. Considering that virtual reality provides a safe learning environment in which users can practice challenging techniques and procedures without risking damage to expensive composite materials or equipment. Finally, a small percentage of our respondents thought VR composite learning was interesting. VR simulations allow hands-on practice without using actual objects or equipment. Users may interact with virtual composite components, perform repair processes, and view the results of their activities in real time, developing their practical skills in a secure environment

3.4.2 Design Concept Generation

3.4.2.1 Function Tree

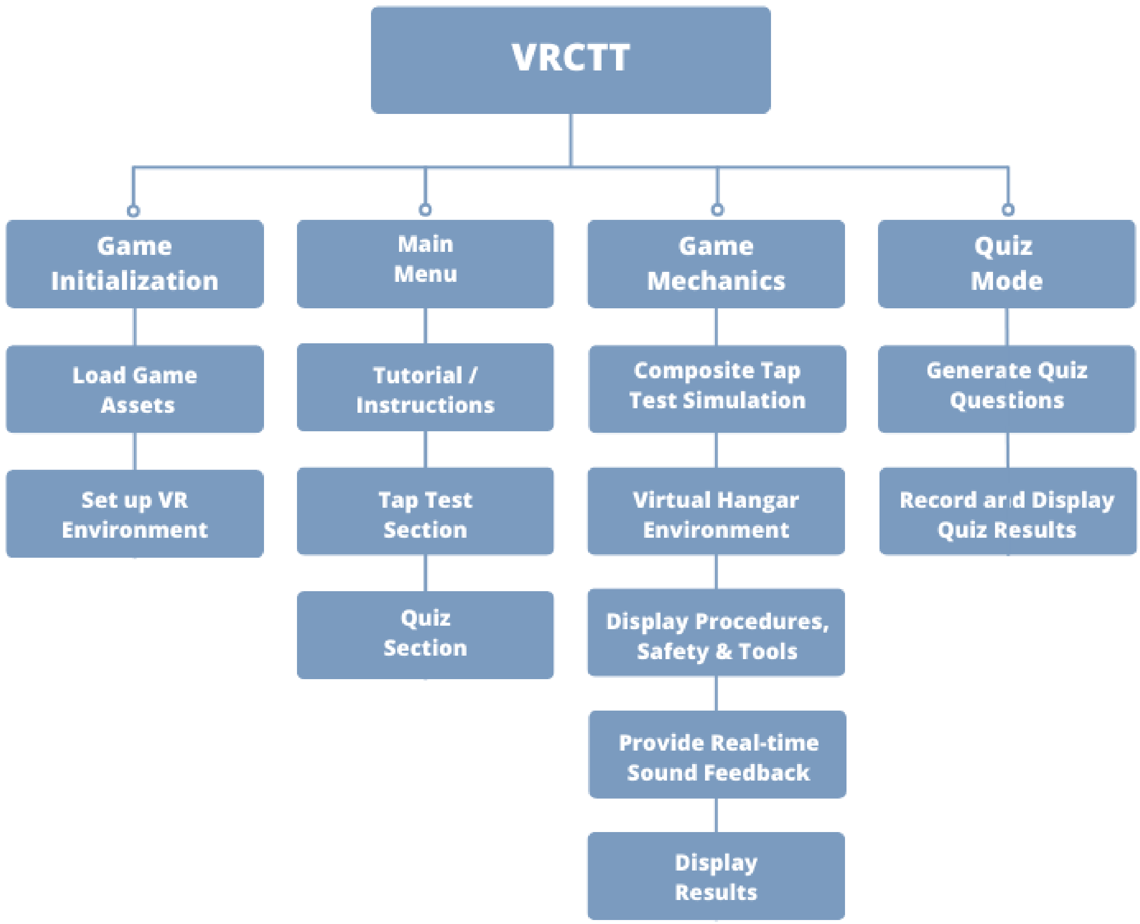


Figure 3.21: Function Tree

3.4.2.2 Morphological Matrix

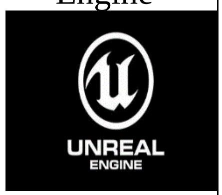
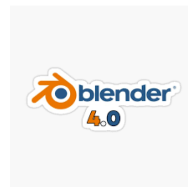
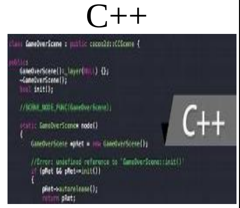
FUNCTION	IDEA 1	IDEA 2	IDEA 3	IDEA 4
TYPE	Game 	Game 	Scenery 	Game 
SOFTWARE	Unreal Engine 	Oculus Medium 	Blender 4.0 	Unity 
HARDWARE	Motion Controllers 	Vive XR Elite 	Oculus Quest 2 	Valve Index 
PROGRAMMING LANGUAGE	Phyton 	C++ 	Java 	C# 
INTERACTION	Hand Movement 	Hand Movement 	Hand Movement 	Hand Movement 

Table 3.1: Morphological Matrix

3.4.2.3 Proposed Design Concept 1

FUNCTION/FEATURES	IDEATION	JUSTIFICATION
TYPE	Game	Learning using games
SOFTWARE	Unreal Engine	Popular VR app nowadays and it's used for creating high quality VR application and games
HARDWARE	Motion Controllers	Enable to interact and manipulate object
PROGRAMMING LANGUAGE	Python	Its readability and ease of use
INTERACTION	Hand Movement	Need the movement of hand to control the hand movement in VR

Table 3.2: Proposed Design Concept 1

3.4.2.4 Proposed Design Concept 2

FUNCTION/FEATURES	IDEATION	JUSTIFICATION
TYPE	Game	Learning by playing game
SOFTWARE	Oculus Medium	Offers the ability to produce abstract art, organic shapes & complex character.
HARDWARE	HTC Vive XR Elite	Super lightweight and comfy
PROGRAMMING LANGUAGE	C++	Much easier to manipulate code
INTERACTION	Hand Movement	Easy to control for beginner

Table 3.3: Proposed Design Concept 2

3.4.2.5 Proposed Design Concept 3

FUNCTION/FEATURES	IDEATION	JUSTIFICATION
TYPE	Scenery	Learning by watching video
SOFTWARE	Blender 4.0	Introduce incredible features but breaking compatibility with certain hardware
HARDWARE	Oculus Quest 2	Allows user to easily move around their environment and provide an excellent VR experience
PROGRAMMING LANGUAGE	Java	Fairly easy to learn
INTERACTION	Hand Movement	Just move your hand around to also move the virtual cursor

Table 3.4: Proposed Design Concept 3

3.4.2.6 Proposed Design Concept 4

FUNCTION/FEATURES	IDEATION	JUSTIFICATION
TYPE	Games	Learning by playing a game
SOFTWARE	Unity	Unity's versatile tools, extensive documentation and large community
HARDWARE	Valve Index	Exceptional display quality, comfort and advanced tracking capabilities provide a high-end VR experience for immersive gaming
PROGRAMMING LANGUAGE	C#	Offering a powerful yet beginner-friendly approach to building complex VR game logic and interactions
INTERACTION	Hand Movement	Allowing players to realistically interact with the virtual environment in VR games.

Table 3.5: Proposed Design Concept 4

3.4.2.7 Summary of Accepted Concept

Final Concept Selection

FUNCTION/FEATURES	IDEATION	JUSTIFICATION
TYPE	Games	Learning by playing a game
SOFTWARE	Unity	Unity's versatile tools, extensive documentation and large community
HARDWARE	Oculus Quest	Allows user to easily move around their environment and provide an excellent VR experience
PROGRAMMING LANGUAGE	C++	Much easier to manipulate code
INTERACTION	Hand Movement	Need the movement of hand to control the hand movement in VR

Table 3.6: Final Concept

Finally, we are using games for the Type. It's because nowadays learning using games is more effective than watching video. Second, we are choosing Unity for the Software because it’s much easier to understand and not very complicated. Next, we are using Oculus Quest for Hardware because it’s very familiar hardware and worldwide hardware. After that, we chose C++ for the Programming Language cause it’s much easier to manipulate code than the other. Lastly, we agree to do Hand Movement for the Interaction. Allowing players to realistically interact with the virtual environment in VR games.

3.4.3 Evaluation & Selection of Conceptual Design

Pugh Matrix

3.4.3.1 Pugh Matrix Concept 1 As A Datum

FUNCTION	FACTOR	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4	CONCEPT 5
Type	0.3	**D**	3	2	3	3
Software	0.5	**A**	3	3	3	3
Hardware	1.0	**T**	2	3	2	3
Programming language	1.0	**U**	3	2	1	3
Interaction	0.2	**M**	2	2	2	3
Total Score	2		7.8	7.5	5.8	9
Ranking			2	3	4	1

Scale 1 (Lowest/Hardest),3 (Highest/Easier)

Table 3.7: Pugh Matrix Concept 1 As A Datum

3.4.3.2 Pugh Matrix Concept 2 As A Datum

FUNCTION	FACTOR	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4	CONCEPT 5
Type	0.3	0.3	**D**	0.2	0.3	0.3
Software	1	0.3	**A**	0.2	0.4	1
Hardware	0.3	0.2	**T**	0.2	0.1	0.3
Programming Language	0.2	0.2	**U**	0.1	0.1	0.2
Interaction	0.2	0.2	**M**	0.2	0.2	0.2
TOTAL SCORE	2	1.2		1	1.1	2
RANKING		2		4	3	1

Scale 0.1 (Lowest / Hardest), 1 (Highest / Easier)

Table 3.8: Pugh Matrix Concept 2 As A Datum

3.4.3.3 Pugh Matrix Concept 3 As A Datum

FUNCTION	FACTOR	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4	CONCEPT 5
Type	0.3	3	3	**D**	3	3
Software	0.2	2	1	**A**	3	3
Hardware	0.2	1	2	**T**	2	3
Programming Language	0.1	1	3	**U**	1	3
Interaction	0.2	3	3	**M**	3	3
TOTAL SCORE		2.2	2.4		2.6	2.7
RANKING		4	3		2	1

Scale 1 (Lowest / Hardest), 3 (Highest / Easier)

Table 3.9: Pugh Matrix Concept 3 As A Datum

3.4.3.4 Pugh Matric Concept 4 As A Datum

FUNCTION	FACTOR	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4	CONCEPT 5
Type	0.2	3	**3**	2	**D**	3
Software	1.0	1	**2**	3	**A**	3
Hardware	1.0	2	**3**	3	**T**	3
Programming Language	0.2	1	**3**	2	**U**	3
Interaction	0.5	2	**3**	2	**M**	3
TOTAL SCORE		4.8	7.7	7.8		8.7
RANKING		4	3	2		1

Scale 1 (Lowest / Hardest), 3 (Highest / Easier)

Table 3.10: Pugh Matric Concept 4 As A Datum

3.5 PRODUCT DRAWING / SCHEMATIC DIAGRAM
3.5.1 General Product Drawing

After entering into the Unity app, there will be an interface layout which contains three main options for the user for using the app. It contains video to differentiate the good and bad sound, tap test section and quiz section. For the tap test section, we have developed 3D model of Learjet 45, tool crib and tap test hammer and also, we have whiteboard beside the tool crib to show infographic of safety, tools and instruction.

3.5.2 Specific Part Drawing / Diagram
3.5.2.1 Product Structure

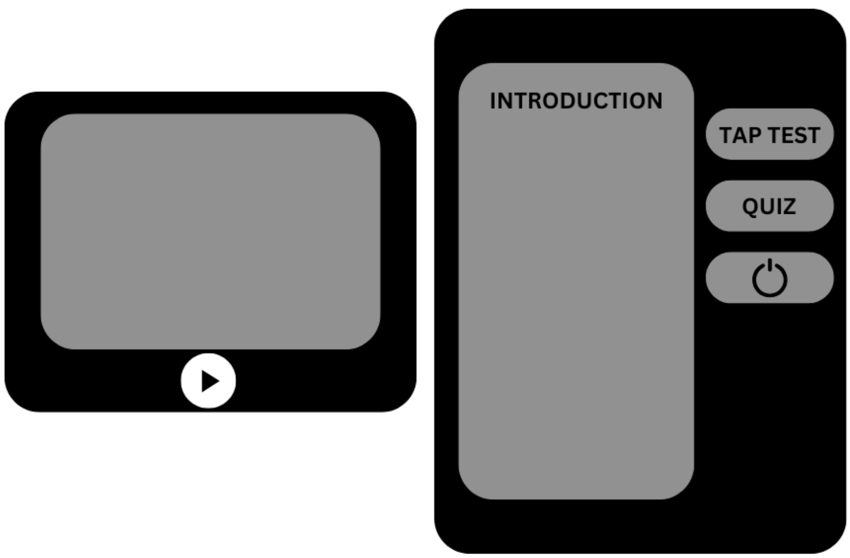


Figure 3.22: Interface Drawing

3.5.2.2 Product Mechanism
Aircraft Composite Tap Test Inspection Points

Figure 3.23: Aircraft Composite Tap Test Inspection Points Drawing

3.5.2.3 Whiteboard Display of Safety Precautions, Tools and Procedures with Tool Crib

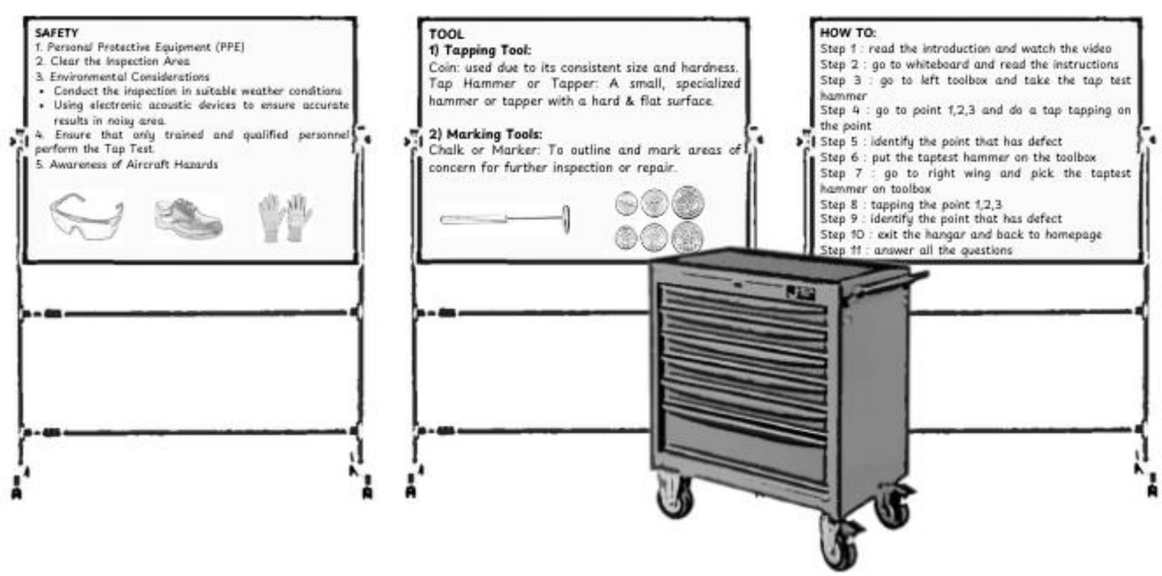


Figure 3.24: Whiteboard Display of Safety Precautions, Tools, and Procedures with Tool Crib Drawing

3.5.2.4 Quiz section in VRCTT

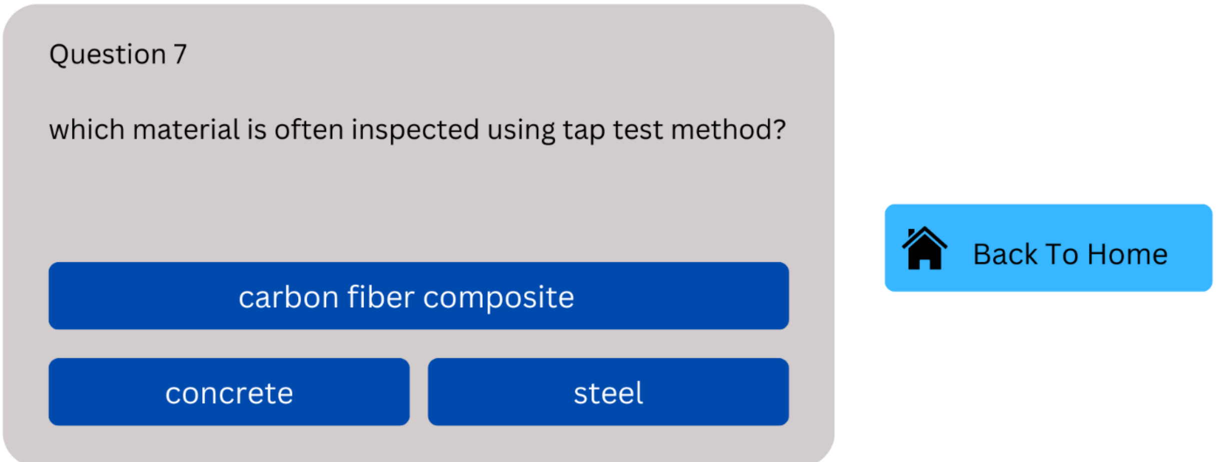


Figure 3.25: Quiz Section Drawing

3.6 PROTOTYPE / PRODUCT MODELLING

3.6.1 Prototype / Product Modelling

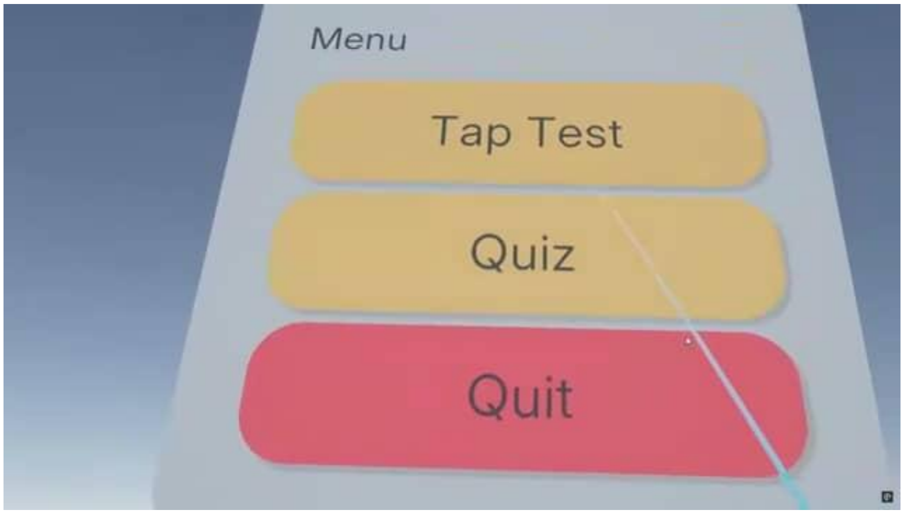


Figure 3.26: Menu Page Prototype

A minimalist menu page design with a straightforward interface, offering no additional elements or dimensions. It allows users to directly access the tap test simulation, providing an efficient and user-friendly way to initiate the composite tap test simulation.

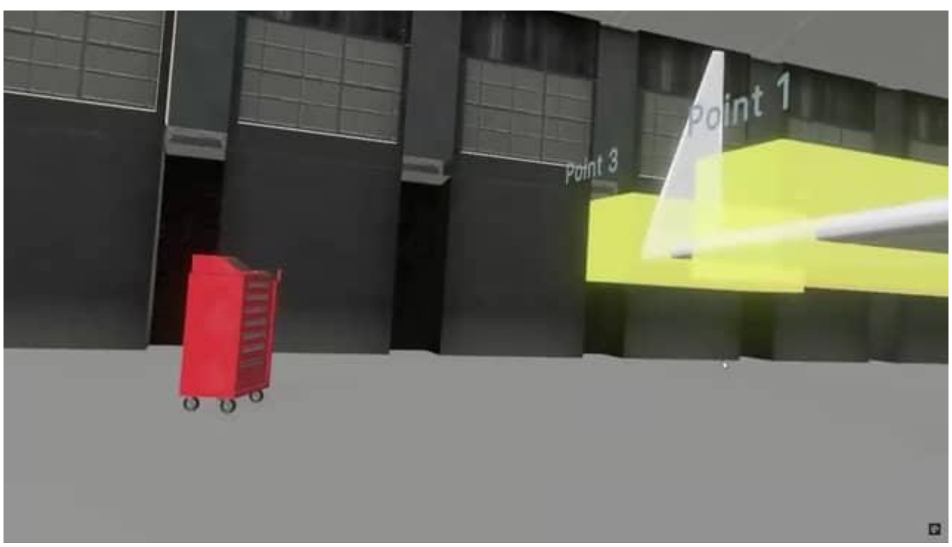


Figure 3.27: Tool Crib Area Prototype

The spacious area near the tool crib allows users to move freely during the tap test simulation. This open layout provides easy access to tools and improves the overall user experience during the simulation.

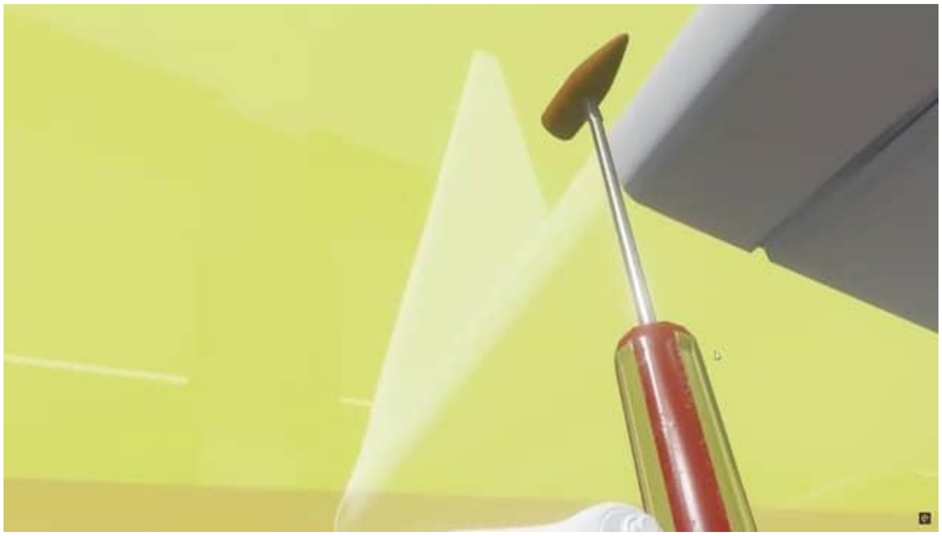


Figure 3.28: Tap Test Hammer Prototype

A simple yet functional tap test hammer designed to simulate real-world conditions effectively. When used, the hammer produces distinct tapping sounds, enabling users to identify whether a specific point on the composite has a defect or not.

3.6.2 Prototype Development

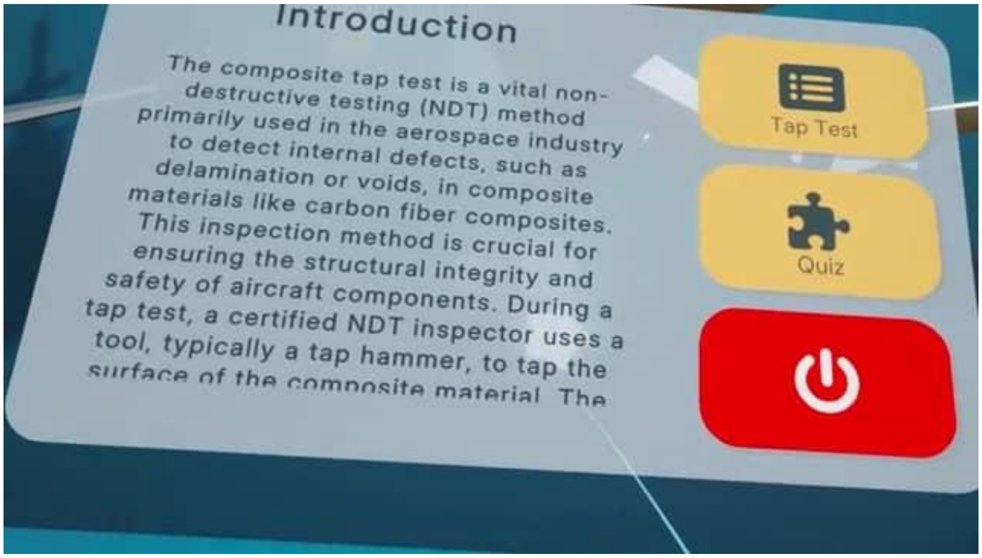


Figure 3.29: Menu Page Development

The menu page has been significantly improved by including a detailed introduction about aircraft composites and the tap test process. Additionally, an instructional video has been added, allowing users to watch the actual procedure for determining defective sounds. These enhancements provide users with valuable context and a clearer understanding before entering the simulation.

Figure 3.30: Tool Crib Area Development

The area near the tool crib now features whiteboards displaying critical information, such as safety precautions, required tools, and composite tap test procedures. This strategic placement makes it more convenient for users to follow the provided guidelines, ensuring they perform the simulation accurately and efficiently.

Figure 3.31: Tap Test Hammer Development

The tap test hammer has been upgraded to appear more realistic, both visually and functionally. The tapping sound is now clearer and more lifelike, further immersing users in the simulation by accurately distinguishing between defective and non-defective points on the composite material.

3.7 DEVELOPMENT OF PRODUCT

3.7.1 Material Acquisition

Material	Purpose	Source
VR Headset **(Oculus Quest 2)**	Provide immersive experiences for user.	
Software Development Tool **(Unity)**	Tool needs to develop the product.	
Programming Tools **(C++)**	Tools needed for programming.	
Sound Calibration Tool **(YouTube)**	Utilize this tool's audio and video to create a virtual reality environment.	
Quiz **(Word)**	Platform that used to develop quiz.	

Table 3.11: Material Acquisition

3.7.2 Machines and Tools

To develop the VRCTT system, we utilized a laptop for tasks such as designing, editing, and integrating 3D models, as well as organizing the notes we collected.

Figure 3.32: Laptop (NyTimes.com, n.d.)

The laptop offered greater flexibility compared to a smartphone, making it much easier to accomplish our work efficiently. In addition, we used the laptop to access various websites like Unity, Cidos, Canva, Word, and ChatGPT. These platforms played a crucial role in creating notes, quizzes, and 3D models for the project. We can confidently say that this device was one of the main factors behind the successful development of the VRCTT system.

Figure 3.33: HTC VIVE PRO 2 (Kengdim.com, n.d.)

We borrowed the VR equipment from the polytechnic in order to construct the VRCTT system. Testing and improving the project's virtual reality components required this VR equipment. Its cutting-edge gear such as the motion controllers and VR headset that allowed us to produce an engaging and dynamic experience for consumer.

3.7.3 Specific Project Fabrication

3.7.3.1 Phase 1 (Base Structure)

Phase 1's objective is to construct the VRCTT system's fundamental structure, which will act as the framework for combining the hardware and software elements required to replicate composite material tap testing in a virtual setting.

Design and Planning

The first step is to finalizing the design involve in our project for base structure. This includes a 3d model of Learjet 45, tool cribs, tap test hammer and whiteboard. To place user in realistic environment, this idea needs a location such as hangar.

Material Selection

We need a structural component that will be able to support the VR hardware including headset, controller while being lightweight and portable to bring anywhere.

Component Sourcing and Preparation

To keep costs down, we just download the existing 3D product from SketchFab for component acquisition and preparation. We also prepare the video for user to differentiate the sound of good and best for tap test.

Assembly of base structure

The interface layout begins with three buttons for user to choose which Quiz, Video and Tap Test. Upon selecting the Tap Test option, the user is transported into a virtual hangar environment to perform tap test. Inside the hangar, 3d model aircraft such as Learjet 45 are assembled alongside essential tool like tool crib. Additionally, a whiteboard place near hangar to provide instruction and information on how to engage with the game, ensuring users understand the purpose and process of the tap test simulation.

3.7.3.2 Phase 2 (Accessories & Mechanisms)

In Phase 2 of the VRCTT project, we worked on developing key interactive features and instructional components to improve the virtual learning environment. With Otaiz Solution's assistance and interaction, we added accessories and steps to the VR environment that allow users to complete a composite tap test and assess their understanding through a quiz.

1. **Tap test mechanism**

   Users perform a composite tap test by using a virtual tool which is tap hammer. To help users differentiate between key sounds during the exam, we included example tap test sounds from the Grumman Pilot YouTube channel. These sounds provide realistic aural cues that differentiate between the "dull" sound, which indicates potential damage, and the "sharp" sound, which indicates material integrity. This learning method assures that users are able to understand the results by imitating a real tap test procedure.

Figure 3.34: Tap Test from Grumman Pilot YouTube Channel (YouTube.com, 26 Sept 2022)

2. **Safety precautions on whiteboard**

   A virtual whiteboard in the environment shows important safety precautions, based on the instructional regulatory bodies commonly used in real-world maintenance situations. By highlighting security precautions, this mechanism trains users to acknowledge and follow basic safety practices before performing the tap test.

3. **Procedure instruction on whiteboard**

   The whiteboard also provides a step-by-step breakdown of the composite tap test procedure. This feature serves as an in-game reference, guiding users through the process from tool selection to interpreting audio feedback. The instructions ensure a structured approach to learning and help users gain confidence with the tap test sequence.

4. **Tool display**

   Illustrations of the coin and tap hammer are shown on the whiteboard, allowing users to acknowledge the tools required in tap test inspection. It gives users an accurate illustration of the tools, allowing them to recognize and comprehend their functionalities during the test method.

5. **Toolbox and ladder integration**

   A ladder and a toolbox serve as additional environmental features that offer realism to the virtual hangar scene. The ladder is positioned to create visual surroundings, and the toolbox contains important components found in a technician's tools, adding to the immersive atmosphere of the learning setting.

3.7.3.3 Phase 3 (Programming & Electrical Circuit)

In the VRCTT (Virtual Reality of Composite Tap Test) project, Phase 3 focuses on **Programming and Electrical Circuit** integration to ensure the system operates effectively and aligns with the project objectives.

1. **Programming Components:**

- VR Environment Creation: Design a virtual environment that replicates a hangar setting for user immersion.
- Interactive Tap Test Simulation: Program the tap tool with touch-sensitive interactions to simulate realistic tapping sounds.
- Defect Identification System: Integrate software algorithms that allow users to detect and analyse composite defects during the test.
- Data Visualization and Feedback: Implement features for visual and auditory feedback based on the tap test outcome, displaying defect location and severity.

2. **Software Tools and Platforms:**

- Use a VR development platform such as Unity compatible with VR hardware like the Oculus or HTC Vive.
- Programming languages such as C++.
- APIs for VR device compatibility to ensure smooth user interaction.

3. **Testing and Debugging:**

- Regularly test the VR application to ensure realistic response and feedback.
- Use feedback from initial tests to enhance interaction accuracy, adjust sound effects, and correct any interface glitches.

4. **User Interface (UI):**

- Create a user-friendly interface that guides users through each step of the tap test simulation.

- Add options for starting, back to home, or quiz, with easy navigation.

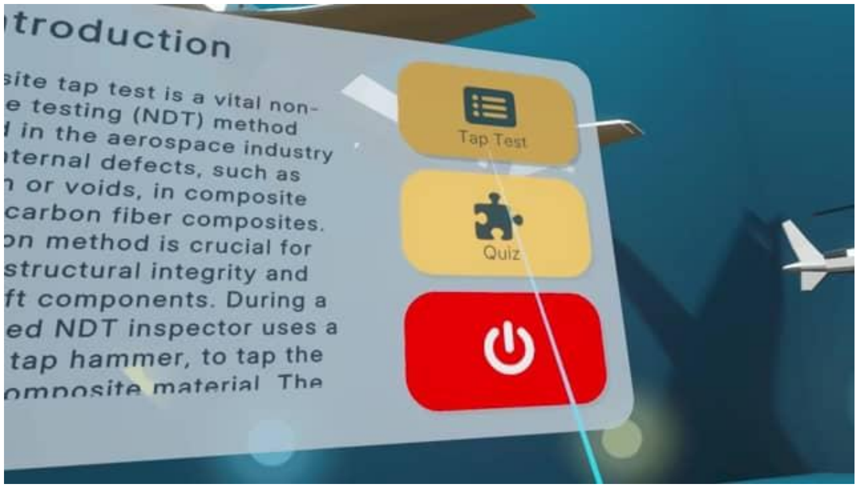


Figure 3.35: Start the Tap Test, Quiz and Close the Game Button Options

Figure 3.36: Back to Home Button Option

3.7.3.4 Phase 4 (Finishing)

1. **Questionnaire**

In VRCTT we put 10 questions at the introduction for users to answer for their knowledge about composite tap test. This question is based the pretest and posttest of the google form but we put the same question in the VRCTT to test their knowledge about tap test.

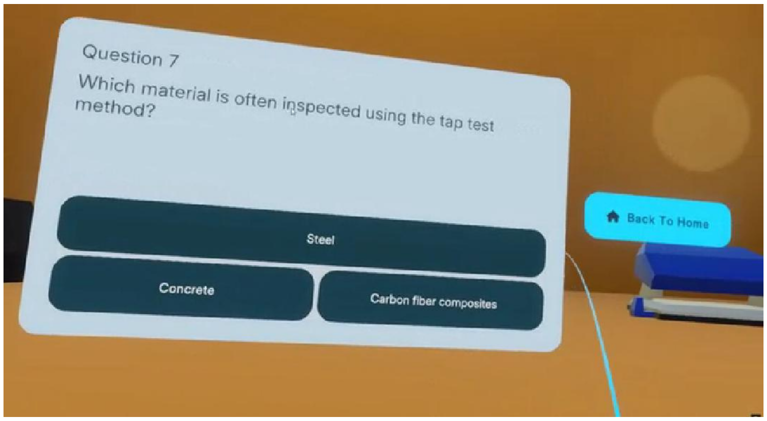


Figure 3.37: Quiz Section

2. **Video in introduction**

In this part we put a video of the different sound that occur when doing the tap test inspection on the composite structure. This video it tells the good sound and bad sound that occur. If the sound is sharp it means good, but if the sound is hollow it means bad.

Figure 3.38: Instruction Video at Introduction

3. Music background

For the music background we use a sound that's make user attract to play. This sound is a relaxed music and not disturb user when they watch the video. It also not disturbs the user when they started to play the tap test.

3.8 PRODUCT TESTING / FUNCTIONALITY TESTS

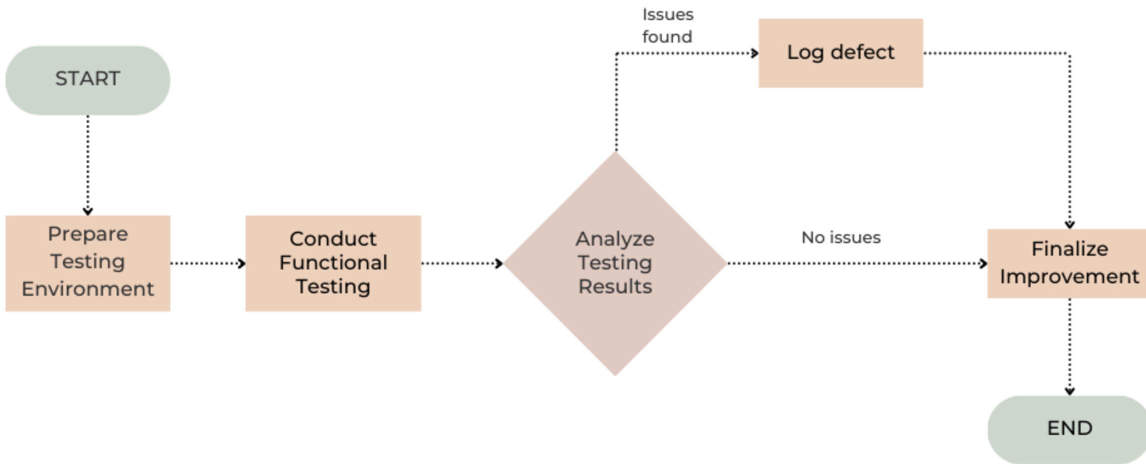


Figure 3.39: Product Testing Flowchart

To ensure the effectiveness and reliability of the VRCTT learning kit, we identified three critical elements for testing based on the product's objectives:

1. **Tap Test Simulation**

   This section evaluates the precision of the virtual tap test environment in replicating real-world settings. It measures the system's ability to replicate different sounds (dull/hollow and sharp) to ensure users are able to differentiate between them.

2. **Navigation in the Virtual Environment**

   Navigation is an important part of the VR environment. This feature evaluates how well users may navigate throughout the virtual hangar.

3. **Quiz Functionality**

   The quiz evaluates the knowledge gained by users after they complete performing tap test.

3.9 LIST OF MATERIALS & EXPENDITURES

	ITEMS	UNIT	PRICE/UNIT	TOTAL
1.	UNITY package (student)	1	RM 0.00	RM 0.00
2.	Canva	1	RM 0.00	RM 0.00
3.	Cidos	1	RM 0.00	RM 0.00
4.	Microsoft Word	1	RM 0.00	RM 0.00
5.	Sketchfab	1	RM 785.00	RM 785.00
6.	Kingston hyperx 8GB Memory RAM	1	RM 89.21	RM89.21
Total				**RM 874.21**

Table 3.12: List Of Materials & Expenditures

CHAPTER 4

RESULT & DISSCUSSION

4.1 PRODUCT DESCRIPTION

4.1.1 General Product Features & Functionalities

The VRCTT system uses virtual reality to enhance composite repair training by providing an immersive and interactive environment. It simulates a tap test, allowing trainees to detect inconsistencies in composite materials, such as cracks or delamination by tapping on virtual surfaces use tap test hammer. The hand-held device replicates the actual tap test tool, enabling users to practice and refine their skills in a safe, cost-effective, and repeatable virtual setting. This system helps students improve their ability to identify material flaws, preparing them for real-world composite repair tasks in industries like aerospace.

4.1.2 Specific Part Features

4.1.2.1 Product Structure

The development of the Virtual Reality Composite Tap Test (VRCTT) system combines a number of essential structural elements to produce an immersive, realistic testing environment. Every component is essential to allowing users to examine and engage with composite materials as though they were being handled physically. The system's primary structural elements are broken down in depth below.

1. VR Headset

The visual interface required to view the composite materials undergoing testing is provided by the VR headset, which is essential to the user's immersive experience. We use a standalone VR headset, such as the Oculus Quest 2, which was selected for its cost, performance, and user-friendliness.

Purpose: The user can engage with the composite material just like they were in a real-world situation by entering a completely virtual environment through the headset. The headset simulates a composite repair testing environment by providing users with a 360-degree view of the virtual world.

Field of View: The wide 90-degree field of view (FOV) offered by the Oculus Quest 2 increases immersion by giving the impression that the user is in the hybrid material's surroundings. A wider field of view (FOV) provides a more natural viewpoint and aids in distance measurement, which is essential for tasks requiring accuracy.

2. Handheld Devices (Simulated Tap Test Tool)

The VRCTT system contains a handheld device that replicates the tap testing instrument in order to replicate the actual procedure of performing a tap test on composite materials.

Shape and Design: The size and shape of the simulated tap tool are intended to resemble those of a conventional composite tap test tool. With a handle that simulates the feel like tap test hammer commonly used in tap testing. The soft-touch material and ergonomic design of the handle guarantee a comfortable grip even after extended use.

Functionality: As users "tap" on the virtual composite material, sensors and vibrating motors inside the handheld device combine to provide physical reactions, such vibrations.

1. **Composite Sample Models (Video)**

A key component of the composite sample models is the insertion of audio indicators that replicate the noises generated in an actual tap test. This audio feedback aids users in differentiating between various material situations (e.g., sharp, dull, good composite, and damaged composite).

4.1.2.2 Product Mechanism

The VRCTT has several mechanisms that improve the learning experience for users through allowing them to perform the composite tap testing process in a virtual environment. These mechanisms are:

1. **User navigation and interaction in a VR environment**
   Users put on a VR headset and enter an immersive environment that simulates an aircraft maintenance hangar. They move throughout the environment to pick up the tool required for tap test, while following display instructions.

2. **Step-by-Step procedural instructions**
   Users read instructions on virtual whiteboard before start the tap test process. This feature assures that users comprehend the tap test's processes and objectives.

3. **Interactive tap test simulation**
   In the tap test, users pick and utilize a virtual tap hammer to conduct the test on composite materials. The VRCTT system provides two sorts of sounds (dull/hollow and sharp) that mimic real tap test sounds based on source from Grumman Pilot's tap test example. This aural feedback enables users how to distinguish between sounds that represent material integrity and damage.

4. **Knowledge assessment quiz**
   Following the tap test simulation, users answer a quiz that includes ten questions about composite materials. This quiz highlights the knowledge received during the simulation and allows users to self-assess their comprehension of the topic.

4.1.2.3 Software / Programming

This VR tool provides users with a hands-on experience to identify defects in composite materials without the need for a workspace or physical equipment. Here are the specific software features and programming elements that enhance the product:

1. **Simulated Tap Tool Interaction:**

   Feature: A virtual tap hammer that replicates the real-life tool used in composite tap tests.

   Programming Detail: The tap tool is designed to respond to user actions with realistic auditory (tap sound) feedback, simulating the feel of tapping on different composite surfaces. Programmed to vary based on the detected material condition (solid or delaminated areas).

2. **Immersive VR Environment:**

   Feature: A VR simulation replicating a real-world composite testing environment such as hangar.

   Programming Detail: Designed using VR development software (Unity), the environment includes realistic visual details, allowing users to move around, grab the tap hammer and perform tap tests. Lighting and 3D modeling make the workspace feel tangible.

3. **Cross Platform Compatibility:**

   Features: Designed for compatibility with multiple VR headsets, including Oculus Rift, HTC Vive and various VR devices.

   Programming Details: Developed using a cross-platform VR development kit and API to ensure smooth performance across multiple devices. This flexibility allows users to use existing hardware or upgrade with minimal adjustments.

4.1.2.4 Accessories & Finishing

1. **<u>3D model</u>**

   For the items in the VRCTT we search it from the sketchfab for the 3D model such as Learjet 45, Forklift, Shelf, Boxes, Toolbox, Whiteboard, Fire Extinguisher and Maintenance Ladder. This sketchfab really savings times to make the VR environment since we can just download the 3D model and paste it to the VR for an edit to the environment inside the hangar.

2. **<u>Quiz</u>**

   This quiz section was made to test the knowledge of the player, this quiz is same as the google form for the pre-test and post-test. After player have done playing the Tap Test, they can answer the quiz section to test player knowledge about composite tap test. The quiz consists of 10 question only, once they finish answer the question it will appear the score they get.

3. **<u>Sound in VRCTT</u>**

   There is two sound for the Tap Test, which is dull/hollow and sharp sound. The dull/hollow sound refers to the bad sound that we don’t want it on the real composite parts. The sharp sound refers to the good sound, this sound is what we want. The sound will randomly appear on the point 1,2,3 on the aircraft left and right wing.

4.1.3 General Operation of the Product

The general operation of the VRCTT product begins with launching the Unity app. Upon entering, users will see an interface with three main options: a video section to differentiate good and bad sounds, a tap test section, and a quiz section.

In the tap test section, users will find a 3D model of a Learjet 45, a tool crib with a tap test hammer, and a whiteboard displaying safety, tools, and instructions through infographics. Here, users can interact with the 3D models to begin the tap test simulation. They can pick up the virtual tap test hammer, approach the Learjet model, and tap on different composite surfaces. The simulation provides immediate auditory feedback for each tap, helping users distinguish good and bad sounds for defect detection.

The whiteboard near the tool crib acts as a quick guide, updating as users progress to reinforce safety protocols, tool usage, and instructions. After completing the tap test, users can proceed to the quiz section, which includes questions on the tap test procedure, safety guidelines, and tool identification. This quiz reinforces learning by ensuring that users understand the tap test process, safety protocols, and sound differentiation.

4.1.4 Operation of the Specific Part of the Product

4.1.4.1 Product Structure

Setup and Initialization

In order to ensure that the hardware and software are properly configured for the user, a few basic setup tasks must be completed before the VRCTT system may be operational. The procedure has been laid down as follows:

1. **Powering and Configuration**
   - Turning VR Headset

     Here the step:

     1. Press and hold the power button on the VR headset until the indicator light turns on.
     2. Wait for the display to turn on.
     3. Follow the prompts to connect the headset to a device (either standalone or via computer).

   - Pairing with Handheld Device

     Next:

     1. Pair the hand-held device (tap test tool) with the VR headset.
     2. Connect the device via Bluetooth or another wireless method.
     3. Ensure the VR system detects the tool's movements and actions.

   - Adjusting VR Space

     After that:

     1. Adjust the VR boundary settings to set up a virtual play area.
     2. Use the headset's cameras to mark a safe area.
     3. Ensure the area is free of obstacles to avoid accidents while using the

VR system.

2. **System calibration**

Certain systems might require the usage of unique sensors or markers positioned across the surroundings. These markers assist the VR system in determining the hand-held device's orientation and position so that it precisely matches the user's motions in the real world.

User interaction

1. **Tap test Simulation**.
   - Holding and Maneuvering the Handheld Device

     The user will hold the handheld device, which simulates the experience of a tap tool, and tap the virtual composite samples to simulate a real-world tap test. The VR system will track the user's motions, and the handheld device will provide feedback based on the simulated material during test.
2. **Safety Consideration**
   - Clear Surrounding.

     Since users are fully immersed in the virtual reality environment, it is essential to make sure that there are no blockages in the physical space so that users may move around without tripping or running into furniture.

4.1.4.2 Product Mechanisms

The VRCTT (Virtual Reality of Composite Tap Test) learning tool uses a series of interrelated mechanisms to offer users an accurate and realistic composite tap testing simulation. Each mechanism has a particular function in the learning process, ensuring that users not only understand the method but also learn practical skills in a controlled and secure atmosphere.

1.VR environment setup and user immersion

When users put on the VR headset, they enter a virtual environment designed after an aircraft maintenance hangar, leading in an immersive learning environment. The virtual hangar contains visual cues, such as tool stations and information boards, that guide users through training process.

2.Instruction and procedure display

A virtual whiteboard displays the tap test’s instructions, safety precautions and procedure steps. This component guarantees that users understand the objective and sequence of activities by imitating real-world procedural assistance they might receive in a hangar.

3.Tool selection and application

Users are able to interact with virtual tools like tap hammer which is required to carry out the composite tap test. The tool interaction approach enables users to select and apply these tools to specific areas of composite material within the Learjet’s wing. This interaction simulates using real tools and helps users become familiar with the tap test equipment.

4.Auditory feedback mechanism

The VRCTT system includes actual tap test sounds taken from actual situations to replicate the differences between dull/hollow and sharp sounds. This aural feedback is essential in this operation because it allows users to differentiate between damaged and undamaged materials. By conducting the tap test and listening to the sound feedback, users learn to determine material condition based on sound.

4.1.4.3 Software / Programming

1. **<u>Defect Detection and Feedback</u>**

   Operation:

   As the user taps on various areas of the composite material, the software continuously analyzes the response (sound) to detect potential defects such as cracks, voids, or delamination.

   Software/Programming Details:

   Defect Recognition: Algorithms evaluate the acoustic properties triggered by the tap. A defect will generate different tap responses, which the software interprets to identify the type of defect such as delamination produces a distinct sound compared to a solid material.

Figure 4.1: VRCTT Tap Test Session

2. **<u>User Interface and Guided Training</u>**

   Operation:

   The software includes a user-friendly interface and guided training features to help users learn the tap test procedure.

Software/Programming Details:

UI Controls: The VR environment includes an intuitive menu system for users to start the simulation, end the simulation, or view instructions video directly through the virtual interface.

Training Mode: The software runs video instructions to teach the user how to properly perform a tap test. In guided mode, step-by-step instructions are given also, while in free mode, users can perform tests independently with minimal prompts.

Figure 4.2: Whiteboard Display of Safety Precautions, Tools, and Procedures with Tool Crib Setup of VRCTT

3. **Data Logging and Performance Tracking**

Operation:

During the test, the software logs all user actions, including areas tapped, defect detection accuracy, and user decision-making.

Software/Programming Details:

Session Tracking: Every tap, defect identified and user interaction is stored in a backend database. The software tracks the user's progress and provides performance analytics at the end of the session.

Progress Reports: The software generates a report summarizing the user's performance, including metrics on detection accuracy, knowledge of composite and number of defects detected.

Review Mode: During the tap test simulation, users can review their performance, with the software displaying the areas or points where defects were detected versus missed.

4.1.4.4 Accessories & Finishing

1. **<u>Music background</u>**

   We found that at the homepage of the VRCTT is silent and no music sound which make it kind a boring, so we put an attractive background music sound for the homepage. The music that we put is a relaxed music for users to enjoy when they read the introduction and instruction guide for user at the homepage.

2. **<u>Environment detailing</u>**

   The environment at the homepage VRCTT is nothing and just plain, so we put a background colour of blue and we put an aircraft and helicopter surrounding with a star which make it more attractive for user to play when at the homepage. In the Tap Test game, we put an item in the hangar to not make it looks empty, the items that we put is shelf, forklift, boxes, steps and another toolbox. This item makes the hangar looks full and messy which not make it looks empty.

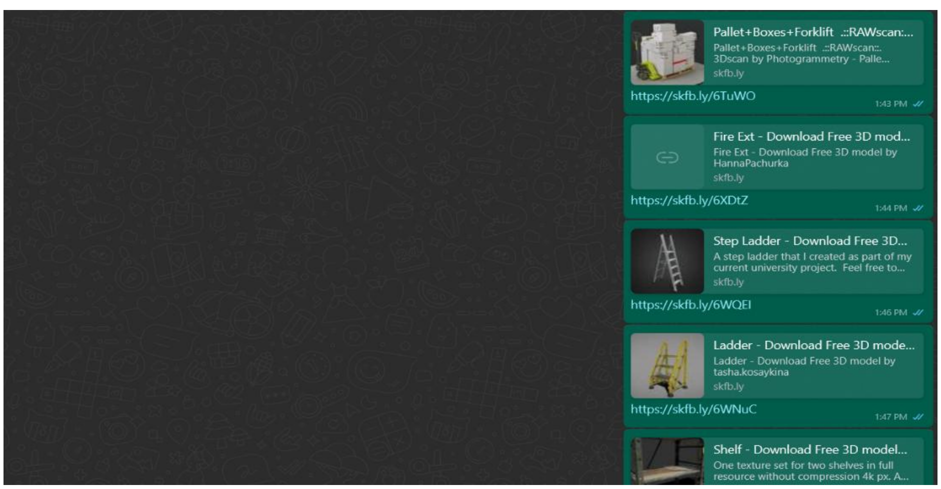


Figure 4.3: Choosing the Sketchfab

3. <u>Instruction user guide</u>

For the instruction for player we put a step by step instruction to helps player knows what to do once they enter the VRCTT. This instruction was found after we give a testimony on students to play which make them have no idea what to do when there's no instruction guiding them. Example of the instruction that we put in VRCTT: -

Step 1: read the introduction and watch the video

Step 2: go to whiteboard and read the instructions

Step 3: go to left toolbox and take the tap test hammer

Step 4: go to point 1,2,3 and do a tap tapping on the point

Step 5: identify the point that has defect

Step 6: put the tap test hammer on the toolbox

Step 7: go to right wing and pick the tap test hammer on toolbox

Step 8: tapping the point 1,2,3

Step 9: identify the point that has defect

Step 10: exit the hangar and back to homepage

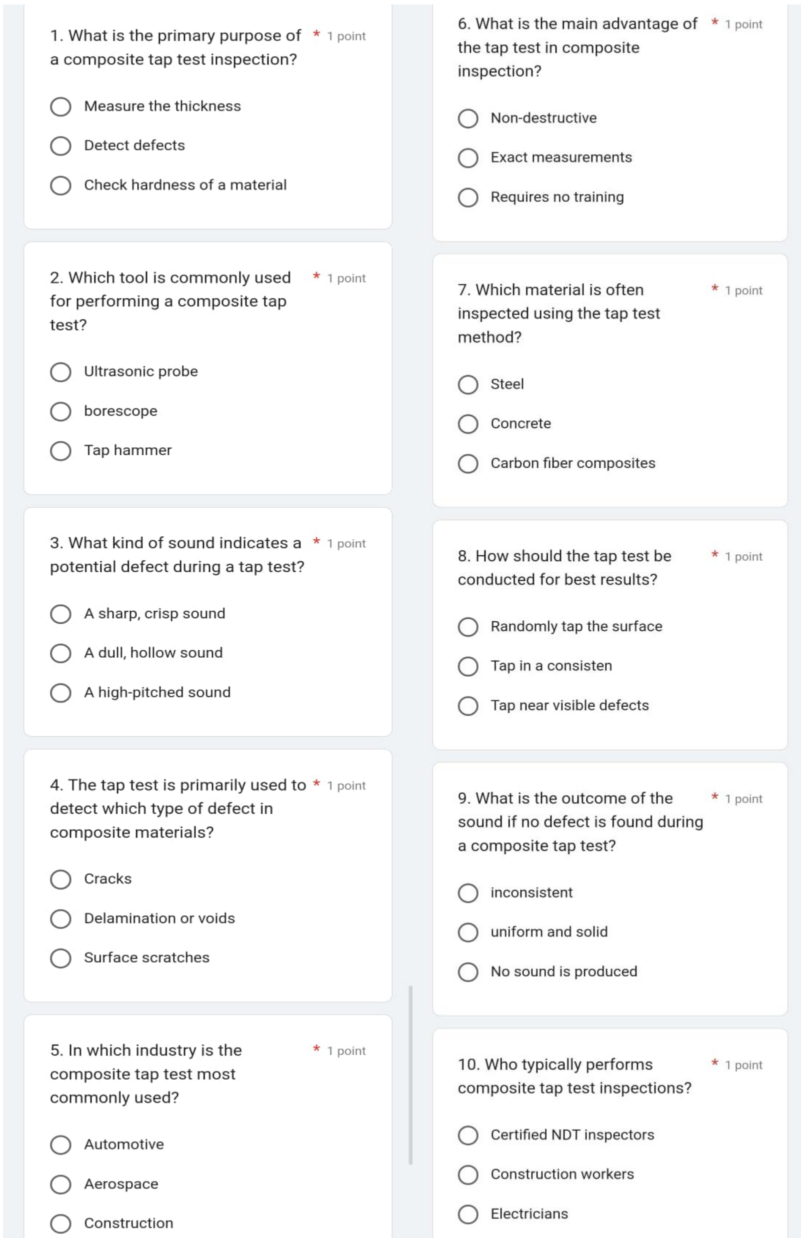
Step 11: answer all the questions

4.2 PRODUCT OUTPUT ANALYSIS

To analyse the effectiveness of the VRCTT (Virtual Reality of Composite Tap Test) learning tool, we conducted pre- and post-tests to a sample of 50 participants. The test results were intended to test participants' knowledge of composite tap testing before to and after using the VRCTT tool.

Testing Methodology:

i) Pre-Test: Participants took a pre-test on Google Forms to measure their baseline knowledge.


1. What is the primary purpose of a composite tap test inspection? * 1 point

- Measure the thickness
- Detect defects
- Check hardness of a material

2. Which tool is commonly used for performing a composite tap test? * 1 point

- Ultrasonic probe
- borescope
- Tap hammer

3. What kind of sound indicates a potential defect during a tap test? * 1 point

- A sharp, crisp sound
- A dull, hollow sound
- A high-pitched sound

4. The tap test is primarily used to detect which type of defect in composite materials? * 1 point

- Cracks
- Delamination or voids
- Surface scratches

5. In which industry is the composite tap test most commonly used? * 1 point

- Automotive
- Aerospace
- Construction

6. What is the main advantage of the tap test in composite inspection? * 1 point

- Non-destructive
- Exact measurements
- Requires no training

7. Which material is often inspected using the tap test method? * 1 point

- Steel
- Concrete
- Carbon fiber composites

8. How should the tap test be conducted for best results? * 1 point

- Randomly tap the surface
- Tap in a consisten
- Tap near visible defects

9. What is the outcome of the sound if no defect is found during a composite tap test? * 1 point

- inconsistent
- uniform and solid
- No sound is produced

10. Who typically performs composite tap test inspections? * 1 point

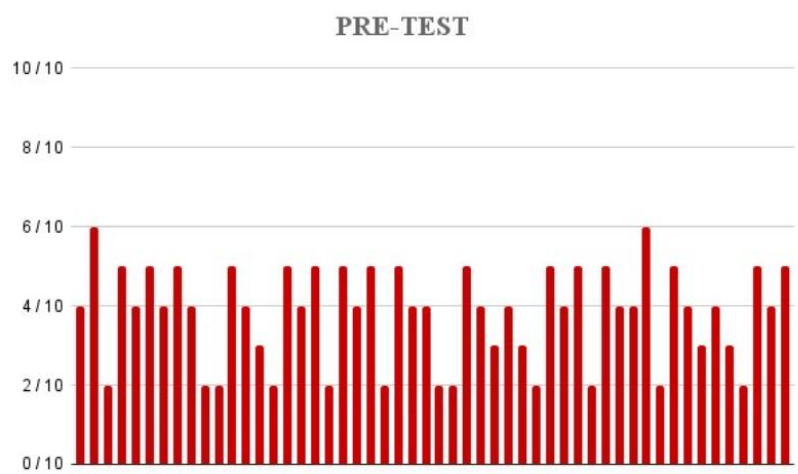
- Certified NDT inspectors
- Construction workers
- Electricians

ii) Post-Test: After using the VRCTT program, participants took a post-test to assess their learning.

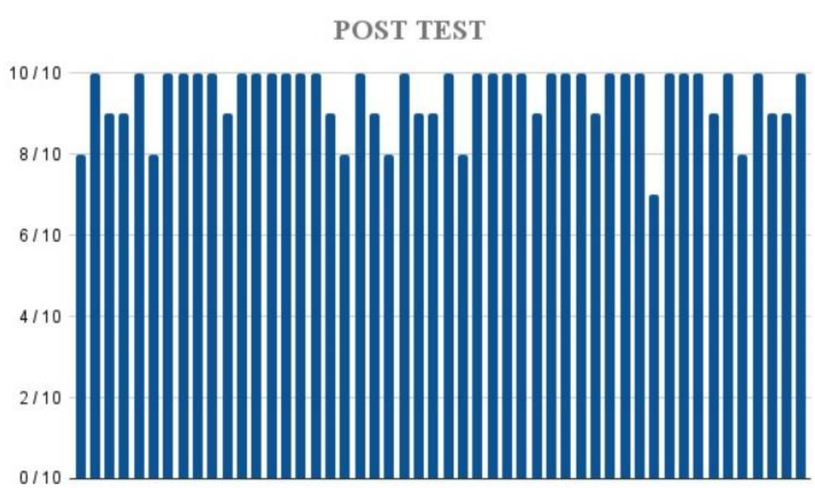
To assess the effectiveness of the VRCTT (Virtual Reality of Composite Tap Test) learning tool, we administered pre- and post-tests to a sample of 50 participants. The assessments were meant to assess participants' knowledge of composite tap testing before to and after utilizing the VRCTT tool.

Results

i) Pre-Test mean score: 3.68/10



i) Post-Test mean score: 9.46/10



The significant improvement in scores shows that the VRCTT learning tool improved their understanding of composite tap testing. This enhancement improves the tool's effectiveness as a learning tool for aircraft maintenance training.

4.3 ANALYSIS PROBLEM ENCOUNTERED AND SOLUTION

4.3.1 Product Structure

Problem Encountered	Solution
Lack of Handling VR Headset	Assigned team member to handle the setup, adjustment, and storage of the VR headset with care.
Headset Fitting Issue	Added adjustable padding and straps for a customizable fit.

Table 4.1: Product Structure Problem Encountered and Solution

4.3.2 Product Mechanisms

Problem Encountered	Solution
Realistic sound simulation	Actual tap test sound was sourced from the Grumman Pilot's YouTube channel to ensure realistic aural feedback in the VR simulation, which promotes realism and user learning.
Tool interaction and UI responsiveness	With the VR developer, we fine-tuned the interface sensitivity and control the settings to improve tool handling precision and provide a more normal experience that closely reflects real-world tool usage.
User guidance and instruction clarity	The whiteboard information was redesigned for clarity, with step-by-step instructions in a structured manner and visual cues to guide users to important stages, resulting in improved orientation and understanding.

Table 4.2: Product Mechanism Problem Encountered and Solution

4.3.3 Software / Programming

Problem encountered	Solution
Lagging	Upgrade laptop RAM to improve processing speed and handle software demands effectively.
Compatibility issues	Update software versions or install compatible drivers to ensure smooth integration with VR components.
Software crashes	Regularly save work and implement auto-save features; update the operating system and software for stability.
High CPU usage	Close unnecessary applications and optimize software settings to reduce CPU load.

Table 4.3: Software/Programming Problem Encountered and Solution

4.3.4 Accessories & Finishing

Problem Encountered	Solution
Lack of money	Make savings properly cause of expensive money usage for the VRCTT.
Lack of cable adapter for the VR	Buy the mini display port to the HDMI cable adapter for the VR.

Table 4.4: Accessories & Finishing Problem Encountered and Solution

CHAPTER 5

(CONCLUSION & RECOMMENDATION)

5.1 ACHIEVEMENT OF AIM & OBJECTIVES OF THE RESEARCH

5.1.1 General Achievements of the Project

The primary goal of the VRCTT project, which was to develop an innovative virtual reality-based system for composite tap testing in aircraft maintenance, was accomplished. The creation of an immersive virtual reality environment that enables users to conduct simulated composite tap tests is one of the main achievements, as it improves the realism and engagement of training sessions. Users are given a realistic experience by the incorporation of 3D objects, including the Learjet 45 aircraft and tools into the virtual hangar.

To help in student becoming familiar with the tap test procedure, the device also provides an easy-to-use interface with a quiz and instructional video. By removing the need for physical composite materials and tools during training sessions, the initiative also achieved its goal of offering an economical and effective way to train aircraft maintenance student.

Additionally, the VRCTT system was successfully tested and improved in response to user feedback and guaranteeing that it functions efficiently and satisfies the requirements of its intended users.

The VRCTT project also received a Gold Medal in the International Language and Education Innovation Competition 2024 (i-INNOLED). This award recognizes its innovative use of virtual reality to enhance aircraft maintenance training and educational practices.

5.1.2 Specific Achievement of Project Objectives

5.1.2.1 Product Structure

The VRCTT system's product structure was created to achieve specific aims in order to produce a training experience that is realistic, interactive, and easy to use.

1. Training Realism

   The structure of the product was designed to make the training experience more realistic. With its 360-degree vision and high-definition graphics, the VR headset fully immerses students in a virtual environment that matches an actual maintenance workshop. During tap testing, students can focus on visual indication like difference of sound.

2. Ease for use

   The simple use of each component ensures that students can concentrate on the training content without getting distracted by complicated technology.

5.1.2.2 Product Mechanisms

The VRCTT (Virtual Reality of Composite Tap Test) product mechanisms have been developed to achieve particular project objectives, each of it aimed to improve the process of learning in composite tap testing.

1.Providing a realistic, hands-on training experience.

To simulate situations in the real world, the VRCTT uses realistic sounds for the tap test, which includes two different sounds (dull/hollow and sharp) that indicate the state of the material. Users can also interact with virtual tools, such as tap hammer, in a VR hangar setting. This hands-on experience enables users to become familiar with the composite tap test process in a controlled yet realistic environment, which enhances their practical knowledge and skills.

2. Ensuring User-Friendly and Intuitive Interaction

The VRCTT is easy to use, with responsive navigation controls and realistic tool interaction. Step-by-step instructions on the virtual whiteboard provide clear procedure, helping users to complete the task with confidence. User response suggested a smooth and natural experience, with less errors throughout procedure carrying out in the VR environment.

5.1.2.3 Software / Programming

For the Achievements & Objectives section of our VRCTT project, these are specific achievements related to software and programming:

1. **<u>Develop a Virtual Reality Software for Composite Tap Testing</u>**

   Successfully developed and implemented VR software that simulates the composite tap test environment. The software accurately represents real-life testing scenarios, providing users with realistic and immersive experience in identifying flaws in composite materials.

2. **<u>Improve Training Outcomes for Non-Destructive Testing (NDT)</u>**

   Through programming and careful design of VR scenarios, VRCTT has contributed to improved training outcomes. The software replicates various defect types and positions, enhancing user familiarity with defect identification and reducing the learning curve associated with traditional NDT methods.

5.1.2.4 Accessories & Finishing

The VRCTT accessories & Finishing have been develop to improve the user experience when playing VRCTT to give user full concentration and to make the VRCTT more attractive.

1. **Designing an Interactive VR Environment**

   We develop a VR for aircraft composite tap test, help user to better understand in tap test procedures. Allows users to practice in a virtual setting without the need for physical aircraft parts, reducing potential damage to actual aircraft.

2. **Developing and Integrating VR Simulation of Composite Tap Test**

   Created a VR-based training system that guides users through the composite tap test procedure, which is typically difficult to understand in conventional methods. The VR simulation includes interactive elements such as instructional videos and quizzes, enhancing user participation and understanding.

5.2 CONTRIBUTION OR IMPACT OF THE PROJECT

The VRCTT project offers a safe and affordable means of practicing composite tap tests, which makes a major contribution to aircraft maintenance training. It makes training more sustainable by lowering the demand for pricey physical resources. Training efficacy is increased by the system's interactive virtual reality environment, which allows learners to practice and learn without the dangers of real-world assessment.

The VRCTT system assists users in getting familiar with tools and equipment by providing them with detailed 3D simulations of the aircraft and tools. Additionally, it improves the learning process by crossing the gap between academic knowledge and real-world experience. The significance of this project is further expanded by opening opportunities for future applications in other industries that need composite testing.

Another key impact of the VRCTT project is that it makes learning and teaching methods easier and more engaging. By incorporating virtual reality, the system transforms the traditional approach to training, allowing students to interact with 3D simulations of aircraft and tools. This hands-on, immersive learning experience enhances understanding and retention of complex concepts, making the teaching process more effective and enjoyable. The ability to visualize and practice without the need for physical materials further streamlines the instructional process.

The VRCTT system is also widely applicable across multiple maintenance organisations and the aviation industry. Its versatility allows it to be used in any aviation-related training facility, making it an accessible and reliable tool for maintenance students at all levels. This adaptability makes it an invaluable resource for organisations looking to improve their workforce's skills in a cost-effective and efficient manner.

Lastly, the VRCTT system offers a cost-effective solution for aircraft maintenance training, reducing the need for costly physical resources while still providing a realistic, interactive, and safe learning experience. This ensures effective training at a fraction of the cost of traditional methods.

5.3 IMPROVEMENT & SUGGESTIONS FOR FUTURE RESEARCH

5.3.1 Product Structure

For future improvement, this product structure can be enhanced by:

Optimizing VR Hardware to include more advanced motion tracking systems and lightweight, ergonomics VR Headset for user comfort.

Expending 3D model by adding more detail and added more aircraft model will allow simulation become wider.

User interface (UI) enhancement can be enhanced by simplifying the design to make it easier to navigate and provide more intuitive control during training simulation.

Customization features can be added to allow user to custom or set for different testing environment or material like radome or aircraft fuselage and also level of difficulties to enabling more training experience.

5.3.2 Product Mechanisms

Although the VRCTT (Virtual Reality of Composite Tap Test) has met its key objectives, there are some parts for improvement that could increase its functioning and learning impact.

1.Enhance quality sounds and accuracy

Advanced sound design techniques could also be utilized to more accurately reflect how sound changes in accordance with user input, such as tapping speed and angle. This enhancement would improve the fidelity of the tap test experience.

2.Improve user interface and customizable guidance

Some users may benefit from different levels of guidance depending on their level of experience. Potential improvements could include variable lesson modes—such as beginner, intermediate, and expert—that allow users to control the level of detail displayed on the virtual whiteboard. Furthermore, interactive tutorials or animated may help new users, making the learning process even more accessible.

5.3.3 Software / Programming

Here are some additional ideas for improvements and suggestions for future research related to the software/programming aspects of VRCTT:

1. **Increase Graphics Quality:** Improve resolution and rendering quality for a more realistic experience, possibly through advanced 3D modelling techniques.

2. **Add Vibration Feedback:** Integrate haptic feedback or vibration to simulate the sensation of the tap, enhancing the user's sense of touch and immersion.

3. **Real-time Data Analysis:** Enable real-time analysis of the tap test results, allowing users to instantly view data insights and identify potential defects.

4. **Voice Command Integration:** Add voice command capabilities for hands-free operation, making it more accessible and efficient during testing.

5.3.4 Accessories & Finishing

The future improvement and suggestions for the VRCTT, I would suggest:

1. **New version of VR headset:** its because we are using the old version of VR headset which is Vive Cosmos from 2019. This VR headset only suitable for pc and not for laptop. I would suggest a new version of VR headset which is from 2022 to 2024.

2. **Use a new version of gaming laptop:** a strong gaming laptop can enhance the VRCTT gameplay by giving a smooth gameplay and nice graphic to the environment.

3. **Upgrade VRCTT with more Interesting gameplay:** maybe in the future the gameplay for the VRCTT would be upgrade for not just tap test but would do the tap test and composite panel repair or vacuum banging.

LIST OF REFERENCES

[1] F. Khan et al., "Advances of Composite Materials in Automobile Applications – A Review," Journal of Engineering Research, Feb. 2024, doi: https://doi.org/10.1016/j.jer.2024.02.017.

[2] Trescak, Tomas. "The Main Problem with Virtual Reality? It's Almost as Humdrum as Real Life." The Conversation, 17 Nov. 2019 https://theconversation.com/the-main-problem-with-virtual-reality-its-almost-as-humdrum-as-real-life-126761. Accessed 16 Feb. 2024.

[3] Wu, Wen-Chung, and Van-Hoan Vu. "Application of Virtual Reality Method in Aircraft Maintenance Service—Taking Dornier 228 as an Example." Applied Sciences, vol. 12, no. 14, 20 July 2022, p. 7283, www.mdpi.com/2076-3417/12/14/7283. Accessed 16 Feb. 2024.

[4] Ilcewicz, Larry. Federal Aviation Administration FAA / CAAs "Composite Meeting" Forward Looking: FAA AVS Composite Plan -Composite Safety & Certification Initiatives. 2015, https://gcs-safety.com/wp-content/uploads/2020/12/Aircraft-Technology-Composite-Repairs.pdf. Accessed 16 Feb. 2024.

[5] Abdullah, Junaidi, et al. "Virtual Reality to Improve Group Work Skill and Self-Directed Learning in Problem-Based Learning Narratives." Virtual Reality, 12 Mar. 2019, https://doi.org/10.1007/s10055-019-00381-1. Accessed 16 Feb. 2024.

[6] Ramirez, Erick Jose, and Scott LaBarge. "Real Moral Problems in the Use of Virtual Reality." Ethics and Information Technology, vol. 20, no. 4, 26 July 2018, pp. 249–263, https://doi.org/10.1007/s10676-018-9473-5. Accessed 16 Feb. 2024.

[7] Nezhad, H. Yazdani, et al. "Development of an Augmented Reality Equipped Composites Bonded Assembly and Repair for Aerospace Applications." IFAC-PapersOnLine, vol. 53, no. 3, 1 Jan. 2020, pp. 209–215,

www.sciencedirect.com/science/article/pii/S2405896320301804,https://doi.org/10.1016/j.ifacol.2020.11.034. Accessed 16 Feb. 2024.

[8] Siregar, E., Mulyono, M., Asmin, A., Mukhtar, M., & Firdaus, M. (2019). Differences in Problem Solving Capabilities among Students Given a Problem-Based Learning Blended Learning with Conventional Learning. American Journal of Educational Research, 7(11), 755-763. https://www.academia.edu/download/98704339/education-7-11-3.pdf. Accessed 14 May 2024.

[9] Editor, Mike Nelson, Xbox Wire. "Microsoft Flight Simulator Virtual Reality Update Available Now." *Xbox Wire*, 22 Dec. 2020, news.xbox.com/en-us/2020/12/22/microsoft-flight-simulator-virtual-reality-update-available-now/. Accessed 16 May 2024.

[10] Tecknotrove. "Virtual Reality (VR) in Aviation Industry." *Tecknotrove*, 16 Apr. 2021, tecknotrove.com/virtual-reality-vr-augmented-reality-ar-in-aviation-industry/. Accessed 17 May 2024.

[11] "Virtual Reality Aircraft Maintenance Training." *SPWebsite*, 25 Feb. 2021, www.sp.edu.sg/engineering-cluster/mae/courses/full-time-diplomas/aeronautical-engineering-/project-gallery/virtual-reality-aircraft-maintenance-training. Accessed 16 May 2024.

[12] S. Watts, "AR vs VR: What's The Difference?," *Splunk-Blogs*, Nov. 08, 2023. https://www.splunk.com/en_us/blog/learn/ar-vr.html.

[13] Sofema, "Introduction to Composite Materials in Aviation and TAP Testing," *SasSofia*, Aug. 29, 2023. https://sassofia.com/blog/introduction-to-composite-materials-in-aviation-and-tap-testing/.

[14] B. Parveez, M. I. Kittur, I. A. Badruddin, S. Kamangar, M. Hussien, and M. A. Umarfarooq, "Scientific Advancements in Composite Materials for Aircraft

Applications: A Review," *Polymers*, vol. 14, no. 22, p. 5007, Nov. 2022, doi: https://doi.org/10.3390/polym14225007.

[15] G. Robles, "15 Things You Can Do with Your Oculus Quest VR Headset - 42West," *42 West, the Adorama Learning Center*, Oct. 14, 2021. https://www.adorama.com/alc/to-do-oculus-quest-vr-headset

[16] N. Duggal, "Uses of C++ | What is C++ Used for | C++ Applications | Simplilearn," *Simplilearn.com*, Dec. 20, 2021. https://www.simplilearn.com/tutorials/cpp-tutorial/top-uses-of-c-plus-plus-programming

[17] Kenwright, B. (2019). Virtual reality: Where have we been? where are we now? and where are we going? https://www.preprints.org/manuscript/201907.0130/v1

[18] R. Sheldon, "What is Virtual Reality?," *WhatIs.com*, Aug. 2022. https://www.techtarget.com/whatis/definition/virtual-reality

[19] Nouri, N., Biener, V., & Grubert, J. (2024). Experiences with Off-The-Shelf Solutions for XR-supported Knowledge Work. https://mixedrealitylab.de/paper/2024-vr/knowledge-work-in-XR.pdf

[20] Y. K. Dwivedi, "Metaverse beyond the hype: Multidisciplinary Perspectives on Emerging challenges, opportunities, and Agenda for research, Practice and Policy," *International Journal of Information Management*, vol. 66, no. 66, p. 102542, Oct. 2022, https://www.sciencedirect.com/science/article/pii/S0268401222000767

[21] Craig, C. M., Stafford, J., Egorova, A., McCabe, C., & Matthews, M. (2022). Can we use the Oculus Quest VR headset and controllers to reliably assess balance stability? *Diagnostics*, *12*(6), 1409. https://www.mdpi.com/2075-4418/12/6/1409

[22] Moss, Elizabeth. "What Is Unreal Engine? - BairesDev." *Www.bairesdev.com*, www.bairesdev.com/blog/what-is-unreal-engine/. Accessed 17 May 2024.

[23] Lang, Ben. "“Oculus Medium” Review with Oculus Touch - a Powerful Tool That’s Easy to Approach." *Road to VR*, 21 Nov. 2016, www.roadtovr.com/oculus-medium-review/. Accessed 17 May 2024.

[24] Blender Foundation. "About — Blender.org." Blender.org, 2019, www.blender.org/about/. Accessed 17 May 2024.

[25] "What Is Unity?" *PubNub*, www.pubnub.com/guides/unity/. Accessed 17 May 2024.

[26] Aviar B.V, "Airport Ground Handling Simulator VR," Meta.com, 2022, https://www.facebook.com/aviarnl/posts/pfbid0t7D8NpgN36vewUFzpU9Wfqpz6uijpgnEvwAeFEzzeUsEPmqVBE61YusQxM9dbKyKl. Accessed 24 Nov 2024.

[27] Harriz "Virtual Maintenance Trainer | Pilot Training Systems | L3Harris," www.l3harris.com. https://www.l3harris.com/all-capabilities/virtual-maintenance-trainer. Accessed 24 Nov 2024.

APPENDIX A: DECLARATION OF TASK SEGREGATION

SUB-CHAPTER	DESCRIPTION
AQIL MUQRI BIN MAHADI	
1.1	Background of Study
1.3.2.4	Specific Individual Project Objectives: Accessories & Finishing
1.5.2.4	Specific Individual Project Scope: Accessories & Finishing
2.1.2	Types of Virtual Reality
2.2.4	Specific Literature Review: Accessories & Finishing
2.3.1.4	Virtual Maintenance Trainer
2.3.2.4	Recent Market Products: VR Boeing 737 Next Gen Thrust Reverser and Opening Procedure
2.4.4	Comparison Between Virtual Maintenance Trainer VS VR Boeing 737 Next Gen Thrust Reverser Opening Procedure VS VRCTT
3.3.2.4	Specifics Project Design Flowchart/ Framework: Accessories & Finishing
3.4.1.1	Questionnaire Survey
3.4.2.2	Morphological Matrix
3.4.2.3	Design Concept generation: Proposed Design Concept 4
3.4.3.2	Pugh Matrix Concept 2 As A Datum
3.5.2.4	Specific Part Drawing / Diagram: Quiz section in VRCTT
3.7.3.4	Phase 4 (Finishing)
4.1.2.4	Specific Part Features: Accessories & Finishing
4.1.4.4	Operation of the Specific Part of the Product: Accessories & Finishing
4.3.4	Analysis Problem Encountered and Solution: Accessories & Finishing
5.1.2.4	Specific Achievement of Project Objectives: Accessories & Finishing

5.3.4	Improvement & Suggestions for Future Research: Accessories & Finishing
IZZUL HAZWAN BIN MOHD FAZLI	
1.2	Problem Statement
1.3.2.3	Specific Individual Project Objectives: Software/Programming
1.4	Purpose of Product
1.5.1	General Project Scopes
1.5.2.3	Specific Individual Project Scope: Software/Programming
2.1.1	Demand In Aviation
2.2.3	Specific Literature Review: Software/Programming
2.3.1.3	Related Patented Products: Airport Ground Handling Simulator VR
2.3.2.3	Recent Market Products: VR Aircraft Inspection
2.4.3	Comparison Between TechnoSIM VR Aircraft Inspection VS VR Composite Tap Test
3.3.2.3	Specifics Project Design Flowchart/ Framework: Software / Programming
3.4.2.6	Design Concept generation: Proposed Design Concept 4
3.4.3.3	Pugh Matrix Concept 3 As A Datum
3.5.2.3	Specific Part Drawing / Diagram: Whiteboard Display of Safety Precautions, Tools and Procedures with Tool Crib
3.6.1	Prototype / Product Modelling
3.6.2	Prototype Development
3.7.3.3	Phase 3 (Programming & Electrical Circuit)
3.8	List Of Materials & Expenditures
4.1.2.3	Specific Part Features: Software / Programming
4.1.3	General Operation of the Product
4.1.4.3	Operation of the Specific Part of the Product: Software / Programming
4.3.3	Analysis Problem Encountered and Solution: Software /

	Programming
5.1.2.3	Specific Achievement of Project Objectives: Software / Programming
5.3.3	Improvement & Suggestions for Future Research: Software / Programming
NURFATEHAH BINTI MOHD NAZRY	
1.3.2.2	Specific Individual Project Objective: Product Mechanism
1.5.2.2	Specific Individual Scope: Product Mechanism
2.1.2	Type of Virtual Reality
2.1.4	Evolution of Virtual Reality
2.2.2	Specific Literature Review: product Mechanism
2.3.1.2	Patented Products: VR Maintenance Training by HQSoftware
2.3.2.2	Recent Market Products: Aircraft De-Icing VR Training
2.4.2	Comparison Between VR Composite Repair VS Sensus VR De-Icing Training VS VR Maintenance Training
3.1.2	Project Collaboration & Transfer of Technology
3.3.1	Overall Project Flow Chart
3.4.1.2	Pareto Diagram
3.4.2.1	Function Tree
3.4.2.4	Design Concept generation: Proposed Design Concept 2
3.4.3.1	Pugh Matric Concept 1 As A Datum
3.5.2.2	Aircraft Composite Tap Test Inspection Points
3.7.3.2	Phase 2 (Accessories & Mechanisms)
3.8	Product Testing / Functionality Test
4.1.2.2	Specific Parts Features: Product Mechanism
4.1.4.2	Operation of The Specific Part of The Product: Product Mechanism
4.2	Product Output Analysis
4.3.2	Analysis Problem Encountered and Solution: Product Mechanism

5.1.2.2	Specific Achievement of Project Objectives: Product Mechanism
5.3.2	Improvement & Suggestions for Future Research: Product Mechanism
AFREINA BINTI MOHD AFANDI	
1.3	Project Objectives
1.3.2.1	Specific Individual Project Objective: Product Structure
1.5.2.1	Specific Individual Scope: Product Structure
2.1.3	VR Technology Implementation
2.2.1	Specific Literature Review: Product Structure
2.3.1.1	Japan Airline (JAL) Innovation Lab
2.3.2.1	Recent Market Products: Microsoft Flight Simulator
2.4.1	Comparison Between VRCTT VS Microsoft Flight Simulator VS Japan Airline (JAL) Innovation Lab
3.1.1	Utilization of Polytechnic's Facilities
3.3.2.1	Specifics Project Design Flowchart / Framework: Product Structure
3.4.2.5	Design Concept Generation: Proposed Design Concept 3
3.4.2.7	Summary of Accepted Concept
3.4.3.4	Pugh Matrix Concept 4 As A Datum
3.5.1	General Product Drawing Group Writing
3.5.2.1	Specific Part Drawing / Diagram: Interface
3.7.1	Material Acquisition
3.7.2	Machines and Tools
3.7.3.1	Specific Project Fabrication Phase 1: Base Structure
4.1.1	General Products Features & Functionality
4.1.2.1	Specifics Part Features: Product Structure
4.1.4.1	Operation of the Specifics Part of the Products: Product Structure
4.3.1	Analysis Problem Encountered and Solution: Product Structure
5.1.1	General Achievement of the Project

5.1.2.1	Specific Achievement of Project Objective: Product Structure
5.2	Contribution or Impact of the Project
5.3.1	Improvement & Suggestion for Future Research: Product Structure

APPENDIX B: SUMMARY OF SIMILARITY REPORT (TURNITIN)

THESIS.pdf

ORIGINALITY REPORT

14%	9%	4%	9%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Jabatan Pendidikan Politeknik Dan Kolej Komuniti Student Paper	3%
2	vimeo.com Internet Source	1%
3	www.roadtovr.com Internet Source	<1%
4	www.coursehero.com Internet Source	<1%
5	eprints.usm.my Internet Source	<1%
6	thomas-trier.de Internet Source	<1%
7	pureadmin.qub.ac.uk Internet Source	<1%
8	"Transforming Education with Virtual Reality", Wiley, 2024 Publication	<1%
9	www.pubnub.com	

		Internet Source	<1 %
10	dergipark.org.tr	Internet Source	<1 %
11	"Extended Reality", Springer Science and Business Media LLC, 2024	Publication	<1 %
12	Submitted to Glyndwr University	Student Paper	<1 %
13	Submitted to Embry Riddle Aeronautical University	Student Paper	<1 %
14	Submitted to Polytechnic Institute Australia	Student Paper	<1 %
15	www.mdpi.com	Internet Source	<1 %
16	www.sp.edu.sg	Internet Source	<1 %
17	repository.uin-malang.ac.id	Internet Source	<1 %
18	Submitted to Jupiter High School	Student Paper	<1 %
19	Ersoy, Mustafa. "Development of Synthetic and Real-World Pose Estimation Dataset to be		<1 %

Used in Human Tracking System", Middle East Technical University (Turkey), 2024
Publication

20	Submitted to University of Strathclyde Student Paper	<1 %
21	mixedrealitylab.de Internet Source	<1 %
22	Submitted to Taylor’s Education Group Student Paper	<1 %
23	V. Sharmila, S. Kannadhasan, A. Rajiv Kannan, P. Sivakumar, V. Vennila. "Challenges in Information, Communication and Computing Technology", CRC Press, 2024 Publication	<1 %
24	Submitted to German University of Technology in Oman Student Paper	<1 %
25	1library.net Internet Source	<1 %
26	Submitted to Homestead Senior High School Student Paper	<1 %
27	Submitted to UC, Boulder Student Paper	<1 %
28	Submitted to University of Sheffield Student Paper	<1 %

29	Submitted to Al Ain University Student Paper		<1 %
30	Submitted to Houston Community College Student Paper		<1 %
31	Submitted to SUNY, New Paltz Student Paper		<1 %
32	Submitted to University of Abertay Dundee Student Paper		<1 %
33	Submitted to University of Glamorgan Student Paper		<1 %
34	www.talespin.com Internet Source		<1 %
35	Submitted to Queensland University of Technology Student Paper		<1 %
36	Submitted to Nanyang Technological University Student Paper		<1 %
37	Niharika Karnik, Urvi Bora, Karan Bhadri, Prasanna Kadambi, Pankaj Dhatrak. "A Comprehensive study on Current and Future Trends towards the Characteristics and Enablers of Industry 4.0", Journal of Industrial Information Integration, 2021 Publication		<1 %

38	Submitted to Universiti Utara Malaysia Student Paper	<1 %
39	Submitted to University of Southern California Student Paper	<1 %
40	games-stats.com Internet Source	<1 %
41	program-ace.com Internet Source	<1 %
42	Submitted to De Montfort University Student Paper	<1 %
43	Mark Mcgill, Aidan Kehoe, Euan Freeman, Stephen Brewster. "Expanding the Bounds of Seated Virtual Workspaces", ACM Transactions on Computer-Human Interaction, 2020 Publication	<1 %
44	Submitted to Universiti Teknikal Malaysia Melaka Student Paper	<1 %
45	Submitted to Westminster International University in Tashkent Student Paper	<1 %
46	en.wikipedia.org Internet Source	<1 %
47	Submitted to Bedford College Group Student Paper	

		<1%
48	Submitted to University of Hertfordshire Student Paper	<1%
49	dokumen.pub Internet Source	<1%
50	faa.niar.wichita.edu Internet Source	<1%
51	www.compositesworld.com Internet Source	<1%
52	www.theseus.fi Internet Source	<1%
53	Submitted to Heriot-Watt University Student Paper	<1%
54	smd.ueh.edu.vn Internet Source	<1%
55	Gomes, Carla Sofia Madeira. "Access to XR: Exploring the Potential of Immersive Experiences in Virtual Reality for low Vision and Blind Users", Universidade do Porto (Portugal), 2024 Publication	<1%
56	dentapoche.unice.fr Internet Source	<1%
	www.slideshare.net	

57	Internet Source	<1%
58	Submitted to GEMS INTERNATIONAL SCHOOL, AL KHAIL Student Paper	<1%
59	Submitted to The Chicago School of Professional Psychology Student Paper	<1%
60	Submitted to University of Bradford Student Paper	<1%
61	Submitted to University of Nottingham Student Paper	<1%
62	Wang, Yuchao. "Modeling Reality in the Virtual: Usability Insights into Voxel Modeling in a vr Environment", Purdue University, 2024 Publication	<1%
63	ejournal.khazar.org Internet Source	<1%
64	francis-press.com Internet Source	<1%
65	Submitted to Arab Open University Student Paper	<1%
66	Submitted to University of Wales Institute, Cardiff Student Paper	<1%

67	ir.unimas.my Internet Source	<1%
68	kipdf.com Internet Source	<1%
69	umpir.ump.edu.my Internet Source	<1%
70	www.freshpatents.com Internet Source	<1%
71	www.frontiersin.org Internet Source	<1%
72	Submitted to University of Teesside Student Paper	<1%
73	digitalmahbub.com Internet Source	<1%
74	iris.polito.it Internet Source	<1%
75	underminerstudios.com Internet Source	<1%
76	Alastair M. Morrison, Dimitrios Buhalis. "Routledge Handbook of Trends and Issues in Tourism Sustainability, Planning and Development, Management, and Technology", Routledge, 2023 Publication	<1%

77	Sajad Faramarzi, Joseph D. Dayag. "chapter 7 Augmented Reality and Virtual Reality", IGI Global, 2023 Publication	<1 %
78	de Oliveira Lopes, Ana Luísa Freire Martins. "Realidade Virtual Como Meio de Comunicação de Produtos de Mobiliário Customizado", Universidade de Aveiro (Portugal), 2024 Publication	<1 %
79	docta.ucm.es Internet Source	<1 %
80	etd.aau.edu.et Internet Source	<1 %
81	fdocument.org Internet Source	<1 %
82	"Chapter 300016 3D Game Engines", Springer Science and Business Media LLC, 2024 Publication	<1 %
83	Submitted to CSU, Hayward Student Paper	<1 %
84	Pires, José Henrique Machado. "Virtual Reality for Imbalance Induction and Analysis of Neuromuscular Postural Reactivity", Universidade do Minho (Portugal), 2024 Publication	<1 %

85	pure.ulster.ac.uk Internet Source	<1%
86	www-emerald-com-443.webvpn.sxu.edu.cn Internet Source	<1%
87	Kelly S. Hale, Kay M. Stanney. "Handbook of Virtual Environments - Design, Implementation, and Applications", CRC Press, 2002 Publication	<1%
88	Neto, Bernardo Almeida. "Development of Digital Twin in Augmented Reality for Laser Equipped Industrial Robots", Universidade do Porto (Portugal), 2024 Publication	<1%
89	Olayiwola Oladiran, Louisa Dickins. "PropTech and Real Estate Innovations - A Guide to Digital Technologies and Solutions in the Built Environment", Routledge, 2024 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		

APPENDIX C: MYIPO CERTIFICATION FOR COPYRIGHT

COPYRIGHT ACT 1987

COPYRIGHT (VOLUNTARY NOTIFICATION) REGULATIONS 2012

CERTIFICATE OF COPYRIGHT NOTIFICATION
[Subregulation 8(2)]

Notification Number	:	CRLY2024W06421
Title of Work	:	THE DEVELOPMENT OF VIRTUAL REALITY OF COMPOSITE TAP TEST
Category of Work	:	LITERARY
Date of Notification	:	03 OCTOBER 2024
Date of Creation	:	01 OCTOBER 2024

This is to certify, under the Copyright Act 1987 [Act 332] and the Copyright (Voluntary Notification) Regulations 2012 that the copyrighted work bearing the Notification No. above for the applicant **POLITEKNIK BANTING SELANGOR** as the **OWNER** and **MOHAMMAD AZMIN BIN ZAINAL (870206385049)** as the **AUTHOR** have been recorded in the Register of Copyright, in accordance with section 26B of the Copyright Act 1987 [Act 332].

KAMAL BIN KORMIN
CONTROLLER OF COPYRIGHT
MALAYSIA

(Agency under the Ministry of Domestic Trade and Cost of Living)

APPENDIX D: ASIA DIGITAL ENGINEERING (ADE) COLLABORATION LETTER

ASIA DIGITAL ENGINEERING

ASIA DIGITAL ENGINEERING

(+60)3-8660 4333
abdulfatah@airasia.com
REDQ, Jalan Pekeliling 5, Kuala Lumpur International Airport, 64000 Sepang, Selangor

To:

Mr. Mohammad Azmin bin Zainal

Politeknik Banting Selangor,
Persiaran Ilmu, Jalan Sultan Abdul Samad,
42700 Banting, Selangor

7th October 2024

CONFIRMATION OF RECOGNITION OF VIRTUAL REALITY OF FLIGHT INSTRUMENT (VRFI)

I hope this letter finds you well. On behalf of Asia Digital Engineering, I would like to express our sincere gratitude for your approval of the project integrating virtual reality (VR) technology into the training of aviation students and trainers.

Your support is crucial as we work to enhance aviation education and skill development through immersive simulations. By allowing students and trainers to engage with realistic VR environments and interact with flight instruments, we foster a deeper understanding of their functions and real-world applications. This innovative approach not only enhances learning outcomes but also promotes safety and confidence in handling aviation systems.

With VFRI, we can simulate complex flight situations and instrument readings, giving students the opportunity to practice and refine their skills in a controlled, risk-free environment. We are confident that this will contribute significantly to producing well-prepared, competent aviation professionals.

We look forward to collaborating with you on this groundbreaking initiative and raising the standards of aviation training.

Regards,

Fatah Hashim
Digital and Innovation
Asia Digital Engineering (ADE)

APPENDIX E: OTAIZ SOLUTION COLLABORATION LETTER

Otaiz.Com

OTAIZ SOLUTION

+6019-765 3961

herwanotaiz@gmail.com

Lot 3177, Jalan Masjid Kg. Pasir Putih, 81700 Pasir Gudang, Johor

---

To:

Mr. Muhammad Azmin bin Zainal

Politeknik Banitng Selangor,

Persiaran Ilmu, Jalan Sultan Abdul Samad,

42700 Banting, Selangor

7 th October 2024

CONFIRMATION OF RECOGNITION OF VIRTUAL REALITY OF COMPOSITE TAP TEST (VRCTT)

I'l hope this letter finds you well. On behalf of Otaiz Solution, I am pleased to formally accept your proposal for collaboration on the Virtual Reality of Composite Tap Test (VRCTT) project.

We recognize the significance of this project in advancing the field of non-destructive testing through virtual reality technology, and we are enthusiastic about the opportunity to contribute our expertise and resources. This innovative method not only improves learning outcomes, but also enhances safety in composite tap test skills.

We are looking forward to a productive and successful partnership. Thank you for the opportunity to collaborate on this exciting project.

Thank you,

Regards,

Herwan bin Samsuddin
Director
Otaiz Solution

APPENDIX F: I-INNOLED 2024 COMPETITION CERTIFICATION

CERTIFICATE OF ACHIEVEMENT

This is to certify that

AQIL MUQRI BIN MAHADI, IZZUL HAZWAN BIN MOHD FAZLI
AFREINA BINTI MOHD AFANDI, NURFATEHAH BINTI MOHD NAZRI

Are awarded

GOLD MEDAL

For the project entitled

VIRTUAL REALITY OF COMPOSITE TAPTEST

at the
i-INNOLED 2024 (15-16 October 2024)

organized by
FACULTY OF MAJOR LANGUAGE STUDIES, USIM

ASSOC. PROF DR. ZAINUR RIJAL ABDUL RAZAK
DEAN
FACULTY OF MAJOR LANGUAGE STUDIES

ASSOC. PROF DR. HAZLINA ABDULLAH
DIRECTOR
i-INNOLED 2024

APPENDIX G: AEROMECH COMPETITION CERTIFICATION

POLITEKNIK MALAYSIA
BANTING

Sijil Penganugerahan

Sekalung tahniah kepada

EN. MOHAMMAD AZMIN BIN ZAINAL (PENYELIA)	**870206-38-5049**
AQIL MUQRI BIN MAHADI	**040806-02-0171**
IZZUL HAZWAN BIN MOHD FAZLI	**040225-16-0037**
AFREINA BINTI MOHD AFANDI	**040229-02-0138**
NURFATEHAH BINTI MOHD NAZRY	**040811-05-0156**

mendapat

ANUGERAH PERAK

sempena

PERTANDINGAN PROJEK AKHIR
PELAJAR AEROMECH SESI I 2024/2025

dengan tajuk projek

THE DEVELOPMENT OF VIRTUAL REALITY (VR) COMPOSITE TAP TESTING

pada

5 NOVEMBER 2024

bertempat di

POLITEKNIK BANTING SELANGOR

TS. IBRAHIM BIN BURHAN
PENGARAH
POLITEKNIK BANTING SELANGOR

No. Siri:PBS/UPIK/AN_0032

AEROMECH
POLITEKNIK BANTING

APPENDIX H: RESEARCH OF VIRTUAL REALITY SKILL TRAINING APPLICATIONS

frontiers in Virtual Reality

REVIEW
published: 30 April 2021
doi: 10.3389/frvir.2021.645153

A Review on Virtual Reality Skill Training Applications

*Biao Xie[1], Huimin Liu[2], Rawan Alghofaili[1], Yongqi Zhang[1], Yeling Jiang[3], Flavio Destri Lobo[3], Changyang Li[1], Wanwan Li[1], Haikun Huang[1], Mesut Akdere[3], Christos Mousas[2] and Lap-Fai Yu[1]**

[1]*Design Computing and Extended Reality Group, Volgenau School of Engineering, Computer Science, George Mason University, Fairfax, VA, United States,* [2]*Virtual Reality Lab, Department of Computer Graphics Technology, Purdue University, West Lafayette, IN, United States,* [3]*Purdue Human Resource Development Virtual Lab, Department of Technology Leadership and Innovation, Purdue University, West Lafayette, IN, United States*

This study aimed to discuss the research efforts in developing virtual reality (VR) technology for different training applications. To begin with, we describe how VR training experiences are typically created and delivered using the current software and hardware. We then discuss the challenges and solutions of applying VR training to different application domains, such as first responder training, medical training, military training, workforce training, and education. Furthermore, we discuss the common assessment tests and evaluation methods used to validate VR training effectiveness. We conclude the article by discussing possible future directions to leverage VR technology advances for developing novel training experiences.

Keywords: virtual reality, training, simulation, content creation, personalization

OPEN ACCESS

Edited by:
Xubo Yang,
Shanghai Jiao Tong University, China

Reviewed by:
Chao Mei,
Kennesaw State University, United States
Hai-Ning Liang,
Xi'an Jiaotong-Liverpool University, China
Amela Sadagic,
Naval Postgraduate School, United States

****Correspondence:***
Lap-Fai Yu
craigyu@gmu.edu

Specialty section:
This article was submitted to Technologies for VR, a section of the journal Frontiers in Virtual Reality

Received: *22 December 2020*
Accepted: *19 April 2021*
Published: *30 April 2021*

Citation:
Xie B, Liu H, Alghofaili R, Zhang Y, Jiang Y, Lobo FD, Li C, Li W, Huang H, Akdere M, Mousas C and Yu L-F (2021) A Review on Virtual Reality Skill Training Applications. Front. Virtual Real. 2:645153. doi: 10.3389/frvir.2021.645153

1 INTRODUCTION

Thanks to the recent growth of consumer-grade virtual reality (VR) devices, VR has become much more affordable and available. Recent advances in VR technology also support the creation, application, evaluation, and delivery of interactive VR applications at a lower cost. The VR research community is more active than ever. The IEEE Virtual Reality conference has received a record number of submissions in 2020, an approximate 10% growth compared to the previous year (2019.) The latest commercial standalone VR headset Oculus Quest 2, which was released in 2020 has become the fastest selling VR headset Lang (2021). Such trends contribute to the increasing popularity and success of VR training across different domains. For example, VR training is the most common use of VR within enterprise—62% according to a recent survey Ostrowski (2018).

According to Merriam Webster[1], training is defined either as 1) the act, process, or method of one that trains and 2) the skill, knowledge, or experience acquired by one that trains; or the state of being trained. Conventionally, training happens with physical setups such as classrooms and laboratory spaces through presentations and hands-on practice. However, there are cases in which trainees must travel to specific facilities to receive proper training. To date, VR technology makes it possible to provide real-world training through virtual environments while providing an effective and immersive training experience.

As virtual environments are used to train users to perform real-world tasks and procedures, it is important to compare real-world training with VR-based training. In general, real-world training has

[1]https://www.merriam-webster.com/dictionary/training

APPENDIX I: RESEARCH OF LEARNING IN VIRTUAL REALITY COMPARED TO CONVENTIONAL METHOD

Research in Learning Technology
Vol. 26, 2018

ASSOCIATION FOR LEARNING TECHNOLOGY ALT

ORIGINAL RESEARCH ARTICLE

Learning in virtual reality: Effects on performance, emotion and engagement

Devon Allcoat* and Adrian von Mühlenen

Department of Psychology, University of Warwick, Coventry, UK

(Received 12 June 2018; final version received 23 October 2018)

Recent advances in virtual reality (VR) technology allow for potential learning and education applications. For this study, 99 participants were assigned to one of three learning conditions: traditional (textbook style), VR and video (a passive control). The learning materials used the same text and 3D model for all conditions. Each participant was given a knowledge test before and after learning. Participants in the traditional and VR conditions had improved overall performance (i.e. learning, including knowledge acquisition and understanding) compared to those in the video condition. Participants in the VR condition also showed better performance for 'remembering' than those in the traditional and the video conditions. Emotion self-ratings before and after the learning phase showed an increase in positive emotions and a decrease in negative emotions for the VR condition. Conversely there was a decrease in positive emotions in both the traditional and video conditions. The Web-based learning tools evaluation scale also found that participants in the VR condition reported higher engagement than those in the other conditions. Overall, VR displayed an improved learning experience when compared to traditional and video learning methods.

Keywords: VR; education; experience; mood

This paper is part of the special collection Mobile Mixed Reality Enhanced Learning, edited by Thom Cochrane, Fiona Smart, Helen Farley and Vickel Narayan. More papers from this collection can be found here

Introduction

Interactive technology is progressing at an incredibly fast rate, and advances in virtual reality (VR) technology have led to many potential new applications. Commercial VR headsets are widely used for entertainment purposes, with many individuals' experiences of VR being from video games and other widely distributed media, as these media are widely advertised and well known, leading to higher popularity. However, VR has broader application possibilities, thanks to significant advances in the technology, including the technology now available in a mobile format.

VR technologies allow the user to see and interact with virtual environments and objects. Modern VR is delivered through a headset, which allows the user to see – and in some cases, hear – the 3D environment. In this way the user is totally immersed in the virtual environment, as it replaces the physical environment around them. Immersion and engagement can be considered intrinsically linked in virtual environments

*Corresponding author. Email: D.B.Allcoat@warwick.ac.uk

Citation: Research in Learning Technology 2018, **26**: 2140 - http://dx.doi.org/10.25304/rlt.v26.2140
(page number not for citation purpose)

APPENDIX J: RESEARCH ON PROGRAMMING SOFTWARE

Software Tools for Virtual Reality Application Development

SIGGRAPH '98 Course 14
Applied Virtual Reality

Allen Bierbaum and Christopher Just
(allenb, cjust@icemt.iastate.edu)

Iowa Center for Emerging Manufacturing Technology
Iowa State University

Abstract

With growing interest in Virtual Reality (VR) there has been a dramatic increase in the number of development environments for VR[1]. This paper presents a discussion of features to look for when choosing a development environment for virtual reality applications. These features include the software's capabilities, such as graphics and VR hardware support, the interface it provides for developers, and other items such as support for performance monitoring. It then gives a brief overview of several popular VR development environments from academic and commercial sources, discussing how well they address the needs of VR developers. The paper concludes with an introduction to VR Juggler, a development environment currently in development at Iowa State University. This includes a discussion of how Juggler's developers approached each of the desired features of VR development environments presented in the first section of the paper.

1. Introduction

As interest in Virtual Reality technology has increased, so has the number of tools available to the developers of virtual worlds. Some of these are libraries and toolkits, while others are application frameworks, and still others are full development environments, integrating every aspect of the creation of a VR application – modeling, coding, and execution – into a single package.

Each of these development systems has a unique set of features and, since there are not yet any standards for VR software, their own interfaces to those features. Each supports a particular set of hardware, giving developers and end users a particular level of abstraction. Each takes a different approach to handling the complex interactions of operating systems, networks, input devices, displays, audio outputs,

[1] Note: CAVE, ImmersADesk, PowerWall, Flock of Birds, SpacePad, CyberGlove, DataGlove, Direct3D, Windows NT, Windows 95, BOOM, PINCH gloves, and Iris Performer are all registered trademarks of their respective companies.