# DEVELOPMENT AND IMPLEMENTATION OF VIRTUAL REALITY IN HIGHER EDUCATION FOR AVIATION: A CASE STUDY

**The Hoang Nguyen [1, 2]*, John Tan [1], Seck Tan [1] and Luu Van Thuan [2]**

1. Air Transport Management – Business, Communications & Design Cluster, Singapore Institute of Technology, 1 Punggol Coast Road, Singapore 828608, Singapore
2. Faculty of Aeronautical Engineering, Vietnam Aviation Academy, 104 Nguyen Van Troi, Ho Chi Minh City, Vietnam

Correspondence: *thehoang.nguyen@singaporetech.edu.sg

**Abstract:** This paper aims to introduce a practical approach for incorporating the virtual reality (VR) technology in aircraft operational maintenance training within aviation-oriented educational curriculum. Firstly, the development stages of the VR application are outlined. Subsequently, the paper elaborates further on the specific steps for integrating this VR application and its related instructional content into educational settings. Preliminary surveys and also feedback from the students have highlighted the VR's educational values for aviation-focused programs. All in all, this presented work is demonstrating how educators can practically and effectively integrate an advanced technology into the existing curricula to enhance student engagement and also interest within a university setting.

**Keywords:** virtual reality; aircraft maintenance; air transport management; experiential learning

## 1. Introduction

Virtual reality (VR) related technologies [1], which have been formulated in years 1960s [2], have recently been predicted as the potential booster for global economic growth. VR is expected to highly impact the development of digital economy in various fields including engineering, healthcare, training and education [2]. To date, this emerging technology has already demonstrated several major effects in improving productivity, efficiency and also operational costs. For instance, VR technology has shown its great benefits in product design and development areas [3-5]. Moreover, in training and education, many studies have highlighted the benefits in using VR, especially for procedural tasks, by enhancing learners' engagement and outcome [6-8]. In particular areas where content relevance and technological maturity are crucial, the adoption of specific VR-tech based applications remains constrained due to several inherent barriers [8]. These limitations become even more pronounced in the aviation sector, particularly in aircraft-related operations that are subject to very strict regulatory requirements by state and authoritative bodies concerned with safety within the industry. As a result, this situation leads to many challenges related to the costs and also the time required to develop the appropriate sophisticated applications for both industrial and educational use in aviation-related activities.

Any miscommunication and misunderstanding of the operating procedures of an aircraft can have serious impact on the safety of flight or maintenance operation [9]. The use of VR technology in aircraft training has several great advantages that include increased safety, cost savings, enhanced learning and improved skill transfer [10]. At the moment, in aviation industry, VR-related technologies have recently been deployed in training for some specific applications such as flight simulators for pilots, turnaround inspections and also marshalling for ground crew [11]. On the other hand, for aircraft engineering and maintenance, very few VR-based applications are found in the published literature [12-13]. Additionally, it is also worth noting that not many works found in literature disclose or explain clearly with sufficient details about specific procedure (with clear references) to mimic and also produce the appropriate VR-applications, especially involving "real applications" with data directly sourced from the aircraft OEMs (such as Airbus or Boeing). Without these information, it is hard to claim that the applications are really applicable to real industry applications, which are strictly regulated by aviation authorities. Particularly, there is a lack of comprehensive strategies and practical approach for an effective integration of the VR applications into higher education programs in aviation. A conducted survey on 26 students of a first year university program has shown interesting results for the VR application [13], but it lacked a detailed explanation about the approaches or framework for integrating such systems into the higher education curricula.

Based on the current state of VR application, it is the primary objective of this study to present a comprehensive practical approach to incorporate emerging technologies such as VR into educational programs in institutes of higher learning. This research work outlines the development of a VR-based application from the beginning, along with the strategy and essential steps for integrating this advanced technology-based application into an existing curriculum. Initial feedback from the preliminary groups of student participants is also shared, which provides some insights into the effectiveness of the research project and recommendations for future enhancements.

## 2. Methodology

In this study, the implementation of the self-developed VR-based application follows two primary stages:

- **Development**: New specific VR applications, which are relevant for the purpose of teaching and training, are developed from scratch
- **Implementation**: The developed VR applications are integrated into the formal teaching curricula in universities. In this case, an aviation-related educational programs in Singapore has been selected. Feedback from the users or learners are collected within each of the stages as the indicators or measures for effectiveness and improvements of the VR applications as well as the related teaching approach

For the first stage, the VR application is developed using four phases in loop as indicated in Figure 1, namely analysis, design, development, and test and feedback. Each of the phases consists of several interconnected tasks that need to be addressed [14]. In this study, the maintenance procedure relating to removal of the nose landing gear (NLG) wheel system of an Airbus A320 aircraft, the most popular narrow body aircraft type around the world, is selected. It should be noted that the maintenance work on landing gear wheel systems, such as removal or installation, is the daily tasks of aircraft engineers in real life.

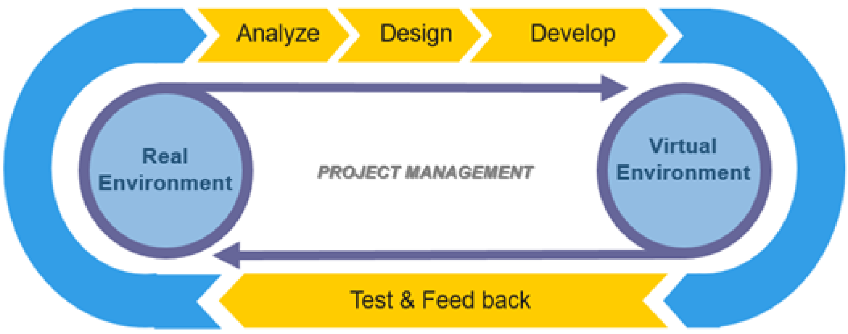


Figure 1: Development phases of VR application

In short, the analysis phase requires a careful analysis of procedural tasks involved in the selected maintenance work. The Airbus AMM procedures coded as "32-41-12-000-001-A" and "32-41-12-400-001-A" that are referenced for removal and installation of the NLG wheel system of an Airbus A320 are utilized [15]. The reference documents provide a detailed guideline to perform the maintenance job such as the safety warning, job set-up information, work zones, referenced, job set-up and also working procedure. Meanwhile, following design phase of the information system include determination of the simulation flow, designing the users' interfaces and experience in the virtual environment. Two practical modes, including training mode and also assessment mode, have been designed. Following the selected maintenance procedure, several working scenes including in the aircraft cockpit and on parking ramp are simulated. In this study, the selected VR devices are Oculus Quest 3, a standalone headset equipped with two controllers that allow to integrate virtual hands to interact with virtual environment [16]. Next, development phase is to implement the design ideas and carry out the development of VR application. Studying and determining the appropriate program development workflow, from the modeling of 3D objects using CAD software to coding and integrating in VR devices, is crucial for the success of the project. In this study, the full-scale 3D models are created utilizing the computer-aided design (CAD) software (i.e. Solidworks), texturing is carried out by using free software "Blender" and finally the open source C# language-based VR platform, "Unity" is utilized. Last but not least, the next successive phase "testing" involves activities carried out by experienced experts to verify if the VR application has been well-developed and produced from the information technology perspectives and also from procedural compliance perspectives. Testing and verifying whether the developed VR application can properly and adequately reflect the reality in the aircraft maintenance practices are vital for the success of this kind of applied research following the strict requirements from authorities and industry. In this study, several experienced aircraft maintenance experts, who have more than 10 years of direct experiences with the certified qualifications from Vietnam Civil Aviation Authorities, are invited to test the VR application and give their critical feedback for gradual improvement. In addition, other target end users of the VR application such as students and trainers are involved in this phase to give their perception feedback.

On the other hand, for the implementation stage, it is realized that the developed VR application could be used in various training and educational programs at different levels (i.e. vocational or bachelor degrees) that are related to aviation for appropriate modules or courses. Moreover, when considering how to integrate new content, especially involving emerging technologies, into an existing content and program, there are two viable approaches: creating a separate module or incorporating into the existing module(s). For this pilot study, the latter option is done. Incorporating modern technologies directly into existing curriculum offers several benefits, including seamless integration with minimal disruption to the current educational structure. This approach not only help to enhance the comprehension of the traditional content by placing it in a modern technological context, but it is also less resource-intensive as well compared to creating a new module. For this study, the application is incorporated into the Maintenance Management module within the existing Air Transport Management (ATM) program for the Bachelor of Science degree in an autonomous university, Singapore Institute of Technology (SIT). The existing curriculum of the related course has been modified by introducing a new content called "Emerging Technology and Digitalization in Aircraft Maintenance", which is taught in two in-class sessions accounting for 15% of the total in-class time of the related module (i.e. a module has 6 credits and the total degree program consists of 180 credits). The main goal is to provide an awareness level to the students of such a highly specialized VR-application. With regards to the scope and also the allotted time in current formal module, the content for teaching is limited to only introduction of VR technology and practicing awareness for learners. The content aims to provide students with an appreciation of such emerging technology with application in the field, in addition to learning of a particular standard aircraft operation related industrial procedure (i.e. aircraft maintenance on A320's landing gear system) that is strictly regulated in all phases. Through this, learners could enjoy their first experience in reality-like working environment on commercial airplane with trained safety awareness as strict requirements in any real industrial aircraft-related procedures.

Table 1 summarizes the sequence of the in-class teaching steps. What is novel about this practical approach is that, prior to instructing the learners on use of VR applications, a workshop is conducted (i.e. Step 3) on emerging technologies to provide detailed insights into development of sophisticated VR-based application from scratch, using the limited resources available in the university setting. This approach equips the students with a deep understanding of the related technologies such as VR, which in turn enhances their appreciation of how these emerging technologies can be applied to their specific learning content in the subsequent step (i.e. Step 4). Furthermore, surveys are also conducted before and after the session in order to get information and feedback from learners. In this case, the purpose of before-training survey is to know the background and knowledge level of the participants about VR and the subject while the after-training survey is intended to investigate the learners' first perception on the effectiveness of the VR-based teaching.

Table 1: Step-by-step teaching approach using VR

| Steps | Activity | Description | Supporting tools, equipment |
|---|---|---|---|
| 1 | Pre-training survey | To investigate learners' profile and background. | Online survey form (Google sheet) |
| 2 | Lecture | To lecture leaners the involved aircraft related procedure (Airbus AMM) using classical technique of teaching (without support of VR application and devices). | Documents (pdf format)<br>Ex. Airbus AMM |
| 3 | Workshop | To present principles of Virtual reality technology and development phases of a new application (in aviation). | VR devices (Oculus Quest 2 or 3 for demonstration) |
| 4 | Virtual Reality practice | To teach learners to understand the involved procedure (Airbus AMM) by practicing in VR. Several steps are presented:<br>(i) familiarize the VR devices;<br>(ii) familiarize the VR working environment and practicing required tasks;<br>(iii) assessment (group). | VR application and devices (Oculus Quest 2 or 3);<br>7 units of devices were employed in class for this pilot project |
| 5 | Post-training survey | To preliminarily investigate learners' interest and feedback. | Online survey form (Google sheet) |

## 3. Results and Discussion

3D full-scale models of the Airbus A320 aircraft, related component assembly, tools, equipment and accessories (i.e. safety tag), which are associated with the involved Airbus AMM procedures, are modeled using CAD software tool. In addition, the corresponding work environment and scenes where the selected maintenance actions will be carried out such as the parking ramp, aircraft's cockpit and the others are also well modeled in the application. As typical examples demonstrating the success of the current project, Figure 2 and Figure 3 represent the comparison between a real-life maintenance action and developed VR-based simulations on the studied aircraft systems for jacking the nose landing gear and removing two locking nuts in the assembly of the Airbus A320 aircraft, respectively.

(a) Reality (b) Virtual simulation

Figure 2: Jacking of the nose landing gear for Airbus A320 aircraft

(a) Reality (b) Virtual simulation

Figure 3: Removal of two locking nuts (Ref. AMM task 32-41-12-020-050-A)

For this pilot study in implementing the VR application, constructed surveys have been designed and tailored to obtain the essential initial feedback from students enrolled in the module of "aircraft maintenance management" in Air Transport Management degree program at SIT. One class is typically consisted of 60 students, in which relevant 36 students (i.e. more than 50% of the class size) have joined the full VR-related teaching sessions as depicted in Figure 4. They all have responded to the conducted surveys. It should be noted that the majority or approximately 97.2% of the student participants were in the second year of the training program.

(a) Familiarize with VR device (b) Virtually conducting the system assembly task

Figure 4: Students' gestures during VR-based training session in class

In this study, the age of the participants is predominantly between 18 to 25 years old, constituting 91.7% of the cohort, with a smaller segment of 8.3% between the ages of 26 to 35 years old. Regarding gender, 66.7% of the participants are male and the rest are female. Furthermore, a prior experience with VR as claimed by the learners varies: 45.1% of them had no previous VR experience, 47.1% of them had limited experience whereas the small remaining percentage had moderate VR experience. The post-training survey data reveals the amount of time participants spent practicing with the VR application. 38.9% of them have engaged with VR tool for 1 to 3 hours. The remaining 61.1% of them reported spending less than 1 hour on the VR application, indicating a brief introductory interaction with the technology due to the VR-devices and the time limitation of the training sessions designed to be concise in this pilot study. After the training, the leaners in the VR training program provided their feedback across several aspects. The survey addresses overall perception of the learners regarding the relevancy and efficacy of VR-based teaching method in aiding the intended learning outcomes like understanding of the knowledge and acquiring the skills applicable to the subject. The descriptive results of the five questions in post-training survey, rated over a 5-point Likert scale, are shown in Table 2. The learners' perception is considered 'positive' if rated 4 or 5 on the 5-point Likert scale, 'neutral' if rated 3 and 'negative' for the rating of 1 or 2.

Table 2: Descriptive results of the post-training survey

| Question | Content | % Answers | | | Score | |
|---|---|---|---|---|---|---|
| | | Positive (%) | Neutral (%) | Negative (%) | Mean | Mode |
| Q1 | VR technology helps in understanding complex aircraft maintenance procedures | 69.4 | 19.4 | 11.2 | 3.94 | 5 |
| Q2 | Effectiveness of VR compared to traditional learning methods | 83.3 | 16.7 | 0.0 | 4.22 | 4 |
| Q3 | Impact of VR on interest in aircraft maintenance | 77.8 | 19.4 | 2.8 | 4.11 | 4 |
| Q4 | Contribution of VR experiences to practical skills in aircraft maintenance | 75.0 | 22.2 | 2.8 | 4.08 | 4 |
| Q5 | Accessibility of VR technology for educational needs in aircraft maintenance | 52.7 | 33.3 | 14.0 | 3.53 | 3 |

On the whole, data in Table 2 indicates a favorable perception towards the VR technologies in the studied context. Some key insights and discussions can be drawn from this descriptive data. Firstly, a majority of 69.4% think that VR aids them in grasping the complex maintenance procedure. An average rating of 3.94 and a mode of 5.0 (out of 5.0) denote a consensus among the respondents. Secondly, the VR-based approach appears as superior to the traditional approach. This is acknowledged by 83.3% of the students, which is also reflected by the average score of 4.22 and a mode of 4.0 (out of 5.0) for the VR-based tools' attributes. Thirdly, VR-based teaching approach has successfully heightened interest in aircraft maintenance for 77.8% of the students. The impact, scoring an average of 4.11 with a mode of 4.0 (out of 5.0), suggests that VR not only make the learning process more engaging but also more intriguing, possibly leading to greater motivation among students. Moreover, 75% believe that VR has a role in enhancing their practical skill sets. The average score, which is approximately 4.08, and a mode of 4.0 (out of 5.0) indicate a generally positive belief in the VR contribution towards skills improvement. This is aligned with the VR's hands-on, experiential learning capabilities, which are vital in procedure-related training. Nonetheless, it should also be noted that accessibility rating is mixed, where 52.7% of the participants reported a satisfactory accessibility while 14% encountered difficulties and a third of them were ambivalent. In this case, the lowest average score of 3.53 and a mode of 3.0 (out of 5.0) can be taken to imply that the respondents found the VR technology moderately accessible for educational needs in this case application. Additionally, the post-training survey also include four open questions to identify specific features of VR-technology that the students find as most beneficial in enhancing their learning experience and to uncover any challenges that the leaners encountered when using such technology. The results reveal that students find realistic simulation, hands-on practice, and also visual and interactive learning as the most beneficial aspects of the VR technology for learning aircraft maintenance procedures. However, they have also faced some challenges including physical discomfort (i.e. headset fit for Quest 3 glasses) and initial learning curve in getting accustomed to the VR system.

The students have proposed several improvements such as the multi-player functionality with enhanced audio integration and more practicing time.

## 4. Conclusion

This work has presented the full cycle of development and implementation of a VR-technology-based application, which is developed in-house from scratch into existing module within Air Transport Management degree program at SIT. The VR application is successfully developed from scratch to fully digitalize the selected work following the strict procedures from the aircraft manufacturer. This implies possible realization of affordable and accessible training solutions, which are based on emerging state-of-the art technology, enable users including students, lecturers and professional personnel to learn and also practice aircraft-related tasks right in a room-based environment, avoiding any hazard and risks in actual physical working conditions surrounding commercial aircraft. Regarding the teaching approach, the obtained initial feedback from surveys after experiencing VR-training by the students in a university-level aviation program generally reflects the relevancy and efficacy of such practical implementation in this context of higher education. The compacted complex content that includes both theVR-technology and commercial aircraft operational related aspects, designed and taught in a time-constrained teaching session, has amplified initial success of this pilot project in terms of teaching outcomes.

For future works, current VR application will be expanded to other associated aircraft maintenance tasks as related to Airbus A320 ATA 32 system while some of the technical and ergonomic aspects will be improved. Other aircraft systems such as power plant, as well as additional aircraft types like Airbus 350 and Boeing 737 aircraft, can potentially be added as extension of current application. Furthermore, different environmental working conditions such as day, night, visibility levels and weather conditions could also be incorporated to evaluate their effects towards the completion of the maintenance work. Additionally, the presented development methodology can be applicable to many other critical missions in aviation such as emergency and safety (including emergency landing and evacuation, firefighting), or to daily operational activities of airlines (i.e. pre-flight checks). Last but not least, an in-depth study on the learning effectiveness for the target end-users (i.e. learners in various aviation-related programs and levels) will also be elaborated.

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