https://doi.org/10.2352/EI.2024.36.13.ERVR-182

Interactive Aviation Maintenance Classroom

L. Taylor Starr, Colorado State University, Fort Collins, CO, USA
Kelvin Shorts, Colorado State University, Fort Collins, CO, USA
Marie Vans, Colorado State University, Fort Collins, CO, USA

Abstract

Aviation Maintenance Technicians (AMTs) play an important role in guaranteeing the safety, reliability, and readiness of aviation operations worldwide. Per Federal Aviation Administration (FAA) regulations, certified AMTs must document mechanic-related experience to maintain their certification. Currently, aviation maintenance training methods are centered around classroom instruction, printed manuals, videos, and on-the-job training. Due to the constantly evolving digital landscape, there is an opportunity to modernize the way AMTs are trained, remain current, and conduct on-the-job training. This research explores the implementation of Virtual Reality (VR) platforms as a method for enhancing the aviation training experience in the areas of aircraft maintenance and sustainability. One outcome of this research is the creation of a virtual training classroom module for aircraft maintenance, utilizing a web- based, open-source, immersive platform called Mozilla Hubs. While there is a general belief that VR enhances learning in general, very few controlled experiments have been conducted to show that this is the case. The goal of this research is to add to the general knowledge on the use of VR for training and specifically for aircraft maintenance training.

Introduction

Aviation maintenance operations that support United States Army air fleets play an important role in guaranteeing the safety, reliability, and readiness of the Army Warfighter. This readiness includes aircraft, support equipment and weapon systems. To maintain the required readiness that Army commanders require and expect, a huge responsibility is put upon Aviation Maintenance Technicians (AMTs) to keep air fleets equipped and operational. The journey to become a certified AMT follows a highly structured and regulated path that is supervised by the Federal Aviation Administration (FAA) and Department of the Army (DA). To become a certified AMT, all personnel (military and civilian) must go through aircraft maintenance training before they can perform maintenance on any aircraft. This training is typically performed in the classroom, the hangar, or in the field (land and/or sea) by the Warfighter (approximately 100,000 technicians), via the use of videos (on a laptop computer) and printed manuals once the on- the-job portion of the training is complete.

Background

There has been significant advancement in technology over the last 40 years, and this advancement has also changed the way we train, learn, and communicate information. Every year, the Army trains thousands of new AMTs at the U.S. Army Aviation Center of Excellence at Fort Novosel, Alabama. Many of these new trainees are under 25 years of age and have several generational differences in learning from their instructors and/or leadership. Differences between generations can be the by-product of unique historical circumstances that members of an age cohort experience, particularly during a time when they are in the process of forming opinions[1]. The more we understand generational differences, the better we can tailor AMT training to better fit the user. Niemczyk1 recommends Gen Y, Millennials, and Gen Z (born 1981 and beyond) learn by the "4 A" learning model:

- Active: meaning the instructor and student have high levels of interaction with each other and with the curriculum
- Awareness: involves self-assessment by the student, and evaluation by the instructor
- Anticipate: is used to illustrate how theoretical concepts may be encountered in life or in the workplace
- Associate: Assist learners in remembering what they may already know about the concept/procedure

As it relates to Military Training programs, Lieutenant General Leopoldo, Deputy Commander of Army Forces Command[2] stated: "Today, Army units operate in an environment of unpredictability, and arguably even instability. Units are placed on rotational missions based on their availability, and these missions vary in location, length, manning, readiness requirements and equipment just to name a few. Modernization today occurs when we can find a window to fit it in, or simultaneous with other activities. Every week, month and year is filled with constant change and high tempo for soldiers." As Army units are being requested to support more diverse missions, a training system is needed to provide warfighters with more agile and modern tools to refine doctrine, and reorganize units, if necessary, based on theater-specific requirements.

According to Boeing's 2021 Boeing Pilot & Technician Outlook[3], advancement in technology and equipment will drive demand for more AMTs. This, coupled with older AMTs beginning to retire, will ensure AMT demand long into the future. At facilities like the Corpus Christi Army Depot, civilian AMTs are on contract to support the repair and overhaul of aircraft. As the expected attrition continues, a burden will be put on active-duty military AMTs to continue the required aviation maintenance duties. According to an Army Command Sergeant Major[4], "The big difference between the Army and a mechanic in civil aviation is that the civilian mechanic with an A&P license is asked to do a myriad of tasks on the aircraft. They kind of go along from an apprentice to a journeyman to a master-type career path," he said. "It can take 30-years to gain their level of high proficiency." "Since we don't have that long in the Army, we have a variety of different Military Occupational Skills that a soldier can concentrate on and become very proficient in that skill very quickly,"

The military utilizes a tiered two-level maintenance strategy comprised of field and sustainment maintenance. The objective of this two-level maintenance structure is to provide warfighters and the tactical formation with maintenance capabilities that are needed most to respond to current, emerging, or expected requirements. Figure 15 depicts the two-level maintenance support relationships for field and sustainment maintenance.

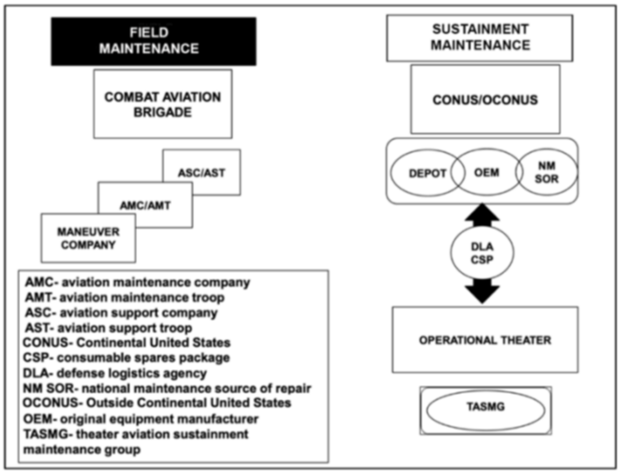

Figure 1. Military Aviation two-level maintenance support relationships[5]

Field-level maintenance[5] is performed by military units, or their supporting units, on their own equipment. Systems are repaired in maintenance facilities, motor pools, mobile shops, or the tactical environment. Duties for this level of maintenance include approved field-level modification work orders, fault and failure diagnoses, battle damage assessment and repair, recovery, calibration, and replacement of damaged or unserviceable parts and components. Other duties include the manufacturing of critical unavailable parts and inspecting, servicing, lubricating, adjusting, and replacing parts, minor assemblies, and subassemblies.

Sustainment-level[5] maintenance is performed at depots and/or Army field support brigades. Once the equipment is received, repair or replace tasks are performed by personnel who have higher technical skills using specialized tools and equipment that are not available at the field level. Those tasks include inspection, test, repair, modification, alteration, modernization, conversion, overhaul, reclamation, and reconstruction of parts, assemblies, subassemblies, components, equipment end items, and weapon systems.

Objectives

The overall goal of this research is to evaluate the advantages and disadvantages of using a VR training platform for AMT training. For this paper, our research objectives are focused on the following specific tasks:

- Understand how Aviation Maintenance Technicians train, learn, and maintain FAA currency requirements.

- Evaluate whether aviation maintenance instruction delivered through an immersive platform that includes VR and 3D virtual environments that can be accessed via desktop will enhance engagement and retention of instructional materials, compared to traditional training methods of classroom instruction, printed manuals, videos, and on-the-job training.

Virtual Reality Benefits in Education and Training

How can VR be used to enhance the learning process? According to Winn[6], the real added value of VR consists of the possibility for students to learn through first-person experience, by the means of interaction and immersion. First-person experiences play a central role in our activity in the world and our learning about it: immersive environments allow constructing knowledge from direct experience by giving the participants the "perceptual illusion of nonmeditation" between them and the computer. VR provides several potential benefits to Aviation maintenance education and training.

- Experiential and active learning – VR requires interaction, which encourages active participation. Students and trainees assimilate knowledge more effectively when they have the freedom to move and engage in self-directed activities within their learning context. Finding and structuring content autonomously, they invest mental effort for the construction of conceptual models that are both consistent with what they already understand and with the new content presented[7].
- Adaptability – VR training can be tailored to the needs of the student and allow individual (personalized) experience at the student's own pace.
- Collaboration Fostering – VR can encourage collaboration and foster the learning of skills through a common virtual environment.
- Motivation Enhancement – interacting with VR can be more motivating than training in a traditional classroom. The 3D environment and avatars make it feel like a game.
- Accessibility – VR can be used to remove barriers and help people with disabilities experience things they could not do otherwise, like fly an airplane or helicopter.

Pedagogical Framework

Dianne Laurillard proposed a theoretical framework with pedagogical patterns that categorize different learning activities into the following: learning through acquisition, inquiry, discussion, practice, and collaboration[8]. The following is a brief description of these patterns.

- Learning through acquisition. The teacher provides narrative explanations or descriptions in which the student takes part. According to Laurillard, this should preferably be supplemented by one or more of the other patterns, and it is vital that the teacher confirms and verifies that the narrative has been understood[9].
- Learning through inquiry. The teacher gives the students a challenge to explore a question and formulate answers, with the guidance from the teacher[9].
- Learning through discussion. The teacher creates a careful plan and set-up for a fruitful discussion about specific topics between students, often but not necessarily with the teacher acting as facilitator[9].
- Learning through practice. The teacher creates a goal-oriented task or project that through its design give students experiential learning and intrinsic feedback from the situation itself[9].

- Learning through collaboration. According to Laurillard, collaboration combines all other forms of learning, especially discussion and practice[9].

Interactive Aviation Maintenance Classroom Prototype

The prototype for the Interactive Aviation Maintenance Classroom was designed with optimal intuitiveness in mind for a wide spectrum of audiences within the aircraft maintenance industry. Regardless of which specific aircraft the maintainer is interested in servicing, this interactive experience provides a unique approach to education from a Virtual Reality (VR) perspective. The virtual experience is divided into three main sections, each one representing a major area of focus for maintainers in training, as required by the Federal Aviation Administration (FAA) and Department of the Army. The user is embodied in the experience as an avatar, which is a visual representation of the user during the use of the platform. Once an avatar enters the world, there is only one hallway available for the avatar to travel down. This path isolation design eliminates confusion and reduces the odds that the person behind the avatar will become disoriented, which may result in a loss of interest in the experience. In the welcome area, trainees are greeted by a screen that contains a course overview pertaining to key concepts that will be explained throughout the remainder of the experience. As the avatar proceeds down the hallway, all the classrooms are located on the left-hand side for a natural progression through the course (see Figure 2).

Figure 2. Virtual Classroom Lobby

Each classroom includes educational learning opportunities using both videography and still imagery approaches. Although there is not a training guide that explains the location of each artifact or suggestions for the user interaction, the design is both intuitive and consistent throughout the experience. All of the videos are located on the main wall of each room, (front and center) for easy identification upon entering the room. Photos that highlight specific airplane parts and repair procedures are on the side walls, with corresponding 3D images of specific parts of the process that require additional emphasis placed on a table directly below the still imagery (see Figure 3).

Figure 3. Classroom User Interface

Upon entering the virtual space, certificate-seeking trainees will have the option to review the materials they have already mastered as part of the classroom learning environment, prior to being "promoted" to the VR portion of the training. If no overview is needed, they can proceed directly to one of 3 sections of the room offered (interactive manuals, visualizations, or videos) where they will be immersed in a core topic required for AMT certification. The three topics offered as part of this virtual experience include aircraft system failure, broken parts, and performance malfunction scenarios. When the student feels ready, they can take a quiz, which is accessible from within the room. An instructor is available throughout the experience to answer any questions before and after the lesson review and quiz portion of the room. Instructors/Supervisors will also be asked to rate their experience in the VR room via a survey.

The world boundaries for this project depend on what information the warfighter is looking for, since the information can be accessed using a search feature (for those who are not quite sure where the info is located within the digital manual) or via a table of contents (for those who know exactly where to find the info they are looking for).The student (warfighter/aircraft maintainer) will have the largest role, as they are the ones in need of learning how to do something new; however, there will be expectations for the instructor (contractor and/or product manufacturer) to provide, maintain, and/or support the information the maintainer is trying to access. The biggest risk of all is cybersecurity and ensuring the warfighter is able to access sensitive information in a secure and private manner. Information stored on this platform will have to be done so via a username and password that is only distributed to other students and instructors who have a legitimate need to access the virtual room supporting the training. Since Mozilla Hubs is an open-source platform, private instances can be created within firewalls so they are not visible to the outside world.

Steps were taken during the design phase to reduce the probability of the user becoming disoriented or getting lost while navigating the virtual experience. Limitations were placed on the user's ability to move through the experience in various directions, resulting in the ability to only move forward down the hallway and enter rooms on the left-hand side. Once inside the room, there is only one way in and one way out. It is the belief of the designer that this singular pathway approach will assist the student in making appropriate choices where directional decision- making is concerned. Once the learner has completed all three educational opportunities, the end of the experience can be intuitively deciphered by a wall at the end of the hallway, that prevents the user from turning left when exiting the final module.

At the conclusion of each learning experience, the maintainer trainees will take a quiz based on the information they were just exposed to as a result of interacting with the virtual modules. Input from each of the quiz responses is used to determine the effectiveness of the training material provided and the quality of the delivery of the desired learning objectives. Feedback is also gathered at the end of the virtual experience once all three modules are completed by the trainee, allowing the evaluation of whether the user is able to master the learning content from each individual lesson, but also collectively across all three modules. This will aid in identifying issues/gaps in future designs and influence various approaches in connecting each topic as a steppingstone for the next one. Lastly, instructors are solicited for their feedback at the end of the experience to help guide future designs and further shape learning objectives from the perspective of an experienced, knowledgeable user who is already familiar with the material.

Approach

Participants were solicited from several different means of training AMTs to include trade schools, universities, junior colleges, and independent aviation maintenance facilities.

Data from this VR experience will serve as a decision- making analysis tool that equips the professor with the information they need for the next stage of learning, where placement is concerned. Data from each student's assessment will also be used to highlight areas of improvement within the platform. Close attention will be paid to quizzes in the module (and most importantly, questions), that have the lowest consistent scoring among test takers. An investigation as to why test takers are not succeeding in that assessment area and non-VR elements will be incorporated to evaluate if VR is providing the desired training. Adjustments will be made regarding how that related content is being displayed within that particular module. Information will then be relayed to the experience designer and corrective action steps will be taken to actively minimize the failure rate and restore student success in that area.

Results

To test the approach, 74 engineering students explored virtual classroom modules, completed quizzes, and filled in a course evaluation survey. Many of the participants were from a local ABET-accredited engineering program at a leading university. 64 (86%) of the student were under the age of 25 , the other 10 were over the age of 25. 60 of the students (81%) had experience using VR before this study through video games and social media, utilizing headsets and controllers. Only a handful (10%) had ever used it for training and/or learning purposes. Due to this, there were not that many technical issues or navigation issues within the Mozilla Hubs web application. The technical issues are summarized further ahead.

Course Evaluation and Learning

Figure 4 shows quantitative results from the course evaluation survey. The question asked was "After experiencing the Virtual Reality Classroom, how would you prefer to conduct Aviation Maintenance Training in the future?" Although many participants enjoyed the virtual classroom, 65.6% preferred to conduct training via traditional methods (e.g. Books, Videos, Lecture, Instructor, etc.) while 34.4% preferred the Virtual Reality Classroom.

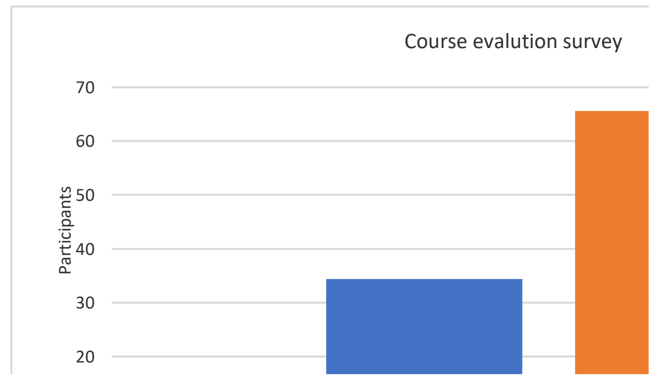

Figure 4. Course evaluation survey results

A trial run of the environment was completed and demonstrated that our approach is on track. The three quizzes resulted in a score of 100% for approximately 35% of the students. 38% received a score of 67%, while 18% received 33% and 8.6% failed (no correct answers). The results show that the most difficult quiz was that which was focused on "Performance Issues" while the least difficult was the quiz on "Broken Parts." The three quizzes were completed by 67 different students; however, only 36 students completed all three quizzes. For those that completed all three quizzes, 16 out of 36 (44%) received scores of 100%, while 25% of those taking all three received a score of 89%. The fact that only 54% of the students felt comfortable enough to finish all three quizzes points to a need for enhancing the training. Further research is required to determine whether the level of expertise in the technology (virtual reality) and exposure to the domain (aircraft maintenance) would help explain the distribution of the scores as well as the reluctance of the 46% who did not finish all 3 quizzes.

The participants learning outcomes are summarized in Figure 5.

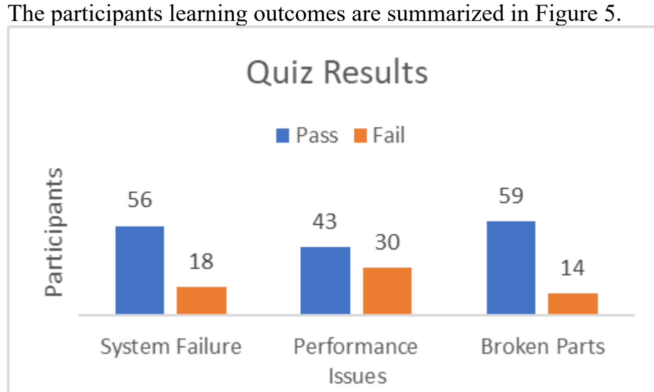

Figure 5. Individual Classroom Quiz Results

The results point to areas that need to be updated. The quizzes need to be revisited to identify the causes of the uneven scores. At least 58 participants completed a general survey about the experience after completing the learning. We are currently in the process of analyzing those comments in detail, but in general the most frequently stated sentiment had to do with the engaging nature of the learning method and how much “fun” it was for them. In addition, almost half (49%) indicated that the aircraft maintenance VR classroom was the first time they had ever used VR for a learning experience. A cursory examination of negative comments points to possible bottlenecks that lead to the discontinuation of the learning before completing the three quizzes. In general, people who received lower scores on the first or second quiz give up and didn’t finish the rest of the experience. In addition, understanding when students give up and stop using the platform will help with identifying the areas that need more curriculum design effort.

Improvement to the Virtual Reality Classroom and Mozilla Hubs

These technical problems occurred, in no particular order.

- Navigation and performance. Some students reported issues while navigating around the virtual reality space. There were reported issues of difficulty of maneuvering around the virtual classroom without VR goggles using a mouse and keyboard. These reports were not specific enough to allow an in-depth analysis of the actual technical cause. One student reported it was hard to maneuver around the classroom chairs and they kept getting stuck facing down toward the floor. A few other students reported navigation and performance issue and attempted to mitigate these issues by using a different web browser.

- Resolution. Many of the images uploaded to Mozilla Hubs had their resolution lowered for faster rendering. This resulted in several images looking pixelated and hard to clearly see/identify for some participants.

It should also be noted that participants had different levels of experiences with VR technologies and web- based tools. This could have resulted in some participants overcoming issues by themselves and not reporting.

Discussion

The usage of Mozilla Hubs did not change the overall learning patterns, since the planning and setup of the training modules mostly remained the same. It was only the classroom platform that changed from traditional methods (e.g. Books, Videos, Lecture, Instructor, etc.) to VR.

- Learning through acquisition in VR. For acquisition to work properly, it is required that the teacher can narrate well, via communication channels such as voice, body language, and visual aids such as slide decks and moving images. It also demands good opportunities for feedback from and interaction with the students to verify a shared understanding and shared mental models9. There is clear potential for VR to enhance AMT utilizing Mozilla Hubs and several other free and paid platforms.

- Learning through practice. This is probably one of the largest benefits to utilizing the VR classroom. AMT instructors can create a goal- oriented task or project that through its design give students experiential learning and intrinsic feedback from the situation itself.

Aviation Maintenance has and will continue to play a crucial role in supporting aviation operations around the world. Continued training is necessary and mandatory to ensure safety. As far as changes in FAA regulations around the ways training is performed, VR is not intended to entirely replace on-the-job training; nevertheless, it can serve as a valuable supplemental teaching and learning resource to augment and reinforce traditional methods.

Conclusion

In this paper, we developed a VR Classroom prototype to enhance the way AMT is conducted. Our goal is to deliver a virtual reality classroom that can continually adapt and adopt new aviation platforms, while remaining flexible to mission needs. We will use the results from analyzing scores and survey comments to redesign the quizzes as well as the experiential survey. Future work will focus on the development of additional experiments to demonstrate the efficacy of this approach to AMT.

System usability is a key requirements to the success of any successfully system. Further research is required on to balance regulations, technology, and VR capabilities to create the appropriate curriculum for AMT.

References

[1] Pew Research Center (2015) The Whys and Hows of Generations Research. Retrieved April 28, 2022. https://www.pewresearch.org/politics/2015/09/03/the-whys-and-hows-of-generations-research/

[2] Congressional Research Service, The Army’s New Regionally Aligned Readiness and Modernization Model. Retrieved April 5, 2022. https://sgp.fas.org/crs/weapons/IF11670.pdf

[3] Boeing (2021) Pilot and Technician Outlook 2021 – 2040. Retrieved April 28, 2022. https://www.boeing.com/resources/boeingdotcom/market/as sets/downloads/BMO_2021_Report_PTO_R4_091321AQ- A.PDF

[4] Aviation Maintenance Magazine,(AMA) Is the Mechanic Shortage Impacting the U.S. military?. July 8, 2018. Retrieved May 1, 2022: https://www.avm-mag.com/is-the- mechanic-shortage-impacting-the-u-s-military/.

[5] Department of the Army. Army Aviation Maintenance, October 2020. Retrieved April 12, 2022. https://armypubs.army.mil/epubs/DR_pubs/DR_a/ARN310 28-ATP_3-04.7-000-WEB-1.pdf

[6] Winn, W. (1993). A conceptual basis for educational applications of virtual reality. Technical Report TR 93–9.

[7] Mantovani, F. Gaggioli, A (2003) Virtual Reality Training for Health-Care Professionals

[8] Laurillard, D.: 'Teaching as a Design Science : Building Pedagogical Patterns for Learning and Technology' (Taylor & Francis Ltd 2012. 2012

[9] Eriksson, T. "Failure and Success in Using Mozilla Hubs for Online Teaching in a Movie Production Course" (2021) Immersive Learning Research Network

[10] F. De Crescenzio, M. Fantini, F. Persiani, L. Di Stefano, P. Azzari and S. Salti, "Augmented Reality for Aircraft Maintenance Training and Operations Support," in IEEE Computer Graphics and Applications, vol. 31, no. 1, pp. 96- 101, Jan.-Feb. 2011

[11] N. D. Macchiarella and D. A. Vincenzi, "Augmented reality in a learning paradigm for flight aerospace maintenance training," The 23rd Digital Avionics Systems Conference (IEEE Cat. No.04CH37576), Salt Lake City, UT, USA, 2004

[12] M. Hincapié, A. Caponio, H. Rios and E. González Mendívil, "An introduction to Augmented Reality with applications in aeronautical maintenance," 2011 13th International Conference on Transparent Optical Networks, Stockholm, Sweden, 2011, pp. 1-4

[13] Henderson, Steven J. Feiner, Steven K.(2007) Augmented Reality for Maintenance and Repair (ARMAR). Retrived Jan 6, 2023. https://apps.dtic.mil/sti/citations/ADA475548

[14] Niemczyk, M. (2017). Generational shift: Why we should modify our instructional strategies for the next generations of aviators. National Training Aircraft Symposium (NTAS) 2017 – Training Pilots of the Future: Techniques & Technology.

Author Biography

L. Taylor Starr received her B.S. and M.S. in Engineering from Tennessee State University. She is a Ph.D. Candidate at Colorado State University.

Kelvin Shorts received his B.S. and M.S in Engineering from Embry-Riddle Aeronautical University. He is a Ph.D. Candidate at Colorado State University.

Marie Vans is an associate Professor of Systems Engineering fellow at Colorado State University. She Marie is also an adjunct faculty member of the San José State University, School of Information