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Research Article

Design and Validation of Virtual Reality Application Operations Manual for Avionics Technology Program

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ABSTRACT:

This study titled "Design and Validation of Virtual Reality Application Operations Manual for Avionics Technology Program", addressed the operational and technological gaps associated with integrating standalone Virtual Reality (VR) systems into aviation education at WCC Aeronautical and Technological College (WCC ATC) Binalonan. While immersive tools such as Boeing 737, Airbus 320, and Cessna 172 simulation modules provided safe, high-fidelity environments for developing technical proficiency and muscle memory, their institutional use remained provisional due to the absence of formalized standard operating procedures. Utilizing a descriptive-evaluative approach combined with the Design Science Research Methodology (DSRM) and a modified Technological Pedagogical Content Knowledge (TPACK) framework, the study evaluated the existing infrastructure supporting Meta Quest 3 and 3S hardware. Data gathered from sixty-nine respondents, comprising avionics students and laboratory instructors, alongside evaluations from a panel of seven subject matter experts, identified key technical bottlenecks including firmware maintenance, battery management, and cybersecurity protocols. The research instrument achieved a high Scale-Content Validity Index (S-CVI) of 0.96. Post-implementation evaluations revealed significant improvements across all assessed domains, yielding high general weighted averages for hardware gap analysis (4.21), guideline requirements (4.39), and operational guideline validation (4.36), with a general weighted average of 4.30. The resulting validated operations manual successfully established comprehensive standards for pre-operational calibration, pedagogical integration, cybersecurity compliance, laboratory safety, and routine equipment maintenance. Ultimately, this study transitioned the department from experimental trials to a professionalized, secure, and sustainable digital training environment.

Keywords: Virtual Reality, Operations Manual, Avionics Technology, Laboratory Management, Standardized Procedures

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INTRODUCTION

On a global scale, the aviation industry is navigating a digital change where traditional training is being systematically augmented by immersive technologies. Research from the ScienceDirect (2026) and MIT (2024) suggests that the success of these interventions hinges on a deep understanding of both technical infrastructure and user experience, implying that Virtual Reality (VR), an immersive technology that uses a head-mounted display to place the user inside a three-dimensional, computer-generated environment, significantly enhances learning depth by providing a safe, repeatable environment for mastering high-stakes procedures. However, industry analysis from SIM-AERO (2025) warns that while VR is transformative, it introduces substantial challenges regarding technical reliability and instructor readiness, establishing a clear precedent that hardware must be supported by a robust operational framework to ensure long-term institutional value.

Moving into the technical requirements of such systems, research in Procedia Computer Science and the Journal of Aviation/Aerospace Education & Research (2024) emphasizes that educational VR introduces unique vulnerabilities that are often overlooked. From an Information Technology and

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Cybersecurity perspective, these modules function as networked devices requiring strict Access Management, which functions like a digital key, ensuring that only authorized students and faculty can log in, which prevents unauthorized modifications to training records or the simulation's core settings, and data protection protocols to prevent system failures or unauthorized modifications. These studies suggest that "infrastructure readiness", the technical health and security of the network, is just as critical as the pedagogical content, as the successful integration of simulation technology depends heavily on the institution's underlying digital resilience.

The Department of Avionics Technology at WCC ATC Binalonan, the is the setting for the work, previously navigated this transition through a trial about implementing the use of specialized VR modules, including Cabin Familiarization and Maintenance for the Airbus A320 and Boeing 737, Ground Handling simulation, Safety-critical tasks performed on the airport ramp, specifically the use of standardized hand signals to direct an aircraft during taxiing or parking, for Airbus A320, and Cessna 172, which serves as the digital model for cockpit familiarization and flight simulation modules. While these instruments provided a vital safe digital environment for student practice, their current use remained provisional due to the absence of a formalized Standard Operating Procedure, which is a set of formal instructions that outlines exact from traditional, limited-resource methods to immersive, stand-alone VR simulations, the department aims to provide students with high-fidelity, hands-on experience in complex aircraft systems such as the Boeing 737, Airbus 320, and Cessna 172. However, the rapid adoption of this technology has moved faster than the development of the necessary administrative frameworks. Currently, the lack of standardized maintenance, security, and deployment protocols creates operational vulnerabilities, such as irregular firmware synchronization and inconsistent technical workflows, which threaten to hinder the full potential of these digital learning tools.

This study serves as a necessary intervention to address the operational gaps through the systematic design and validation of clear, actionable operational guidelines. By evaluating the current state of the stand-alone VR infrastructure through the firsthand experiences of students and laboratory instructors, and by subjecting proposed management protocols to rigorous validation by faculty experts, this research formalizes how VR equipment is maintained and utilized. Ultimately, this project seeks to transition the department from its current informal approach toward a cohesive, secure, and sustainable operational model, ensuring that the VR laboratory remains a reliable and effective cornerstone for aviation electronics and maintenance training for years to come.

STATEMENT OF THE PROBLEM

The primary objective of this study is to design and validate a virual reality operations manual for the Avionics Technology Program of WCC ATC in Binalonan, Pangasinan to guide students and faculty towards quality aviation electronics education.
Specifically, this capstone project sought to answer the following questions:

1. What are the requirements in the designing of a Virtual Reality (VR) application operations manual for the Avionics Technology Program of WCC ATC in terms of:
   a) Hardware and Software Specifications,
   b) Laboratory Safety and Operational Protocols, and
   c) Pedagogical and Instructional Integration?
2. What is the level of validity and acceptability of the developed operations manual as evaluated by experts and target users in terms of:
   a) Technical Accuracy,
   b) Cybersecurity Compliance,
   c) Practicality and Ease of Implementation, and
   d) Clarity of Procedural Content?
3. What final form of the Virtual Reality (VR) application operations manual can be proposed based on the findings?

SCOPE AND DELIMITATION

The scope of the study centered on the design and validation of a formal set of operational guidelines for managing stand-alone Virtual Reality (VR) infrastructure within the College of Avionics Technology at WCC ATC. Specifically, the research covered the maintenance and lifecycle management of Meta Quest 3 and 3s hardware, focusing on how these devices functioned as independent, all-in-one tools for aviation training modules, such as those for the Boeing 737, Airbus 320, and Cessna 172. Beyond the hardware, the study addressed the technical and security requirements necessary for daily laboratory operations, including firmware synchronization and routine equipment upkeep. To guarantee that the resulting guidelines were technically sound, secure, and easy to apply in a real-world classroom setting, a panel of seven professional subject matter experts from the College of Avionics Technology faculty provided the necessary validation.

To ensure the study remained focused and practical, several boundaries were established. The research was limited to managing existing training applications and did not involve the actual programming or development of new aviation software. Furthermore, the study was strictly confined to the current inventory of Meta Quest 3 and 3s headsets at WCC ATC, meaning it did not examine tethered VR systems or other hardware brands. To ensure the guidelines were grounded in actual practice, the survey data was drawn from sixty-nine respondents, comprising aviation students and laboratory instructors, whose hands-on experiences informed both the technical assessment and the validation process. The study was explicitly bounded by the design stage, which encompassed the systematic drafting of operational frameworks, hardware parameters, and protocols based on identified laboratory needs, and excluded long-term pedagogical tracking. Furthermore, the validation criteria specifically covered four core aspects: technical accuracy, cybersecurity compliance, practicality and ease of implementation, and clarity of procedural content. Thus, the research prioritized infrastructure management rather than attempting to measure long-term changes in student academic performance or complex campus-wide networking projects.

SIGNIFICANCE OF THE STUDY

The continuous evolution of aeronautical technology demands that educational institutions adopt robust, scalable, and secure infrastructures to remain at the forefront of the industry. This study is significant as it bridges the gap between the rapid deployment of virtual reality (VR) in technical training and the lack of standardized operational protocols currently governing such assets. The following stakeholders stand to gain substantial benefit from the implementation of these findings:

WCC Aeronautical and Technological College – Binalonan Campus. For the Binalonan campus, this research provides a clear, validated framework for managing its virtual reality laboratory. By establishing standardized procedures for equipment care and digital security, the administration gains a practical tool to extend the lifespan of its hardware and minimize technical downtime.

WCC Aeronautical and Technological College – North Manila Campus. As a sister institution, the North Manila campus stands to gain significantly from the replicability of these guidelines. Because the protocols are designed with a standardized approach, they can be easily adapted to the North Manila campus's own facilities.

College of Avionics Technology. The guidelines act as a practical roadmap for the department's faculty and staff. By simplifying complex tasks, such as coordinating system updates and maintaining hardware health, the department can move past technical frustrations.

Avionics Technology Students and Enthusiasts. For students, this research directly translates into a more stable and effective learning experience. When technical disruptions are minimized and training software is kept secure, students enjoy uninterrupted access to their simulations.

Future Researchers. Finally, this study provides a foundational reference for those interested in how virtual reality technology fits into technical education. Future researchers can use this work as a

starting point, adapting these operational guidelines to fit new or emerging technologies.

DEFINITION OF TERMS

To establish a common understanding of the concepts utilized in this study, the terms were operationally and conceptually defined as follows: hardware and software specifications referred to the necessary technical parameters and device configurations for standalone Meta Quest headsets, while laboratory safety protocols and pedagogical integration ensured secure operational guidelines and proper alignment with official avionics curriculum standards.

Design and Validation of VR Application operations manual: The core objective of this study, involving the systematic creation (Design) and expert-led verification (Validation) of a modernized, data-driven manual.

Operational Guidelines: These guidelines serve as a formal roadmap that transitions the department from an experimental, trial-based phase toward a professionalized and sustainable operational model.

Hardware and Software Specifications: This referred to the technical parameters, system requirements, and device configurations—specifically for standalone Meta Quest 3 and 3S headsets—that were necessary for the pre-session setup, firmware synchronization, and optimal functioning of aviation training modules.

Laboratory Safety and Operational Protocols: This referred to the established safety guidelines, physical space management rules, pre-session equipment checks, and student-faculty procedures that were designed to ensure a secure environment during VR simulation activities.

Pedagogical and Instructional Integration: This referred to the alignment of the VR operations manual with the official avionics curriculum standards, ensuring that step-by-step task executions and virtual learning activities effectively supported classroom instructions and aviation electronics education.

Technical Accuracy: This refers to the precision and correctness of the information provided in the guidelines. It ensures that the procedures align perfectly with the actual hardware specifications of the Meta Quest 3 and 3s headsets, as well as the specialized requirements of aviation training software.

Cybersecurity Compliance: These measures how well the guidelines adhere to necessary data protection standards. It focuses on the ability of the procedures to prevent system vulnerabilities, unauthorized access, and potential data breaches within the laboratory's network.

Practicality and Ease of Implementation: This assesses the usability of the guidelines in a real-world classroom setting. It determines whether the protocols are realistic and simple enough for the faculty and staff to follow during their daily laboratory operations without unnecessary complexity.

Clarity of Procedural Content: This evaluates how easy the guidelines are to understand and follow. It ensures that the step-by-step instructions, such as startup routines, firmware updates, and troubleshooting tasks, are written in a language that is accessible, logical, and free of ambiguity for all users

Research Paradigm:

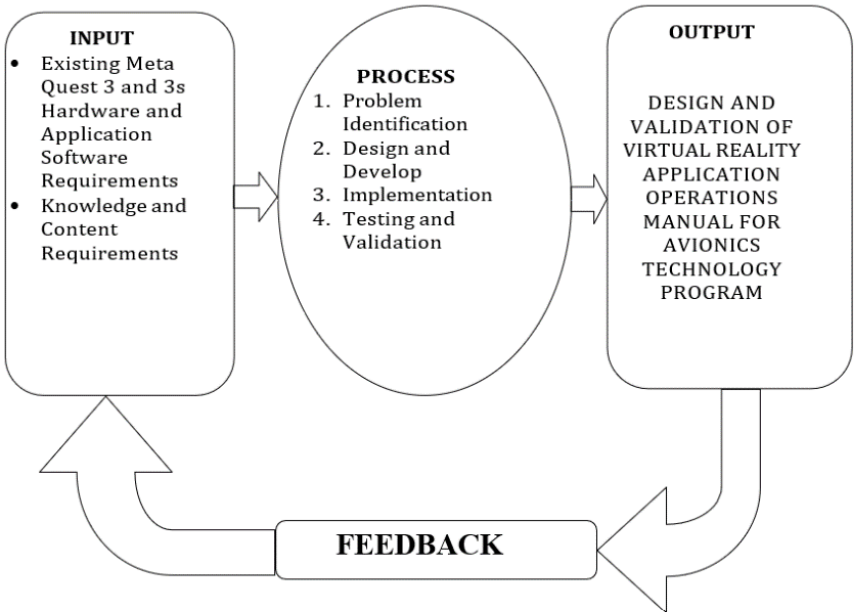


Figure 1. IPO Flow of the Study

This research paradigm utilized an Input-Process-Output (IPO) model to provide a structured, iterative approach to developing and validating the operational guidelines for the virtual reality (VR) infrastructure. The Input phase captured the essential foundational requirements, specifically focusing on the existing inventory of Meta Quest 3 hardware and the software and knowledge needed to maintain these devices effectively. By identifying these prerequisites at the outset, the study ensured that the research remained grounded in the specific technical landscape and operational needs of the College of Avionics Technology.

The Process phase served as the core mechanism of the study, where the research transformed these inputs into a functional solution. This stage followed a systematic four-step sequence: identifying the core problems within current laboratory practices, designing and developing the necessary operational guidelines, implementing these draft protocols, and conducting rigorous testing and validation to ensure their efficacy. By subjecting these protocols to evaluation by faculty subject matter experts, this iterative process ensured that the resulting guidelines were not only technically sound but also highly practical for real-world institutional application.

The Output of this model was the design and validation of the implementation of the VR application operational guidelines, tailored specifically for the Avionics Technology Department at WCC ATC. These guidelines represented a comprehensive set of standards aimed at streamlining maintenance, enhancing security, and ensuring the consistent performance of the VR laboratory. Furthermore, the inclusion of a Feedback loop illustrated that this research was not a static endpoint; rather, it was designed as a

cycle of continuous improvement, where the outcomes informed future adjustments and ensured the VR infrastructure remained a reliable and sustainable cornerstone of the department's technical training program.

System Specifications and Requirements

This study categorized the system specifications into three distinct domains: hardware capabilities, software environment, and network requirements. The hardware specifications centered on the Meta Quest 3 and 3s devices, focusing on the processing power required to render complex aviation cockpits and the battery capacity needed to sustain continuous training sessions. By documenting these physical limitations and strengths, the research ensured that the operational guidelines remained tailored to the specific energy and performance demands of the college's existing device inventory.

The software environment assessment concentrated on the integration and management of aviation-specific simulation applications. This part of the research examined the storage capacity required for high-fidelity modules, such as those for the Boeing 737 and Cessna 172, alongside the firmware requirements necessary for system stability. By establishing a baseline for compatible software formats and update cycles, the study identified how the Avionics Technology Department could successfully maintain the integrity of its training software without requiring constant external technical intervention.

Finally, the study addressed the network requirements that were essential for the seamless operation of a stand-alone VR laboratory. This included an analysis of the wireless bandwidth and connectivity standards required to facilitate routine firmware updates and data synchronization across multiple headsets simultaneously. By defining these parameters, the research clarified the necessary infrastructure support required to minimize latency and technical downtime during laboratory sessions. This holistic approach to system specifications ensured that the proposed guidelines were built upon a solid technical foundation, directly supporting the college's goal of creating a reliable and high-performance VR training environment.

METHODOLOGY:

Research Design

The research design for this study employed a descriptive-evaluative approach, which was selected to systematically bridge the gap between the laboratory's initial experimental phase and a more professional, mission-ready standard. Rather than focusing solely on the impact of the technology, the research evaluated the technical stability and security of the hardware specifications supporting the Meta Quest 3 and 3s infrastructure at the Avionics Technology Department of WCC ATC, Binalonan Campus. This design allowed the study to pinpoint specific technical vulnerabilities and performance gaps, providing the essential data required to draft the operational guidelines.

To obtain a comprehensive understanding of the laboratory's operational health, a mixed-methods approach was integrated into the research design. Quantitative data were collected by tracking system metrics such as network latency and hardware uptime; however, the study also acknowledged that technical specifications provided only a partial perspective. Consequently, qualitative insights were gathered from the primary users, the avionics instructors and students, to measure their perceived ease of use and their assessment of the system's reliability. This ensured that the proposed security and operational solutions were not only theoretically sound but also firmly grounded in the daily realities of the classroom.

Finally, the study was structured as an iterative process, utilizing the Input-Process-Output (IPO) framework as a continuous feedback loop. This meant that the research did not conclude with the mere identification of problems; instead, the effectiveness of the Standard Operating Procedures (SOPs) was actively tested and refined based on the real-world demands of aviation training. By aligning this design with the Technological Pedagogical Content Knowledge (TPACK) and the Substitution, Augmentation, Modification, and Redefinition (SAMR) models, the study provided a clear roadmap for the department to transition from simple technical integration toward a secure,

comprehensive transformation of how avionics maintenance was taught.

System Development and Methodology:

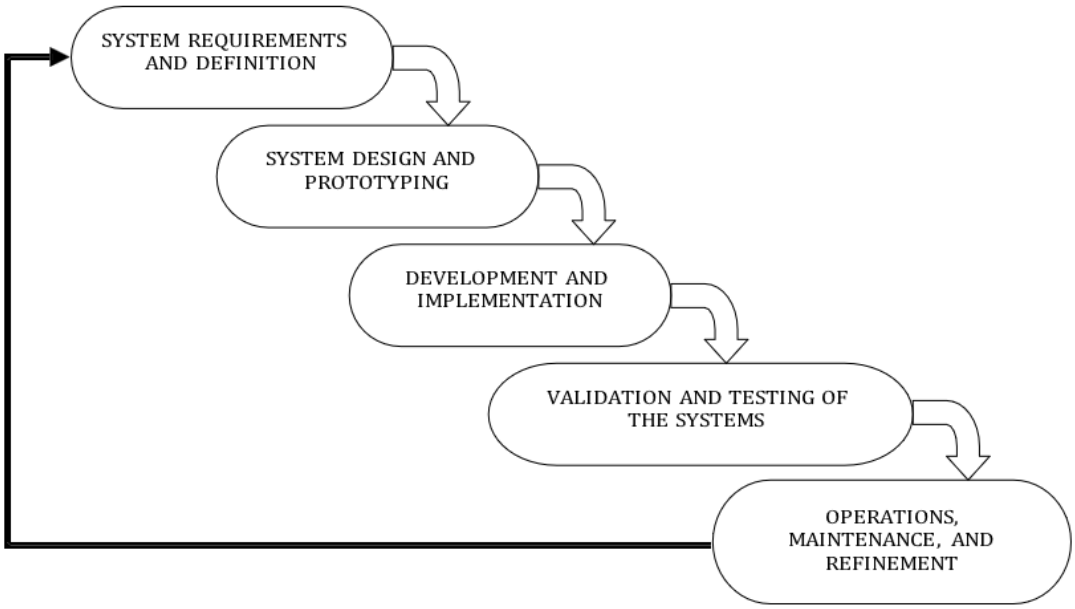


Figure 2. Operations Manual Implementation Flowchart

This flowchart illustrates a structured, cyclical process designed to manage technical infrastructure, ensuring that systems remain effective and sustainable over time. The journey begins with System Requirements and Definition, where the fundamental needs of the environment are identified. This initial step acts as the blueprint, defining what the infrastructure must achieve and the specific challenges it needs to solve. By establishing clear goals at the very start, the process ensures that all subsequent actions are purposeful and aligned with the actual requirements of the users and the facility.

Following the requirements phase, the process moves into System Design and Prototyping, followed by Development and Implementation. In these stages, the conceptual goals are transformed into tangible tools and operational procedures. Prototyping allows for the creation of a preliminary version of the guidelines, which can then be implemented into the daily routine of the department. This phase is crucial because it turns abstract plans into a functional reality, bridging the gap between "what should be done" and "how it is actually performed" in a real-world setting.

The final stages of the flowchart, Validation and Testing and Operations, Maintenance, and Refinement, emphasize quality control and longevity. Validation ensures that the implemented guidelines are not only working but are also effective, safe, and reliable. Once the system is fully operational, the cycle transitions into maintenance and refinement. Because technology and educational needs change constantly, this stage involves ongoing monitoring and adjustments. The bold arrow looping back to the start signifies that this is a continuous loop of improvement; it highlights that the management of complex systems

is not a one-time project, but an ongoing commitment to evolving alongside new challenges.

Data Gathering Techniques

To capture the technical and human nuances of the study, the researcher utilized a Purposive Sampling technique to gather high-fidelity data from individuals directly immersed in the "invisible backbone" of the lab. The study purposefully selected a sample of 69 participants, composed of 65 students and 4 instructors, who possessed first-hand experience with the Meta Quest 3 and Meta Quest 3s hardware. These respondents were chosen because their technical background was essential for evaluating the effectiveness of training modules such as CABIN VR (Boeing 737), CABSIM (Airbus A320) VAGHT (Ground Handling), and the SKILARK (Cessna 172). While the student cohort provided the numeric volume required for a statistical assessment of Perceived Ease of Use and Trust to the systems' infrastructure, the instructor group acted as the expert stratum for a qualitative look at institutional readiness and security procedures.

Table 1. Likert Scale and Descriptive Evaluation

Scale	Range	Descriptive Evaluation
5	4.21 – 5.00	High Strength / Readiness
4	3.41 – 4.20	Strong / Established
3	2.61 – 3.40	Moderate / Developing
2	1.81 – 2.60	Low / Emerging
1	1.00 – 1.80	Critical / Unprepared

The evaluation utilized a 5-point Likert scale to systematically translate the subjective experiences of the students and instructors into measurable, empirical data for the study. By categorizing weighted mean scores into distinct ranges, the framework provided a clear language for assessing the operational health of the Department of Avionics Technology across various technical and institutional dimensions. This structured approach allowed the researcher to move beyond anecdotal feedback and establish a quantitative baseline, identifying areas of "High Strength" or "Established" performance versus those that remained "Moderate" or "Developing." Ultimately, this scale served as the primary diagnostic tool for determining the readiness of the WCC ATC Binalonan Campus to transition from theoretical Virtual Reality concepts toward a standardized, mission-ready operational environment. The data collection was executed through a methodical process that began with obtaining formal authority from the Avionics Department of WCC ATC Binalonan, to access laboratory facilities and the responder pool. Once the research instrument, consisting of a Likert-scale survey and qualitative prompts, was validated by experts, the researcher administered surveys to the students to record insights on data security and hardware performance while conducting semi-structured interviews with instructors to gather recommendations for the Operational Guidelines. In the final stage, the researcher encoded numeric replies for statistical analysis and organized qualitative input for thematic assessment, comparing user feedback against system maintenance logs to identify technical inconsistencies. This integrated process followed the IPO framework, acting as a continuous feedback loop that ensured the resulting Digital SOPs were grounded in the actual technical demands of the Binalonan Campus avionics program.

Ethical Considerations

To maintain a focused and ethical research environment, the study prioritized the protection and privacy of the specific individuals within the Department of Avionics Technology. Because the work involved assessing the department's concealed structure, specifically the vulnerability assessments and access management protocols, the researcher handled all data collection with total transparency. Formal authorization was secured directly from the departmental leadership to engage with the specific

student and instructor cohorts, ensuring that the study operated within the official academic framework of the avionics program throughout the 2nd semester of the academic year 2025-2026.

The researcher implemented ethical safeguards to maintain the trust and safety of the respondents during the evaluation. Every participant was briefed on the study's purpose through informed consent, allowing them to withdraw at any time without any departmental penalty. To protect student privacy, all numeric replies and qualitative inputs were then encoded to maintain strict anonymity and confidentiality. In line with the study's focus on Information Technology and Cybersecurity, all gathered data was stored securely and used exclusively to address the SOPs and Operational Guidelines, ensuring the primary goal remained the improvement of the department's specific training ecosystem.

RESULTS AND DISCUSSIONS:

This Section presented the comprehensive analysis and interpretation of the data gathered to address the specific research problems identified in the study. The primary objective of this section was to examine the effectiveness of the proposed operational guidelines for the VR laboratory by evaluating the existing technological capacity, assessing the requirements for standardized procedures, and validating the proposed intervention through rigorous empirical testing.

The presentation of findings was organized into three key areas. First, it detailed the results of the Needs Analysis, which highlighted the existing gap between the laboratory's technological capacity and the competency requirements necessary for effective VR-mediated aviation training. Second, it discussed the Validation of the Instrument, providing the statistical evidence, including Content Validity Index (CVI) scores, that confirmed the reliability and relevance of the survey tools used to measure the study's variables. Finally, the chapter presented the analysis of the Questionnaire results, which served as the core discussion on the efficacy and acceptability of the proposed Operational Guideline for the VR Laboratory.

Through the synthesis of this data, the study identified significant improvements in technical reliability, cybersecurity compliance, and operational efficiency, thereby providing a clear evaluation of the guidelines' impact on the WCC ATC VR training environment.

Data Analysis and Interpretation:

Needs Analysis Results:

Table 2. Needs Analysis Results

Item	I-CVI
The item accurately assesses the gap between current VR hardware capacity and technical training demands.	1
The item effectively captures the perceived reliability of the existing Meta Quest 3/3s infrastructure.	1
The item clearly identifies specific cybersecurity vulnerabilities within the current laboratory workflow.	0.86
The item appropriately addresses the need for standardized firmware and software update protocols.	1
The item measures the faculty's ability to implement current laboratory SOPs without technical assistance.	0.86
The item correctly evaluates the technical accuracy of the proposed operational guidelines.	1
The item assesses the effectiveness of the proposed security protocols against unauthorized access.	0.86

The item determines the ease of implementation (practicality) of the new guidelines for laboratory staff.	0.86
The item measures the clarity of the instructional flow in the proposed documentation.	1
The item identifies potential barriers to adopting these standardized VR guidelines in a classroom setting.	0.86
The item evaluates whether the proposed guidelines adequately cover long-term hardware maintenance.	1
Total S-CVI AVERAGE	**0.96**

The Needs Analysis Results, as reflected in Table 2, demonstrated a strong consensus among the seven experts regarding the essential nature of the proposed framework, yielding a total Scale-Content Validity Index (S-CVI) of 0.96. With individual Item-Content Validity Index (I-CVI) scores ranging from 0.86 to 1.0, the experts consistently validated that each item was highly relevant and necessary for the laboratory's operational improvement. This high degree of expert agreement confirmed that the items were well-aligned with the department's requirements, establishing a robust and credible foundation for the subsequent implementation of the operational guidelines.

Validity and Reliability of the Instrument

The validation of the research instrument was conducted to ensure that the questionnaire was accurate, dependable, and appropriate for the study's objectives. Seven subject matter experts, each possessing experience in fields such as cybersecurity, aviation technology, and IT, independently reviewed the eleven items designed to measure the VR laboratory's technical constraints, security risks, and training gaps. The experts evaluated each item based on its relevance and clarity, utilizing a four-point rating scale to determine whether the statements effectively captured the intended operational challenges.

The analysis of this expert feedback yielded an impressive Scale-Level Content Validity Index (S-CVI) of 0.96, which served as a clear indicator of the instrument's high quality and professional rigor. Additionally, every individual question achieved an Item-Level Content Validity Index (I-CVI) of at least 0.86, comfortably surpassing the standard research threshold of 0.78. These results confirmed that the questions were not only well-aligned with the needs of the department but were also clear enough for the sixty-nine target respondents to interpret accurately. By validating the survey in this manner, the study ensured that the data collected was based on a solid, expert-approved foundation, thereby minimizing ambiguity and enhancing the overall credibility of the research findings.

Table 3. Hardware and Software Analysis Results

Item	Focus	Post-Test Mean
1	The current VR hardware meets the processing demands of my aviation modules.	4.16
2	The laboratory wireless infrastructure provides stable connectivity for VR training.	4.17
3	Firmware update procedures for the Meta Quest units are clear and efficient.	4.13
4	I am satisfied with the current data privacy and security measures for the headsets.	4.32

5	The existing hardware maintenance schedule is sufficient to prevent device downtime.	4.2
6	I feel adequately trained to troubleshoot minor technical issues during sessions.	4.1
7	The current laboratory setup allows for seamless multi-user synchronization.	4.06
8	Current storage solutions for VR applications are adequate for our curriculum.	4.22
9	Battery management and charging protocols are currently well-defined.	4.45
10	The gap between current laboratory performance and ideal standards is minimal.	4.32
AVERAGE WEIGHTED MEAN		**4.21**

Table 5 shows the post-test results for the Hardware Gap Analysis yielded an average weighted mean of 4.21, which represented a substantial shift toward the "Agree" to "Strongly Agree" range among the sixty-nine respondents. The implementation of standardized guidelines effectively addressed previous technical bottlenecks, with the highest gains recorded in "Battery/Charging Protocols" (4.45) and "Data Privacy Satisfaction" (4.32). Additionally, foundational stability improved, as reflected by scores in "Wireless Connectivity" (4.17) and "Hardware Processing Demands" (4.16), while the "Performance Gap" indicator rose to 4.32, which signalled that the laboratory was then closely aligned with ideal aviation training standards.

Table 4. Guideline Requirements Results

Item	Focus	Post-Test Mean
11	Standardized maintenance schedules would significantly improve hardware lifespan.	4.32
12	A formal cybersecurity protocol is essential for protecting student data in the lab.	4.45
13	Centralized management of application installs would reduce faculty workload.	4.28
14	Clearer, printed user guides would help students navigate the VR interface faster.	4.48
15	Regular audit cycles for hardware performance are necessary for safety.	4.28
16	The department needs a dedicated protocol for managing VR software updates.	4.38
17	Integration of student feedback into the hardware maintenance cycle is important.	4.13
18	Standardizing pre-flight and post-flight device checks is a top priority.	4.45
19	Enhanced guidelines would help bridge the technical skill gap among faculty.	4.23
20	A unified policy for VR equipment usage would improve overall laboratory efficiency.	4.38

AVERAGE WEIGHTED MEAN	4.34

The post-test results on Table 6 for the Guideline Requirements (items 11–20) yielded an average weighted mean of 4.34, which indicated that the 69 respondents were in strong agreement regarding the effectiveness of the implemented policies. The introduction of these guidelines successfully addressed the department's need for structured procedures, as evidenced by the high ratings recorded for "Printed User Guides" (4.48), "Cybersecurity Protocol Need" (4.45), and "Pre/Post-flight Checks" (4.45). Furthermore, the respondents expressed significant satisfa-ction with the "Software Update Protocol" (4.38) and the "Unified Usage Policy" (4.38), which confirmed that these new measures effectively streamlined laboratory workflows and solidified the overall operational framework.

Table 6. Summary of the Questionnaire Evaluation

Evaluation Domain	Composite Mean
I. Hardware Gap analysis	4.21
II. Guideline Requirements	4.39
III. Validation of the Operational Guideline	4.36
GENERAL WEIGHTED AVERAGE	**4.30**

Following the implementation of the new guidelines, post-test evaluations indicated a marked improvement across both domains. The Hardware Gap Analysis saw the average weighted mean rise to 4.21, with significant gains in "Battery/Charging Protocols" (4.45) and "Data Privacy Satisfaction" (4.32), confirming that the technical environment had stabilized. Similarly, the Guideline Requirements section, which then evaluated the success of the implemented policies, showed a post-test mean of 4.34, with high satisfaction in "Printed User Guides" (4.48) and "Pre/Post-flight Checks" (4.45), which demonstrated that the new protocols successfully filled the procedural voids identified in the initial needs analysis.

The validation phase (Items 21–30) reinforced the overall success of the intervention, as it achieved an average weighted mean of 4.36. Participants rated "Clarity/Professionalism" (4.45), "Procedural Flow" (4.45), and "Adoption Recommendation" (4.45) as highly successful, which reflected strong professional approval of the newly implemented framework. The high scores for "Technical Accuracy" (4.38) and "Reliable Resource" (4.38) provided conclusive evidence that the guidelines successfully bridged the technical skill gaps, provided secure maintenance pathways, and established a sustainable, standardized framework for the department.

Discussion of Findings

Designing Requirements for the Virtual Reality Operations Manual

The study first identified a significant Hardware and Software requirements across the existing technological capacity and the actual competency requirements needed for effective VR-mediated aviation training. This baseline data confirmed that, despite the presence of sophisticated VR hardware, the absence of a formalized operational framework created persistent bottlenecks in areas such as battery management, multi-user synchronization, and firmware updates.

Validation and Acceptability of the Operations Manual

The study evaluated the validity and acceptability of the proposed Operational Guidelines for the Virtual Reality (VR) Laboratory, with the

findings demonstrating that the framework achieved high levels of approval across all established criteria. Evaluated by both a panel of seven subject matter experts and 69 institutional respondents, the guidelines were found to be highly valid, successfully providing the professional roadmap necessary to transition the department from an informal, trial-based approach to a sustainable, high-standard digital training environment.

Technical Accuracy. The panel of experts confirmed that the guidelines possessed high technical accuracy, as the procedures aligned precisely with the hardware specifications of the Meta Quest 3 and 3s headsets. By verifying that the technical steps for hardware maintenance and software integration accurately addressed the specific demands of aviation training, the experts established that the guidelines functioned as a reliable technical reference for the department.

Compliance with cybersecurity. The research revealed that the guidelines were highly compliant with data protection standards, effectively mitigating the vulnerabilities inherent in networked VR modules. The experts validated that the proposed protocols were sufficient to prevent system failures, unauthorized access to training records, and network breaches, thereby ensuring a secure and trusted environment for the management of educational data.

Practicality and ease of implementation. The guidelines were rated as highly practical, as the protocols were designed to be both realistic and intuitive for use within the actual classroom setting at the WCC ATC Binalonan campus. The panel noted that the simplified workflows for hardware startup, firmware synchronization, and routine maintenance directly addressed previously identified operational gaps, rendering them highly manageable for faculty and staff during daily laboratory operations.

Clarity of procedural content. The validation process confirmed that the procedural content was exceptionally clear and easy to understand, which successfully minimized ambiguity for all users. The evaluators concluded that the step-by-step instructions provided in the manual were logical and well-structured, which ensured that instructors with varying levels of technical experience were able to perform their tasks consistently and with confidence.

Ultimately, these findings confirmed that the research addressed critical operational challenges and established a robust, reliable framework that effectively supported the future of aviation electronics and maintenance instruction.

CONCLUSION

The study successfully bridged the technical and operational gaps within the Avionics Technology Department's virtual reality laboratory by transitioning from informal, trial-based practices to a structured, standardized framework. The implementation of the developed operational guidelines resulted in significant improvements across all metrics, as respondents demonstrated strong satisfaction regarding the clarity, accuracy, and professional flow of the new system. These results validated that the intervention effectively addressed the departmental needs and ensured that the laboratory operations aligned with the rigorous standards required for professional aviation training.

Ultimately, the study concluded that the adoption of standardized guidelines was essential for sustaining a high-quality learning environment. The consistency in positive feedback across the hardware gap analysis, guideline requirements, and final validation phase underscored the project's success in fostering a more secure and efficient facility. By establishing a culture of accountability and regular maintenance, the department mitigated the risks of equipment failure and unauthorized access. This standardized approach not only enhanced the immediate functionality of the Meta Quest 3/3S hardware but also provided a sustainable blueprint for the long-term operational excellence of the laboratory.

Recommendations

Based on the empirical findings and the high levels of institutional readiness identified throughout the study, the following actions are proposed to optimize the operational health and educational impact of the VR laboratory:

1. **Institutional Adoption.** The department officially integrated the developed operational manual and the mandatory safety and handling briefing into the laboratory's standard curriculum to ensure that all students and faculty maintained a uniform understanding of proper hardware use.
2. **Establishment of a Maintenance Registry.** To ensure long-term accountability, the department implemented a maintenance logbook where users were required to sign off on pre- and post-flight equipment checks, which facilitated better tracking of hardware performance and health over time.
3. **Periodic Review Cycles.** The guidelines were scheduled for review on a semi-annual basis to account for potential software updates, new VR technological advancements, and changes in aviation training requirements.
4. **Institutional Adoption.** The department officially integrated the developed operational manual and the mandatory safety and handling briefing into the laboratory's standard curriculum to ensure that all students and faculty maintained a uniform understanding of proper hardware use.

Establishment of a Maintenance Registry. To ensure long-term accountability, the department implemented a maintenance logbook where users were required to sign off on pre- and post-flight equipment checks, which facilitated better tracking of hardware performance and health over time.

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