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Aircraft Servicing Virtual Reality Ground Operation Training for WCC Aeronautical and Technological College

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Abstract — Virtual Reality (VR) technology offers an immersive and interactive environment, making it ideal for aviation training simulations. While VR training has its limitations due to disparities between virtual and real-world scenarios, this study aimed to enhance existing VR applications and developed a VR-based Aircraft Servicing Ground Operation Training for aircraft Marshalling, Refueling, and Servicing tasks by integrating additional Aircraft Line Maintenance tasks and to provide a safe alternative to real-world training, reducing accidents and incidents. The said VI for Ground Operation was evaluated using ISO25010 software quality standards to evaluate the application's functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. The results shows a positive feedback from both students and instructors, emphasizing its completeness and appropriateness in addressing functional requirements. The VR-based Aircraft Servicing Ground Operation Training demonstrated outstanding performance efficiency, excellent compatibility, high usability, and robust security. It showcased exceptional maintainability and portability, underlining its adaptability and ease of use across various platforms. Based on these positive outcomes, several recommendations were sought, that there should be a continued research to bridge the gap between virtual and real-world scenarios, ensuring optimal user performance in actual aviation maintenance contexts. Regular updates of the project is recommended to incorporate evolving technologies and industry best practices, collaboration with industry experts to enhance the program's realism, periodic evaluations with end-users to address emerging needs and concerns, keeping the project relevant and effective. Furthermore, exploring partnerships with educational institutions and aviation industry players can foster a collaborative learning environment, promoting knowledge sharing and best practices.

Keywords — Virtual Reality, aircraft servicing, training program, safety enhancement, Aviation Simulation

I. Introduction

Virtual Reality (VR) is a cutting-edge human-computer interface that simulates a real-world environment, according to Ian Gibson of the National University of Singapore. In the virtual environment, the participants have mobility. They have the ability to manipulate it by reaching into it, grabbing it, and changing its shape.

Immersion and interaction are the two main goals of virtual reality. The act of deliberately concentrating on the material one wants to work with while filtering out all other distractions is known as immersion. Human interaction with events in the virtual world is referred to as interactivity. The main goal of virtual reality is to immerse the user in a virtual environment that makes them feel as though they are actually there. Linking the human perceptual and physical state of a person with the virtual environment is necessary for this.

Virtual reality aids in solving problems across a variety of field including enjoyment, communication, and scientific and medical studies. It is used for training as people can have a safe environment to make mistakes and learn. It can also be a cost-effective way of delivering training in an agile way.

As a training simulator, virtual reality is employed in the field of aviation. Aviation mechanics can study and examine components of an aircraft remotely in an immersive environment using virtual reality. However, there are drawbacks to employing virtual reality training because the virtual and real worlds are very different from one another. When placed in situations where their decisions may have real-world repercussions, they might not be able to perform at their best. Nevertheless, a person can still quickly learn to execute aircraft maintenance operations, fly a plane, and many other things without endangering their own or others' lives by using virtual reality to replicate potentially dangerous real-world activities like flying training and aircraft line maintenance procedures.

Kassandra Peralta et al. (2019) previously developed a WCC based virtual reality marshalling application that enables a person to train aircraft marshalling safely. Line maintenance is risky because both the aircraft and the maintenance staff pose threats to one another. Moving aircraft present a significant threat to a maintenance personnel due to the pilot's restricted field of vision, while an aircraft personnel present a risk because a naive maintenance trainee can cause accidents if their actions are sloppy. The researchers experienced and used the application and it inspired the researchers to upgrade and update the previous application rather than just aircraft marshalling. The researchers decided to integrate more Aircraft Line Maintenance activities to help students, teachers, and aircraft mechanics to practice other Aircraft Line Maintenance activities safely.

The overall goal of this research is to provide Aircraft Servicing Virtual Reality Ground Operation Training for WCC Aeronautical and Technological students and teachers to use as a teaching tool. To provide virtual reality software that will provide WCC Aerotech College

instructor and students with a safe and cost-effective approach to learn about aircraft ground operations. To investigate the potential benefits and opportunities that virtual reality may provide to WCC Aerotech College's aviation mechanics and future aircraft mechanics. To develop an application that may aid WCC Aerotech College, instructors, and students in imparting and acquiring sound knowledge regarding ground operation training using VR technology, while avoiding risking the students' safety during real training.

Literature Review

Hughes (1998) introduced the Replacement, Amplification, and Transformation (RAT) framework as a means of evaluating the integration of technology in educational contexts. This framework analyzes the extent to which technology replaces, amplifies, or transforms traditional pedagogical practices.

Schmidt (2009) developed and validated an assessment tool for preservice teachers, focusing on their Technological Pedagogical Content Knowledge (TPACK). This framework examines the interplay between technology, pedagogy, and content knowledge, highlighting their interconnectedness in effective teaching.

Tan (1999) explored the feasibility of using satellite communication systems to deliver distance learning in maritime education and training. This research delved into the potential of virtual classrooms to expand access and flexibility in this field.

Rheingold (1991) examined the transformative potential of virtual reality (VR), discussing its applications across various domains and the ethical considerations surrounding this emerging technology.

Booth (2019) investigated the utilization of virtual and augmented reality (VR/AR) in Air Force training. His research highlighted the potential of these technologies to enhance training effectiveness, reduce costs, and improve safety.

Al-Shafi (2018) reported on Qatar Airways' pioneering adoption of IATA's Ramp VR, a virtual reality training program for ramp agents. This marked a significant step in integrating VR into real-world aviation training scenarios.

Jaakola (2022) explored the current landscape of virtual reality solutions and their potential applications in aviation training. This study examined various VR applications and their impact on learning outcomes and skill development.

KPASS Airport (2017) showcased the integration of virtual reality into airport operations, highlighting its potential to enhance passenger experiences, streamline processes, and bolster safety measures.

Benedetto et al. (2013) investigated the impact of e-readers on visual fatigue, contributing to the understanding of ergonomic considerations in digital reading technologies.

Champney et al. (2007) examined the time course of symptoms, such as nausea and dizziness, following exposure to virtual environments. Their research proposed potential strategies for readaptation and symptom mitigation.

Gabunilas (n.d.) and George (n.d.) presented a case study of a Korean Air Lines pilot who successfully landed a plane despite crew incapacitation. This study underscores the critical role of pilot training and decision-making under duress.

Van Krevelen and Poelman (2010) conducted a comprehensive survey of augmented reality technologies, applications, and limitations, offering valuable insights into the current state and future potential of augmented reality.

Urvoy et al. (2013) reviewed the technological, psychophysical, and psychological factors influencing visual fatigue and discomfort associated with 3D-TV viewing. Their work provides valuable insights for enhancing the user experience of 3D displays.

These references underscore the growing relevance of virtual and augmented reality in the aviation industry, particularly in education and training. They highlight the potential of these technologies to revolutionize training methodologies, enhance learning outcomes, improve safety standards, and streamline operations, ultimately contributing to a more efficient and resilient aviation sector.

II. Methodology

The researchers employed a quantitative, descriptive-development research design, using descriptive experiments to develop virtual reality for training aircraft servicing. The setting is the WCC airport, recreated in the researchers' application. It imitates ramp servicing to familiarize students with real-life scenarios in aircraft maintenance. The respondents include WCC-ATC instructors and Aircraft Maintenance Technology students. The researchers ensure ethical considerations, obtaining informed consent and maintaining confidentiality and anonymity. The evaluation instrument consists of eight factors: Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Security, Maintainability, and Portability. These factors are evaluated using various indicators and tested by experienced technicians from WCC. Data was collected through questionnaires, surveys, and observations from WCC-ATC participants. The researchers obtain permission to conduct the study and gather data directly from participants. Mean and standard deviation are used for data analysis. Mean is calculated by dividing the total scores by the number of scores. Standard deviation evaluates data dispersion in relation to the mean. Ethical considerations include obtaining voluntary informed consent from participants, ensuring

confidentiality, anonymity, and avoiding coercion. Safety precautions, such as being aware of surroundings and avoiding injuries during virtual reality interactions, are also highlighted.

The researchers identified minimal knowledge and material requirements, such as basic computer skills and knowledge of aircraft maintenance, to set boundaries for the application. The application was developed using C++ and Unreal Blueprint. Commands written in C++ were integrated into Unreal Blueprint for execution. The system unit specifications include a Ryzen 5 CPU, GTX 1660 Super GPU, 16 GB RAM, and 480 GB SSD storage, ensuring high-performance computing for seamless multitasking and efficient graphics processing. The application was developed as a VR application aiming to enhance safety and reduce human error in aircraft servicing. It underwent testing by faculty members and students of the AMT department. The application requires specific minimum specifications, including Intel i5 or Ryzen 5 CPU, GTX 1660 or above GPU, 16GB RAM, and 128GB internal storage. Testing involved beta testing by researchers, faculty members, and students. The inspection process included orientation on usage, demonstrations, and surveys for user feedback. The project management utilized PERT-CPM (Program Evaluation and Review Technique-Critical Path Method) and Gantt charts. The PERT chart depicted the estimated time for completing tasks, ensuring efficient time management. The Gantt chart tracked project progress through research planning, project design, programming, and final documentation. Throughout the project, an emphasis was placed on safety protocols, human error reduction, and rigorous testing procedures involving faculty members and students. The application aimed to provide an effective and safe VR training experience for aircraft maintenance students at WCC Aeronautical and Technological College.

III. Results and Discussion

This section serves as a focal point, bringing together their endeavors and highlighting the outcomes of their exploration. These findings are elucidated through a thorough discussion, placing them in context and offering interpretations. By succinctly summarizing their primary results from data analysis, the researchers delve into an enlightening expedition, linking their findings with existing knowledge to derive significance, explore consequences, and offer valuable perspectives.

Development Phase Analysis

Software Specifications

The researchers utilized Unreal Engine 4 to bring their concept to life, constructing the virtual environment of the WCC Airport ramp. This digital space serves as a learning tool for students and instructors in the AMT department, aiding in their preparation for servicing subjects and On the Job Training (OJT). The application's minimum system requirements for Virtual Reality (VR) functionality were established by the researchers' programmer. These specifications

mandate a Central Processing Unit (CPU) of either Ryzen 5 or Intel i5, a Graphics Processing Unit (GPU) of Nvidia GTX 1660 or Radeon RX590, a minimum of 16 GB of Random Access Memory (RAM), and internal storage of at least 128 GB..

Hardware Specification

The researcher's programmer set the minimum specification requirement for system unit as shown in the table below:

Table 1: ***Minimum Specification***

CPU Central Processing Unit	GPU Graphics Processing Unit	RAM Random Access Memory	Internal Storage
Intel i5 Ryzen5	GTX 1660 Super Above Radeon RX590	16GB RAM	128GB

Table 3 shows the minimum specification requirement of the application in order to run. The researcher best recommended for graphics settings is low for the minimum requirement to optimize the use of the application.

Program Specifications

The proposed virtual reality application aims to facilitate various tasks such as marshalling, Foreign Object Debris (FOD) clearing, refueling, defueling, and performing a 360 check on the WCC ramp. Users have the flexibility to edit application gestures according to their preferences, and gesture calibration is also possible within the application. These features were specifically designed to train Aircraft Maintenance Technology Students for their On the Job Training (OJT) within the WCC Airport ramp.

Figure 1: ***Marshaling Feature***

The special feature of the researcher's application was the refueling, where student users would experience how to refuel an aircraft. In Figure 9 below, the user followed the procedure on how to refuel the aircraft.

Figure 2: ***Refueling Aircraft***

In Figure 10, the user follows voice instructions in the application for refueling. They start by turning off the master switch and inserting the ground receptacle. Placing the correct fire extinguisher is crucial; wrong choices trigger error sounds, while correct ones prompt positive feedback. After climbing the ladder and clicking the depth stick, the user deduces fuel quantity by subtracting from the tank's 28-gallon capacity. Errors in input result in error sounds. Using a Jerry-can, the user refuels through a blue circle above the fuel tank hole. Upon completion, the application confirms refueling success.

Figure 3: ***Servicing Performing FOD Walk in Ramp and Runway***

The researcher's application includes a servicing feature where users clear Foreign Object Debris (FOD) from the ramp and runway. Upon completion, the application acknowledges the task. Additionally, users perform a 360 inspection by obtaining a checklist from the hangar, entering the aircraft, and activating the master switch to start the inspection. During the inspection, users click on various parts of the aircraft; upon completion, a narrator confirms the inspection's finish.

Technical Analysis

Technical Design

The VR marshalling and servicing application for the Cessna 172 at WCC Aerotech College's Ramp and Hangar offers a 3D-simulated environment with aircraft, equipment, and instrument panels. It guides students through marshalling, refueling, defueling, a 360-degree check, and a FOD walk. This tool enhances safety, mitigating risks in field training. Instructors of aviation maintenance technology can use it for training and supplementing students' education on FOD walks, aircraft marshalling, and refueling procedures.

System Design

A virtual reality environment has been developed for aviation training, specifically focusing on the Cessna 172 aircraft and the WCC Aviation Airport ramp and hangar. This immersive learning experience requires specific hardware and software, including a laptop or PC with an Intel Core i5 or Ryzen 5 processor, a GTX 1660 GPU, 16GB of RAM, and 128 GB of internal storage. The environment is designed using Unreal Engine 4 Blueprint, allowing for the creation of realistic 3D models simulating real-world scenarios.

Students use a virtual reality headset connected to a computer running Unreal Engine 4 Blueprint to access the environment. This setup offers a unique and realistic learning experience, enabling students to fully immerse themselves in the virtual environment and interact with it in ways traditional training methods cannot. The primary goal of object modeling is to create accurate 3D representations of the Cessna 172 aircraft and the WCC Aerotech college ramp and hangar. These models must accurately depict various components like the fuselage, wings, landing gear, and engine, enhancing realistic interaction during training. Additionally, realistic materials, textures, and lighting are incorporated for an immersive training experience.

Before the application runs, users interact with an Oculus Device, which reads their body and head motion. These movements serve as input processed by the application and Oculus App, converting them into actions displayed in the virtual environment. The system flowchart outlines the necessary steps for users, emphasizing adherence to correct procedures taught in the curriculum. Users must calibrate marshalling signals, select tasks, and perform correct gestures to complete tasks. The application validates user inputs and provides feedback.

Moreover, the security design of the virtual reality system is crucial. It involves implementing measures like encryption, secure authentication, data backups, and data loss prevention to protect the VR system, researchers, users, and data from unauthorized access, theft, or manipulation. Security design ensures the integrity, confidentiality, and privacy of VR systems and data, enabling users to enjoy the benefits of VR without security concerns.

Final Output Perspective

After conducting the demo, the researchers discovered that the application was becoming confused while calibrating various types of marshalling gestures. The researchers quickly fixed the application by reducing the marshalling signals to just four: Turn right, Turn left, Slow down, and Normal stop. When the marshalling signal was reduced the application can immediately recognize the gesture input of the user.

Verification, Validation, and Testing

Overall, verification, validation, and testing are three critical phases in guaranteeing software system quality and reliability. The researchers must ensure that the system will function correctly and produce accurate and reliable results by verifying that the software system meets the specified requirements and standards, validating that it is fit for its intended use, and testing it to identify and correct any issues.

The researchers performed functional testing, which involved comparing the system to the functional criteria stated for the study. The researchers tested the system's capacity to gather and process data, evaluate outcomes, and execute any other duties that were necessary.

After each module was completed, the researchers did unit testing to ensure that everything was functioning correctly and to discover any issues or flaws early in the process. The researcher did various tests during the development process to ensure that each component of the program is running properly and free of defects and faults.

The main objective of integration testing by the researcher is to guarantee the correct functionality and accurate results of the entire system of our virtual reality by identifying problems or errors that arise during the integration testing. Integration testing can help prevent issues from occurring later in the research process.

The purpose of system testing in research is to ensure that the system satisfies the criteria and objectives of the research project and that it will produce accurate and reliable findings. The researchers may verify that their data and conclusions are true and trustworthy, and that their study outcomes are significant and impactful, by doing thorough system testing.

Acceptability testing was conducted by the researchers at the end of the development period, when integration and system testing had been finished. Acceptance testing ensures that the research system is functioning and suitable for use in the research project. The research phase

includes testing the system against the project's needs and criteria. The system's performance, accuracy, and dependability may be evaluated, as well as its compliance with any regulatory or ethical criteria for the research effort.

Non-Functional Testing

The Researchers conducted testing on the application. During a performance test the researcher found out that when using the minimum specification of the system unit the most efficient graphic setting is low to prevent it from crashing. The application was tested for load test and the researchers found out when in high graphic settings, and minimum specs the application is crashing. Stress testing was also conducted and the researcher found out that when the minimum specification of PC is used and its graphics setting is on high quality the application will lag and crash

In the development of the application the researcher ensured that the application will not gather information of the user. The main goal of the application is to educate the AMT students for their preparation in servicing subject and On-the-Job-Training. All the confidential information of the student and instructor will not be collected by the application. It will only process the calibration of the user's gesture input for marshalling the signal.

The researchers conducted a demo of their application to the students and instructors of the Aircraft Maintenance Technology department to see and identify if the application was working well. The comments received by the researchers are positive. Where in the five aspects of testing the users agreed that the application is outstanding but only the inspection.

Structural Testing

The researchers conducted structural testing on the aircraft marshalling and servicing application during the development process to evaluate the internal structure of the program and ensure that it met the required standards. As a researcher, it is important to note that structural testing is a method used to evaluate the internal structure of software. This includes analyzing the code, architecture, and design to identify any potential flaws or weaknesses that may affect the program's functionality. Through the process of conducting structural testing, the researchers was able to identify and resolve any issues related to the program's design and implementation before moving on to integration testing and system testing. Ensuring that the program was developed to a high standard and would function correctly when integrated with other components of the system was crucial. Ultimately, the combination of unit testing, integration testing, system testing, acceptance testing, and structural testing helped the researchers to create a strong and reliable system that met the needs of the research project.

Levels of Testing

During the development of the research project, several levels of testing were performed to ensure that the system was functioning properly and met the necessary criteria. The researcher initiated the process of unit testing, which was performed after the completion of each module to verify the proper functioning of all program components and eliminate any defects or faults. Next, the researchers proceeded with integration testing to verify the accurate functioning and precise outcomes of the entire virtual reality system by detecting any issues or mistakes that emerged during the integration testing. The researchers performed system testing to ensure that the system met the criteria and objectives of the research project and would generate accurate and reliable findings. Finally, acceptance testing was conducted at the end of the development period to verify that the research system was operational and appropriate for use in the research project. Acceptance testing, as a researcher, would entail testing the system against the project's requirements and standards, assessing the system's performance, precision, and reliability, and verifying its adherence to any regulatory or ethical standards for the research endeavor.

Economic Analysis

Process Cost

The researcher's project amounting to Php109,000 includes several expenses that were covered by the funding they received. The transportation costs, which were a significant expense, were covered to ensure that the project could be carried out smoothly. In addition, a programmer fee was paid to develop the necessary software and tools to conduct the research. This was crucial in ensuring that the project met its objectives and that accurate results were obtained. Another key expense that was covered was the cost of conducting surveys. This was necessary to collect data that would be analyzed to draw meaningful conclusions. Finally, miscellaneous expenses were also covered, which included any additional costs that arose during the course of the project.

Overall, the researcher's financing was extremely important to the project's accomplishment. By covering the various expenses incurred during the course of the research, the funding enabled the project to be carried out smoothly and efficiently. This allowed the researcher to obtain accurate results and draw meaningful conclusions, which can be used to inform future research and decision-making.

Financial Analysis

The application was idea of the researcher that made possible by the programmer. In creation of the application, the programmer used unreal engine to create the virtual reality application. The outcome of the project was outstanding because the environment looks real. Thanks to the Unreal Engine that made the application realistic. The expenses of the researcher cover the programmer’s fee, 3D models, Printing, and other expenses. The researchers negotiate to the programmer’s fee in order to have low-cost projects without compromising the quality.

When the AMT department uses the application as a learning material for the students of WCC. In the course of time, the school will benefit. In the course of time, the school will benefit because the students will be oriented in the application on what are the do's and don'ts inside the ramp. This will lessen the accident and incident inside the ramp.

Financial Ratios

The researchers utilized cost-based pricing to ascertain the product's price. As a researcher, it can be stated that cost-based pricing is a pricing strategy that determines the price of a product based on its production cost. To determine the selling price of a product, the cost is increased by a certain percentage of the total cost. In the study conducted, the total cost amounts to 100,000. The profit margin is 50%. The total selling price is P150,000.

Survey Results and Discussions

Table 2: ***Evaluation Interpretation Table***

Scale	Range	Descriptive Equivalence
5	4.21-5.00	Very High Extent
4	3.41-4.20	High Extent
3	2.61-3.40	Moderately Extent
2	1.81-2.60	Low Extent
1	1.00-1.80	Very Low Extent

Functional Suitability

Table 3: ***Functional Suitability***

n=100

Functional Suitability	Students' Evaluation	Instructors' Evaluation	Mean	Descriptive Equivalence
Functional Completeness	4.59	4.20	4.39	Very High Extent
Functional Corrections	4.60	4.30	4.45	Very High Extent
Functional Appropriateness	4.60	4.50	4.55	Very High Extent
COMPOSITE MEAN	**4.60**	**4.78**	**4.55**	**Very High Extent**

The results of the evaluation of functional suitability of the Virtual Reality Training Application in Servicing by students and instructors are presented in Table 3. The researcher found that the mean scores for functional completeness, functional corrections, and functional appropriateness were 4.39, 4.45, and 4.55, respectively. The mean scores suggest that the

application is highly functionally suitable. The mean score for functional suitability is 4.55, indicating a very high extent range.

It is noteworthy that a higher mean score for functional suitability was given by the instructors as compared to the students, specifically for functional completeness (4.20 for students and 4.78 for instructors). This phenomenon may be ascribed to the instructors' proficiency in the field of study and their capacity to evaluate the practical implementation in a more impartial manner. Overall, the findings indicate that the Virtual Reality Training Application in Servicing exhibits a high degree of functional suitability.

Performance Efficiency

Table 4: *Performance Efficiency*

n=100

Performance Efficiency	Students' Evaluation	Instructors' Evaluation	Mean	Descriptive Equivalence
Time-behavior	4.53	4.20	4.37	Very High Extent
Resource Utilization	4.63	4.30	4.47	Very High Extent
Capacity	4.61	4.50	4.56	Very High Extent
COMPOSITE MEAN	**4.59**	**4.33**	**4.46**	**Very High Extent**

The results of the evaluation of the Performance Efficiency of the Virtual Reality Training Application in Servicing by 100 students and instructors are presented in Table 8. Based on the collected data, it can be concluded that the application has a very high extent of performance efficiency as evidenced by the mean scores of 4.37, 4.47, and 4.56 for Time-behavior, Resource Utilization, and Capacity, respectively. According to the data, the composite mean score for Performance Efficiency is 4.46, indicating a very high extent of Performance Efficiency. Overall, the application was evaluated by the users as efficient in terms of its time-behavior, resource utilization, and capacity.

Compatibility

Table 5: *Compatibility*

n=100

Compatibility	Students' Evaluation	Instructors' Evaluation	Mean	Descriptive Equivalence
Co-existence	4.49	4.30	4.39	Very High Extent
Interoperability	4.52	4.20	4.36	Very High Extent
COMPOSITE MEAN	**4.51**	**4.25**	**4.38**	**Very High Extent**

According to Table 5, the Virtual Reality Training Application in Servicing underwent an evaluation for compatibility, particularly in terms of co-existence and interoperability. According to the data collected, the mean score for co-existence was 4.39, indicating a high level of co-existence with other systems as rated by the participants. According to the data collected, the mean score for interoperability was 4.36. This indicates that the application has a high level of interoperability with other systems. Overall, the composite mean.

Usability

Table 6: ***Usability***

n=100

Usability	Students' Evaluation	Instructors' Evaluation	Mean	Descriptive Equivalence
Appropriateness recognizability	4.52	4.10	4.31	Very High Extent
Learnability	4.63	4.40	4.52	Very High Extent
Operability	4.57	4.30	4.43	Very High Extent
User error protection	4.47	4.30	4.38	Very High Extent
User interface aesthetics	4.66	4.40	4.53	Very High Extent
Accessibility	4.57	4.20	4.38	Very High Extent
COMPOSITE MEAN	**4.57**	**4.28**	**4.43**	**Very High Extent**

The usability evaluation results of the Virtual Reality Training Application in Servicing are presented in Table 6, based on the ratings of 100 students and instructors. The mean score for usability is 4.43, which suggests a high level of usability. The mean scores for all usability criteria were between 4.31 and 4.53, indicating that the application received high ratings. The criterion of "user interface aesthetics" had the highest mean score of 4.53, while the criterion of "user error protection" had the lowest mean score of 4.38. Overall, the findings indicate that the Virtual Reality Training Application in Servicing exhibits a high degree of usability for both educators and learners.

Reliability

Table 7: *Reliability*

n=100

Reliability	Students' Evaluation	Instructors' Evaluation	Mean	Descriptive Equivalence
Maturity	4.50	4.30	4.40	Very High Extent
Availability	4.64	4.30	4.47	Very High Extent
Faulty tolerance	4.57	4.30	4.43	Very High Extent
Recoverability	4.63	4.40	4.52	Very High Extent
COMPOSITE MEAN	**4.59**	**4.33**	**4.46**	**Very High Extent**

The results of the reliability evaluation of the system are presented in Table 7. The assessment was based on four parameters: Maturity, Availability, Faulty Tolerance, and Recoverability. The evaluation was conducted by collecting data from 100 participants, which included both students and instructors.

According to the data collected, the mean scores for each parameter were as follows: Maturity (4.40), Availability (4.47), Faulty Tolerance (4.43), and Recoverability (4.52). Based on the scores, it can be concluded that the system demonstrated a high level of reliability for all parameters, and there was a significant degree of similarity between the evaluations provided by both students and instructors.

The researcher found that the composite mean score for the overall reliability of the system was 4.46, indicating a very high extent of descriptive equivalence. According to the research findings, the system was perceived as highly reliable by both students and instructors, and it was able to effectively and consistently perform its functions.

Based on the reliability evaluation, it can be concluded that the system is a reliable and sturdy tool for both students and instructors. The system has demonstrated high levels of maturity, availability, fault tolerance, and recoverability.

Security

Table 8: *Security*

n=100

Security	Students' Evaluation	Instructors' Evaluation	Mean	Descriptive Equivalence
Confidentiality	4.54	4.60	4.57	Very High Extent
Integrity	4.56	4.60	4.58	Very High Extent
Non-repudiation degree	4.43	4.50	4.47	Very High Extent
Accountability	4.51	4.50	4.51	Very High Extent
Authenticity	4.51	4.50	4.51	Very High Extent
COMPOSITE MEAN	**4.51**	**4.54**	**4.53**	**Very High Extent**

The results of the security evaluation of the system are presented in Table 8. The assessment was based on five parameters, namely Confidentiality, Integrity, Non-repudiation degree, Accountability, and Authenticity. The evaluation was conducted by collecting data from 100 participants, which included both students and instructors.

According to the data collected, the average scores for each parameter were: Confidentiality (4.57), Integrity (4.58), Non-repudiation degree (4.47), Accountability (4.51), and Authenticity (4.51). Based on the scores, it can be concluded that the system demonstrated a high level of security for all parameters and achieved a high degree of descriptive equivalence for evaluations from both students and instructors.

As a researcher, I found that the composite mean score for the overall security of the system was 4.53, indicating a very high extent of descriptive equivalence. According to the research findings, the system was perceived as highly secure by both students and instructors. It was able to maintain the confidentiality, integrity, non-repudiation degree, accountability, and authenticity of data and information exchanged through it.

Based on the security evaluation, it can be concluded that the system is a reliable and secure tool for both students and instructors. The evaluation indicates that the system maintains high levels of confidentiality, integrity, non-repudiation degree, accountability, and authenticity.

Maintainability The results of the maintainability evaluation of the system are presented in Table 9. The assessment was based on five parameters: Modularity, Reusability, Analyzability, Modifiability, and Testability. The evaluation was conducted by collecting data from 100 participants, which included both students and instructors.

Table 9: ***Maintainability***

n=100

Maintainability	Students' Evaluation	Instructors' Evaluation	Mean	Descriptive Equivalence
Modularity	4.50	4.40	4.45	Very High Extent
Reusability	4.54	4.50	4.52	Very High Extent
Analyzability	4.46	4.60	4.53	Very High Extent
Modifiability	4.54	4.70	4.62	Very High Extent
Testability	4.62	4.60	4.61	Very High Extent
COMPOSITE MEAN	**4.53**	**4.56**	**4.55**	**Very High Extent**

According to the data collected, the mean scores for each parameter were as follows: Modularity (4.45), Reusability (4.52), Analyzability (4.53), Modifiability (4.62), and Testability (4.61). Based on the scores, it can be concluded that the system demonstrated a high level of maintainability across all parameters. Additionally, both students and instructors provided evaluations that were highly descriptive and equivalent.

As a researcher, I found that the composite mean score for the overall maintainability of the system was 4.55, indicating a very high extent of descriptive equivalence. According to the research findings, the system was perceived as highly maintainable by both students and instructors, and it was deemed easy to modify, test, and analyze.

Based on the results of the maintainability evaluation, it can be concluded that the system is a versatile and adjustable resource that can be utilized by both students and instructors. The system exhibits high levels of modularity, reusability, analyzability, modifiability, and testability.

Portability

Table 10: ***Portability***

n=100

Portability	Students' Evaluation	Instructors' Evaluation	Mean	Descriptive Equivalence
Adaptability	4.54	4.40	4.47	Very High Extent
Installability	4.52	4.60	4.56	Very High Extent
Replaceability	4.57	4.60	4.58	Very High Extent
COMPOSITE MEAN	**4.54**	**4.53**	**4.54**	**Very High Extent**

The results of the portability evaluation are presented in Table 10. The assessment was based on three parameters: Adaptability, Installability, and Replaceability. The evaluation was conducted utilizing data gathered from a sample of 100 individuals, comprising of both students and instructors.

According to the data collected, the mean scores for Adaptability, Installability, and Replaceability parameters were 4.47, 4.56, and 4.58, respectively. Based on the scores, it can be concluded that the system demonstrated high portability for all parameters and achieved a significant level of descriptive equivalence in evaluations from both students and instructors.

The mean score for the overall portability of the system was 4.54, indicating a high level of descriptive equivalence. According to the research findings, the system was perceived as highly portable by both students and instructors, and it was deemed easy to adapt, install, and replace.

Based on the evaluation results, it can be concluded that the virtual reality application is highly suitable in terms of functionality, reliability, security, maintainability, and portability. The ratings provided by both students and instructors in each of these areas indicate that the system is a valuable tool for use in educational settings.

Overall Evaluation

Table 11: ***Overall Evaluation***

n=100

Criteria	Students' Evaluation	Instructors' Evaluation	Mean	Descriptive Equivalent
Functional Suitability	4.60	4.50	4.55	Very High Extent
Performance Efficiency	4.59	4.33	4.46	Very High Extent
Compatibility	4.51	4.25	4.38	Very High Extent
Usability	4.57	4.28	4.43	Very High Extent
Reliability	4.59	4.33	4.46	Very High Extent
Security	4.51	4.54	4.53	Very High Extent
Maintainability	4.53	4.56	4.55	Very High Extent
Portability	4.54	4.53	4.54	Very High Extent
OVERALL EVALUATION	**4.55**	**4.42**	**4.49**	**Very High Extent**

According to the ratings of 100 students and instructors across various criteria, Table 15 presents a comprehensive evaluation of the virtual reality application. The mean scores for each criterion were all above 4.0, suggesting a "Very High Extent" of descriptive equivalence, as per the research findings.

Based on the assessment of functional suitability, the application's mean score was determined to be 4.55, suggesting that the application's functions accurately address all designated tasks and user objectives. The application obtained high ratings for performance efficiency (4.46), compatibility (4.38), usability (4.43), reliability (4.46), security (4.53), maintainability (4.55), and portability (4.54).

The composite mean score for the overall evaluation was 4.49, indicating a "Very High Extent" of descriptive equivalence. This indicates that the virtual reality application developed by the researchers is dependable, safe, and sustainable, and fulfills the requirements of its users in regards to features, speed, adaptability, and user-friendliness.

IV. Conclusion

In conclusion, developing a VR application for training aviation maintenance technology students represents a noteworthy contribution to the aviation industry. The researchers' study aimed to explore the potential benefits of incorporating VR technology in aviation training. They developed a safe and cost-effective VR software and designed an application that facilitates the imparting and learning of ground operation training. Researchers conducted a test to determine the effectiveness of VR training in ground operations for future aircraft mechanics students at WCC Aerotech College. The utilization of VR technology in this training program has the potential to enhance safety measures, simulate a lifelike and engaging environment, and minimize the occurrence of accidents and incidents on the ramp. The various levels of testing that were carried out guarantee that the system is dependable, precise, and fulfills the project's requirements and standards. The effectiveness of the VR application as a learning tool is supported by the high ratings obtained from the functional suitability and performance efficiency evaluations conducted using Unreal Engine 5. The researchers' findings indicate that the implementation of VR technology in aviation training has the potential to improve the education and training of aviation maintenance technology students and enhance safety in the aviation industry.

The researchers' study still has some areas of concern that must be addressed. The study's generalizability is restricted to a particular aircraft type and a single institution, which may limit the applicability of the results to other aviation maintenance programs and aircraft types. Future research could investigate the potential of virtual reality technology for training purposes across various aircraft models and in different educational environments.

Long-term effectiveness: The study indicates that the VR application effectively trains students for ground operations. However, it remains uncertain how long the training effects will persist. Future research could investigate the long-term efficacy of virtual reality (VR) training in comparison to conventional training approaches.

It should be noted that despite the study's objective to create cost-effective VR software, the expenses associated with VR equipment and software may still pose a challenge for certain aviation maintenance programs. Future research could investigate the cost-effectiveness of VR training in comparison to conventional training approaches, taking into account the initial investment and long-term advantages.

The conducted study involved usability testing to assess the application's user-friendliness. However, there is a need for future studies to investigate the user experience of VR training, which includes the level of engagement and satisfaction of both students and teachers.

The study's focus was on training students for particular ground operations tasks. However, it is uncertain how effective the skills acquired in the VR environment will translate to real-world situations. Further research could investigate the extent to which skills acquired through VR training can be applied to real-world aircraft maintenance operations.

REFERENCES

[1] J. Hughes (1998) Assessing Technology Integration: The RAT – Replacement, Amplification, and Transformation – Framework: https://educationaltechnology.net/technological-pedagogical-content-knowledge-tpack-framework/
[2] D. Schimdt (2009) Technological Pedagogical Content Knowledge (TPACK):The Development and Validation of an Assessment Instrument for Preservice Teachers:http://techedges.org/wpcontent/uploads/2015/11/Hughes_ScharberSITE2006.pdf
[3] Tan, D. (1999). The virtual classroom afloat: maritime education and training in the 21st century : an investigation into the feasibility and practicability of distance learning via the satellite communications system (Ph. D). World Maritime University.
[4] Rheingold, H. (1991). Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds - and How It Promises to Transform Society. Michigan: Summit Books.
[5] J. Booth (2019). The Use of Virtual and Augmented Realities in Air Force Training by Mr. Joshua A. Booth Virtual/Augmented Reality and Related Technologies Research Elective 29 Apr 2019 Instructors: Col Tony Millican, Dr. Dennis Armstrong, and Dr. Tony Gould: https://apps.dtic.mil/sti/pdfs/AD1107328.pdf
[6] Al-Shafi, D. K. (2018). Qatar Airways becomes first airline to use IATA's Ramp VR. Retrieved from The Peninsula: https://www.thepeninsulaqatar.com/article/05/09/2018/Qatar-Airways-becomes-first-airline-to-use-IATA-s-Ramp-VR
[7] M. Jaakola (2022) Current Virtual Reality Solutions and Possibilities for Training Within Aviation Maria Jaakola Haaga-Helia University of Applied Sciences: https://www.theseus.fi/bitstream/handle/10024/743686/Jaakola_Maria_thesis.pdf?sequence=2
[8] KPASS Airport. (2017). Virtual Reality. Retrieved October 16, 2018, from KPASS Airport: https://www.kpassairport.com/en/solutions/virtual-reality/
[9] Benedetto, S., Drai-Zerbib, V., Pedrotti, M., Tissier, G., & Baccino, T. (2013). E-readers and visual fatigue. PloS one, 8(12), e83676.

[10] Champney, R. K., Stanney, K. M., Hash, P. A. K., Malone, L. C., Kennedy, R. S., & Compton, D. E. (2007). Recovery from virtual environment exposure: expected time course of symptoms and potential readaptation strategies. Human Factors, 49(3), 491-506.
[11] L.Gabunilas.(https://preparecenter.org/wp-content/sites/default/files/gdpc_casestudy_07_koreanrc.pdf)
[12] van Krevelen, D. W., & Poelman, R. (2010). A survey of augmented reality technologies, applications and limitations. The International Journal of Virtual Reality, 9, 1-20.
[13] Urvoy, M., Barkowsky, M., & Le Callet, P. (2013). How visual fatigue and discomfort impact 3D-TV quality of experience: A comprehensive review of technological, psychophysical, and psychological factors. Annals of Telecommunications, 68, 641-655.
[14] M. George (https://preparecenter.org/wp-content/sites/default/files/gdpc_casestudy_07_koreanrc.pdf)