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A Comparative Study of the Impact of Virtual Reality on Student Learning and Satisfaction in Aerospace Education

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Luca Carlone is the Boeing Career Development Associate Professor in the Department of Aeronautics and Astronautics at the Massachusetts Institute of Technology, and a Principal Investigator in the Laboratory for Information & Decision Systems (LIDS). He received his PhD from the Polytechnic University of Turin in 2012. He joined LIDS as a postdoctoral associate (2015) and later as a Research Scientist (2016), after spending two years as a postdoctoral fellow at the Georgia Institute of Technology (2013-2015). His research interests include nonlinear estimation, numerical and distributed optimization, and probabilistic inference, applied to sensing, perception, and decision-making in single and multi-robot systems. His work includes seminal results on certifiably correct algorithms for localization and mapping, as well as

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A Comparative Study of the Impact of Virtual Reality on Student Learning and Satisfaction in Aerospace Education

Student Paper

Introduction

In the ever-evolving field of aerospace engineering education, integrating cutting-edge technologies is instrumental to fostering effective and engaging learning experiences for students. Virtual reality (VR) is an example of such technology that can bridge the gap between theoretical knowledge and hands-on experience within the confines of the classroom. VR has the power to immerse users in interactive environments and provide them with unparalleled opportunities for learning, as evidenced by its success in several university courses [1]. In the field of aerospace engineering– where spatial thinking and three-dimensional visualization are essential skills– the potential for VR to enhance pedagogical methodologies is promising [2]. Recognizing this potential, this paper details the design, development, execution, and analysis of an experimental course on aerospace engineering fundamentals taught using VR technologies. This study seeks to determine the impact of VR on student learning outcomes and engagement levels in comparison to a traditional, non-VR method.

Literature Review

Extended reality (XR), which includes both augmented (AR) and virtual reality (VR), has extensive history in the working aerospace industry as a means of enhancing productivity and training. In fact, the term "augmented reality" was conceived by Boeing engineer Tom Caudell in 1992 [3]. Over the years, Boeing has continued to invest in this technology; recently, Boeing released its own AR software dubbed the Boeing Augmented Reality Kit that is used for aiding workers with assembly and maintenance tasks [4]. Other major aerospace companies, such as Airbus, have launched internal AR and VR initiatives; the Airbus Holographic Academy ameliorates engineers with design and inspection tasks and has seen a reduction in inspection and installation time [5]. Furthermore, several NASA research centers also have long-standing history with the adoption of XR technologies. NASA's Marshall Space Flight Center, for instance, started their VR program in 1989 and has since worked on innovative ways to train astronauts for spaceflight in VR [6]. NASA's Langley Research Center developed its own head-mounted display (HMD) in the 1990s for AR pilot exercises; meanwhile, at the NASA Jet Propulsion Lab (JPL), researchers developed XR projects such as ProtoSpace, an AR 3-D computer aided design (CAD) multi-user visualizer, and Project Onsight, a VR planet visualizer [4]. Other use cases in aerospace include VR flight simulators, AR air traffic control guides, and mixed-use data visualization [4, 7]. In short, the aerospace industry has seen a multitude of innovative, diverse applications of XR technologies.

XR has also seen numerous applications in university-level STEM education [1]. With this type of technology, students can see and manipulate virtual 3-D objects, observe the unobservable, and correct misconceptions [8]. For example, Indian Hills Community College leveraged VR technology to create a virtual fermentation lab for students to visualize the fermentation process [9]. Both Sam Houston University and the University of Cincinnati created virtual robotic arm simulations for students to control [10, 11]. Cal State East Bay and Mission College started an introductory general engineering course featuring several VR educational games [12]. Spanning multiple disciplines, Tuskegee University also exposed students to a collection of introductory topics from a multitude of subjects including engineering, biology, math, and physics in VR [13]. Generally, XR can improve student engagement and provide self-paced, personalized learning experiences [2, 14].

Though the examples of XR usages in the aerospace industry and higher education are numerous and promising, very few examples of the two disciplines' overlap exist: the area of XR usage in aerospace engineering education. Currently, the most prominent example of university aerospace education in XR comes in the form of flight simulators, which can be found in colleges all around the country including at the Georgia Institute of Technology, Embry-Riddle Aeronautical University, and the University of Nebraska Omaha, to name a few [15–17]. Built for a single purpose, these flight simulators are limited in their pedagogical scope. The VR course at Tuskegee University, mentioned previously, did cover some aerospace-specific topics within their exercises, but aside from this example, the usage of XR in teaching aerospace beyond flight simulation is predominantly unexplored. To add to the limited examples and to assess whether XR is effective at improving learning outcomes, our experimental course, named *Aeroverse*, was created at the Massachusetts Institute of Technology (MIT).

Research Questions

The purpose of this educational study is threefold. Firstly, we aim to explore innovative ways to seamlessly incorporate XR learning modules to complement MIT's existing aerospace engineering curriculum. Secondly, we seek to assess whether XR technology as a teaching medium can affect the following learning outcomes: summative assessment performance (grades), enjoyment of learning, and changes in confidence levels regarding the ability to achieve learning objectives before and after each class. Finally, we hypothesize that the use of VR technology in aerospace engineering education improves these learning outcomes in our course. With these research questions guiding our study, the next section of this paper delves into the implementation and evaluation of our experimental Aeroverse course.

Methods

Aeroverse is a short, three-week, six-class course in which two days a week students had a one-hour joint lecture and a two-hour lab, the latter being either in VR or non-VR. For this first rendition of the course, all XR content was in virtual reality only, though AR content is being considered for future modules. Professors of the aeronautics and astronautics department structured the curriculum and delivered the lectures, while the graduate student collaborators designed the lab activities and content. Each week had an overarching theme that connected the subjects of the two courses. Table 1 summarizes the topics hereon referred to as modules.

Table 1: **Description and classification of the six modules.**

Theme	Module Nickname	Description	Category	Interaction Type
Aircraft Week	Module A	Explore a Jet Plane	Learning	Individual
	Module B	Fly a Jet Plane	Experience	Individual
Spacecraft Week	Module C	Explore Mars with a Remote-Controlled Vehicle	Learning	Individual
	Module D	Explore Mars with an Autonomous Vehicle	Experience	Individual
Astronaut Week	Module E	Human-Machine Interactions	Both	Group
	Module F	Humans in Space	Both	Group

Course Design

Aeroverse was offered as a for-credit, pass/fail course that focused on introductory fundamental topics and therefore had no pre-requisite requirement. As such, students were expected to attend every class and submit assignments for grades. The assignments included pre-readings before every class, a pre-reading quiz, a pre-class reflection, an in-lab worksheet, a post-class quiz, and a post-class reflection. The post-class reflection recorded how enjoyable students found the class and how confident they were that the class allowed them to meet certain learning objectives. The latter results were compared to the pre-class reflection that recorded how confident they were before the class in being able to meet the same learning objectives. The post-class quiz is a summative assessment, the results of which are used to quantify the performance of the students. A breakdown of the assignments and grading is provided in Table 2.

Table 2: **Types of assignments with expected duration and grading weight.**

Activity	Out/In Class	Duration (minutes)	% of Overall Grade
Pre-class reflection	Out	15	Completion, 15%
Pre-class reading + quiz	Out	75	Correctness, 25%
Lecture	In	60	Participation, 10%
Lab session	In	120	Participation, 10%
Post-class quiz	Out	30	Correctness, 25%
Post-class reflection	Out	15	Completion, 15%

Division of Students

Total active enrolment for the course was 29 students. All students were provided with a personal Meta Quest 2 device for use in class. Students were divided into two groups: Group 1 and Group 2. Assignment to either Group 1 or 2 was performed manually using demographic data from the pre-course survey to reduce possible knowledge bias. Both groups comprised a similar number of graduate students/upperclassmen and underclassmen undergraduates, experienced and non-experienced VR users, and aerospace engineering majors and non-aerospace majors. In total, each group had three VR lab experiences and three traditional learning experiences. Both groups took turns being either VR (measured) or non-VR (controlled) in an alternating fashion, as seen in Figure 1; Table 3 below summarizes this structure. Rotating the groups mitigates potential personal preference biases, sampling bias, and unequal educational benefit (the course was listed as an XR course and would have been unfair for some students to not experience any XR at all).

Table 3: **Division of students assigned to VR or non-VR lab sessions by module.**

Module Nickname	VR	Non-VR
Module A	Group 1	Group 2
Module B	Group 1	Group 2
Module C	Group 2	Group 1
Module D	Group 2	Group 1
Module E	Group 1	Group 2
Module F	Group 2	Group 1

(a)

(b)

Figure 1: (a) Students in Group 1 experiencing Air Week Module A in VR. (b) Students in Group 1 experiencing Space Week Module D in non-VR.

The figures in Appendix A summarize the student makeup and familiarity with VR before the course. The student pool was primarily composed of aerospace engineering and electrical engineering/computer science majors. The population included undergraduates and graduates of all years as seen in Figure A1. The results of the pre-course survey stated that, of the 29 students, over half had never used a Meta Quest 2. Most had little experience with VR in general, and none had any experience with coding for VR. Despite this, when asked to provide an opinion on the likelihood of VR having a teaching advantage over non-VR, the responses skewed positive towards ”Likely” or ”Very Likely.” The qualitative results of the pre-course survey are summarized in Figure A2.

Joint Lecture

The one-hour joint lecture before students broke off into groups for the lab sessions was tailored to make up for where the lab sessions lacked in terms of learning objectives. For some modules, the VR lab sessions only partially met the desired learning objectives. This was either due to lack of development time, inability to modify the simulation (when using pre-existing simulations developed by a third party), or if the topic was deemed more appropriate to teach outside of VR. The joint lecture was essential to provide context to the lab sessions, relevant to both groups.

Lab Content

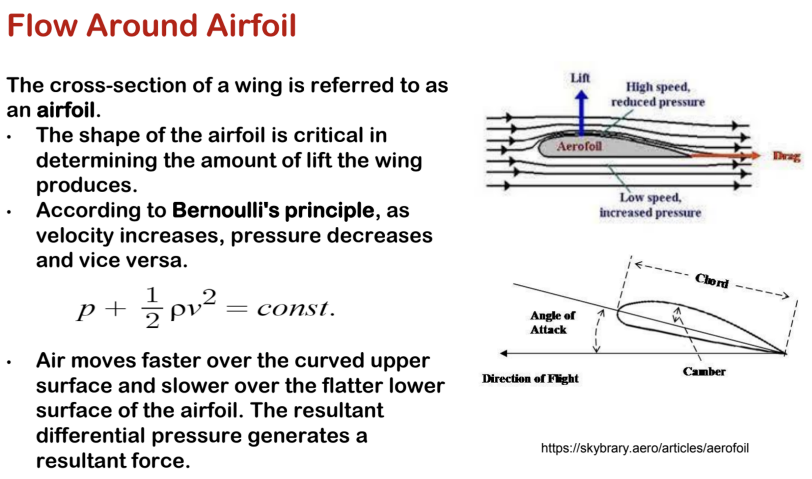
The Aeroverse labs can be classified in three categories: learning-based, experience-based, or both. Learning-based labs focused on teaching students several new topics, whereas experience-based labs engaged students with a particular activity revolving around one particular topic. As mentioned, both VR and non-VR students had a two-hour lab session following a one-hour joint lecture. To emphasize, the goal of the experiment was to measure the effectiveness in teaching medium rather than the difference of content itself. Therefore, the educational content presented to both the VR and non-VR group was designed to be nearly identical whenever possible while still providing students with interesting and fulfilling information. Moreover, both groups were presented with guiding worksheets to be completed during lab with identical questions, and both groups had to complete the same post-class assessment. The completion and submission of assignments was done on laptops in the real world for both groups, since this study is not measuring the effects of completing assignments in VR. Devising a strategy to create fulfilling and informationally identical labs for both groups proved to be a challenge that required meticulous planning, which is outlined in the following subsections.

During early course design for the learning-based labs, the information that would be presented to students was planned in advance in a master document. This master document was the source material for the informational content presented in the VR simulations and given to the non-VR students as a PowerPoint; see Figure 2. With this approach, students are exposed to the same concepts, but the concepts are delivered through different mediums. The learning-based labs A and C provide context to the experience-based labs and therefore precede them.

Modules B and D focused on experiences that built upon knowledge acquired in the previous labs A and C, respectively. To maintain consistency, tasks for students to complete in the experience-based labs had to be designed to be as similar as possible, with the only difference being whether the tasks are executed through VR or not.

Module A: Explore a Jet Plane

The first of the six modules introduces students to aircraft systems with a focus on four topics: fundamentals of flight and aerodynamics, aircraft systems, human interfaces (cockpit layout), and airport design. Other topics beyond these four were considered– such as modeling airflow or the interior of the jet engine– but, due to the limited VR development time of 4.5 months, were ultimately decided against. The Module A joint lecture provided context to the lab session and covered the remaining learning objectives that were not covered by the labs.



Flow Around Airfoil

The cross-section of a wing is referred to as an **airfoil**.

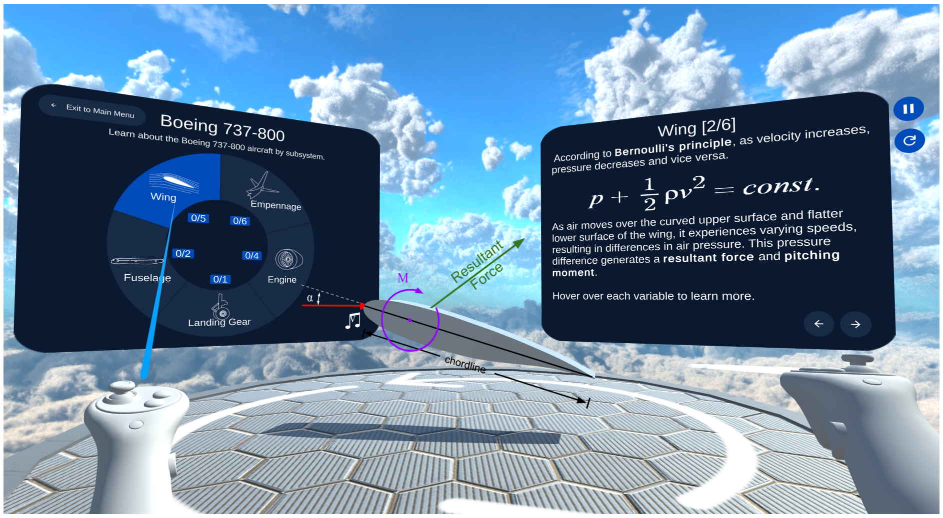
- The shape of the airfoil is critical in determining the amount of lift the wing produces.
- According to **Bernoulli's principle**, as velocity increases, pressure decreases and vice versa.

$$p + \frac{1}{2}\rho v^2 = const.$$

- Air moves faster over the curved upper surface and slower over the flatter lower surface of the airfoil. The resultant differential pressure generates a resultant force.

https://skybrary.aero/articles/aerofoil

(a)



Boeing 737-800

Learn about the Boeing 737-800 aircraft by subsystem.

Wing [2/6]

According to **Bernoulli's principle**, as velocity increases, pressure decreases and vice versa.

$$p + \frac{1}{2}\rho v^2 = const.$$

As air moves over the curved upper surface and flatter lower surface of the wing, it experiences varying speeds, resulting in differences in air pressure. This pressure difference generates a **resultant force** and **pitching moment**.

Hover over each variable to learn more.

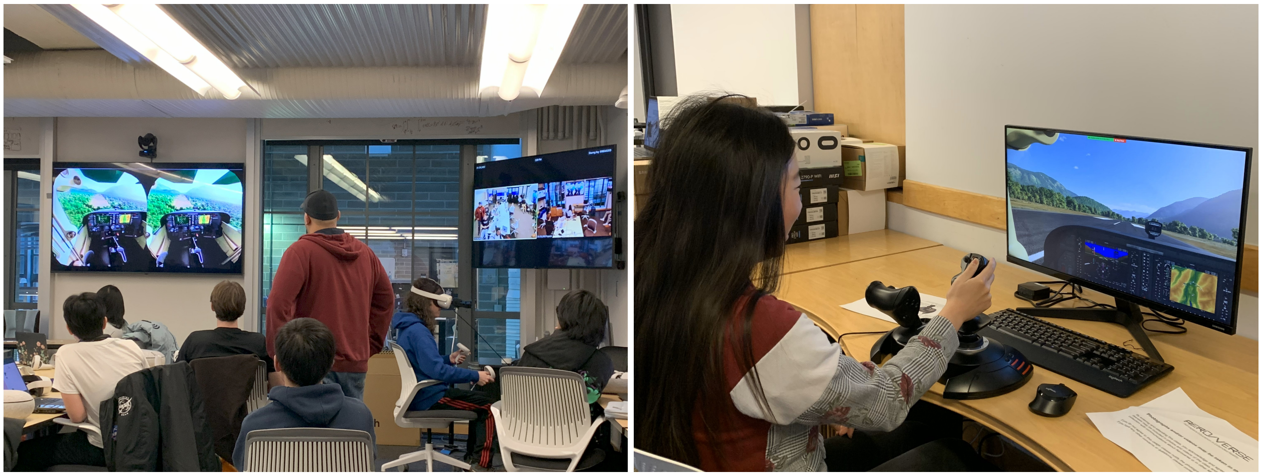
(b)

Figure 2: (a) Example slide from the Module A non-VR lab material. (b) Screen capture of a scene in the Module A VR lab simulation.

In the non-VR lab, students received a second lecture on the aforementioned topics with an accompanying PowerPoint to mimic a traditional lecture setting. In the VR lab, students had the opportunity to interact with an airplane model, sit in a digital (Boeing 737-800) and analog (Cessna 172) cockpit, and walk around a life-size airport. Students completed these activities individually.

Module B: Fly a Jet Plane

Following Module A, Module B allowed students to apply the knowledge obtained to a virtual flight simulation. The joint lecture provided a quick summary of pilot school, covering the most fundamental topics and reiterating the relevant points that they learned in Module A. For the lab session, both groups first watched an experienced pilot (a volunteer student with a pilot certificate) perform a quick flight in Microsoft Flight Simulator, then had the opportunity to try it themselves as seen in Figure 3. The non-VR group used the desktop version of Microsoft Flight Simulator with a HOTAS flight stick, while the VR group used the Meta Quest 2 and the Meta Touch controllers. Because of the limited hardware, students were instructed to sign up for an additional 90-minute lab session outside of regular class hours to reserve a computer for use for additional flying activities.


(a)

(b)

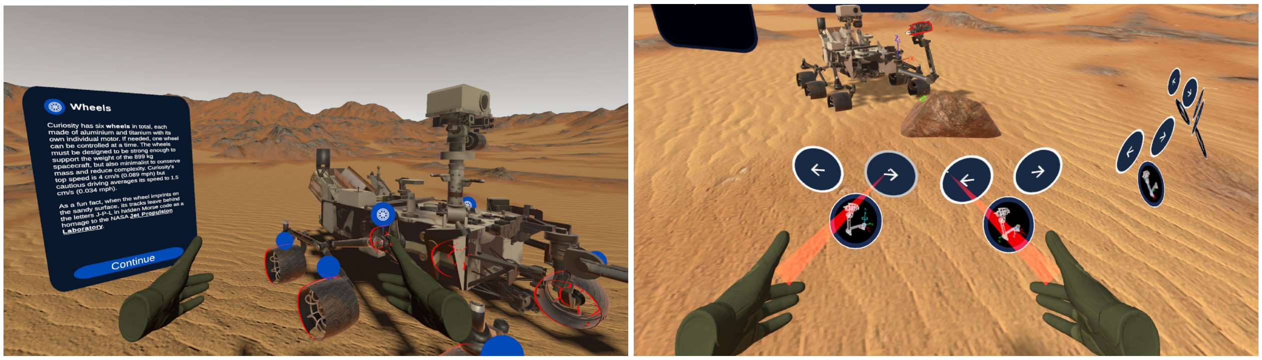
Figure 3: (a) Students in Group 1 watching a student land a Cessna 172 in VR. (b) Student in Group 2 landing a Cessna 172 using a desktop and flight stick.

Due to the heavy computing requirements for Microsoft Flight Simulator, the software needed to be run on external computing hardware. Four custom PCs equipped with an i7-12000k CPU, RTX 4070 Ti GPU, and 32 GB of RAM were purchased for Flight Simulator use. For the VR group, these were connected to the Meta Quest headsets using Oculus Link cables for VR video output and for control inputs (from both the headset and Touch controllers). Two of the PCs were set up for desktop use, while the other two were reserved for VR use.

Module C: Explore Mars with a Remote-Controlled Vehicle

Module C marked the beginning of Spacecraft Week. In this module, students learned about spacecraft systems, remote-controlled operations, and fundamentals of robotics in the context of Mars exploration with the Curiosity rover. The decision to opt for the Curiosity rover instead of the more recent Perseverance rover was influenced by Curiosity's extensive historical data, longer operational history, and the availability of a greater number of 3-D assets for use in building Module C. Students were introduced to the history, motives, mission plan, and configuration of the Curiosity rover in the joint lecture.

Students in the non-VR session were given a self-paced PowerPoint containing information near-identical to the VR simulation that allowed them to complete their worksheet. To expose the non-VR students to Curiosity's driving and to let them interact with the robotic arm, students were directed to the Experience Curiosity website courtesy of NASA JPL. This format imitated a more self-driven learning approach in which students could read and engage with `eyes.nasa.gov/curiosity/` at their own pace. Meanwhile, students in the VR session found themselves on Mars and were able to interact with the parts of the life-size rover, drive it, and operate its robotic arm as seen in Figure 4. The lab was completed individually by each student.



Curiosity has six **wheels** in total, each made of aluminium and titanium with its own individual motor. If needed, one wheel can be controlled at a time. The wheels must be designed to be strong enough to support the weight of the 899 kg spacecraft, but also minimalist to conserve Curiosity's mass and reduce complexity. Curiosity's top speed is 4 cm/s (0.089 mph) but cautious driving averages its speed to 1.5 cm/s (0.034 mph).

As a fun fact, when the wheel imprints on the sandy surface, its tracks leave behind the letters J-P-L in hidden Morse code as a homage to the NASA **Jet Propulsion Laboratory**.

(a) (b)

Figure 4: (a) Students learn about the different subsystems and parts of the Curiosity rover on Mars in Module C. (b) Students operate the robotic arm, one joint at a time, to drill for rock samples.

Module D: Explore Mars with an Autonomous Vehicle

Having received a background on the Curiosity mission, the subsequent Module D continued with the theme, but with a focus on the rover's autonomous navigation. The joint lecture discussed past, present, and future uses of autonomous extraterrestrial vehicles. A short introduction on stereo reconstruction, autonomy architectures, and path planning algorithms was provided. In particular, the A* search algorithm was discussed in detail to prepare students for the coding exercises in the following lab.

In this lab session, all students completed an identical coding assignment using laptops in the real world. This task was divided into three parts: stereo reconstruction, cost map conversion from point cloud, and path planning using an A* algorithm. Students had incomplete versions of these algorithms that they had to modify and complete themselves. In order to visualize how the applied code works in a rover context, students interacted with the Module D rover simulation that allowed them to collect point cloud data, adjust algorithm parameters, and execute complete (stored) versions of the example algorithms. This rover simulation, an image of which can be seen in Figure 5, was either run on the VR headsets or on laptops.

Figure 5: The executable simulation, which may be run via headset or laptop. Students must complete the sections in order and complete their code in the real world.

Module E: Human-Machine Interactions

The VR sessions for both Modules E and F made use of the freely-available Mission: ISS app made by Magnopus on the Meta Store. Students using Mission: ISS did so in pairs. Because the app takes place in the International Space Station (ISS) and simulates microgravity, students were anticipated to become cybersick much faster in this module than in previous ones. Placing students in pairs and having them rotate the use of the headset allows students to still complete the activity without spending extensive time in VR. Figure 6 shows students working together in this manner. To ensure that everyone had exposure to the content, the owner of the headset was instructed to set up casting to their laptop. Casting the headset to a laptop enables observers on the outside to see what the headset user sees.

To complete the accompanying worksheets, the VR groups were given scavenger hunt instructions to seek out different objects aboard the station. While one person interacted with the simulation, the other person read them the prompts in the scavenger hunt-style worksheet. Mission: ISS is published by a third party, therefore none of the content within could be modified; as such, the lab activity was planned around the already-existing materials. The majority of the Mission: ISS content, however, is taken from recorded NASA, ESA, and CSA videos that are available online. The non-VR groups, therefore, had access to these videos in an embedded PowerPoint format. Though the non-VR groups answered the same general questions in their version of the lab worksheet, the scavenger hunt aspects of the worksheet were removed. To mirror the collaborative aspect of the VR groups, the non-VR groups also worked in pairs.

The third and last week revolved around astronauts. Module E centered on human-machine interactions with the robotic Canadarm2 and on the types of experiments performed on the ISS. In the joint lecture, history and background of the space station was discussed, as well as the kinematics of the Candarm2 and the importance of science in space. After completing the required scavenger hunt relating to experiments and machines aboard the ISS, students were then asked to analyze the

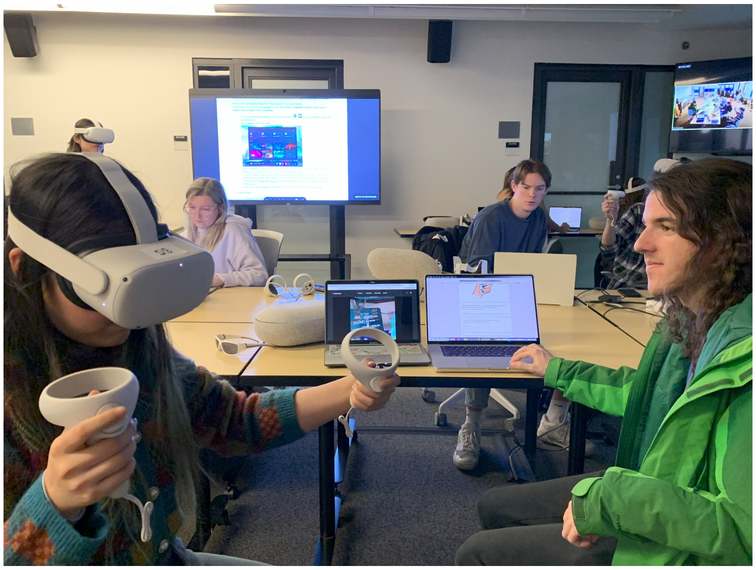


Figure 6: Students taking turns working in pairs using Mission: ISS and completing the worksheet. Live video feed from the headsets were screencasted to laptops.

controls and movement of the Canadarm2. The VR group had a hands-on experience through Mission: ISS in which they interacted with the "Operate the Canadarm" mini-game. Each student was asked to operate and complete this scene. Students in the non-VR group watched two videos: in the first, an astronaut demonstrates how the controls operate; in the second, the Canadarm2 grabs a Dragon capsule for docking. After the mini-game or pair of videos, students were then asked to discuss a series of open-ended questions relating to the Canadarm2 with their partner.

Module F: Humans in Space

The topic of the final Module F was humans in space, human space systems, and systems safety. Former astronaut and current MIT faculty Jeffrey Hoffman delivered the final lecture regarding astronaut training, extravehicular activities (EVAs), and life support systems. During the lab, once the scavenger hunt or embedded videos relating to life support and other human systems was completed, students were told to analyze a spacewalk. The VR group took turns playing the "Go on a Spacewalk" feature in Mission: ISS, though participation for this particular experience was not mandatory for all VR students due to concerns of inducing cybersickness. The non-VR group watched a recording clip of a short spacewalk courtesy of NASA. After these experiences, students in their teams were prompted to have an open discussion based on targeted questions relating to astronaut psychology and preparedness for EVAs.

Results and Discussion

The effectiveness of using VR compared to not using VR was determined by analyzing pre- and post-module reflection responses and post-module assignment grades. The pre-class reading quiz was not indicative of VR effectiveness and the in-lab worksheets were not graded for accuracy, so these assignments are not considered in this paper.

Summary of Pre- and Post-Module Reflection Responses

Within each post-module reflection, all students were asked to rate how well they found the lab session to sufficiently prepare them for the post-class module quiz and how much they enjoyed the lab session on a five-point Likert scale. Furthermore, they were asked to mark how well they believed they achieved a set of learning outcomes, choosing from a three-point scale of ”Not at all,” ”Barely,” or ”Fully”. These same confidence prompts also appeared in the pre-module quiz as a point of comparison. These series of questions were purely opinionated; note that the respondents answered questions on preparedness and subject confidence without having seen their grades.

Figure 7 shows the average rating for the VR and non-VR groups regarding how well the lab session prepared students for the post-module quiz. In all modules, students felt that the non-VR lab session prepared them better for the post-module quiz. In the open-ended feedback section of the survey, one student noted that the lack of note taking when using the VR headset was an “important drawback.” Other responses mentioned that, when preparing for the quiz, it was more time-consuming to replay through the simulations than it would have been simply re-reading lecture slides. Moreover, though labs were completed individually, the non-VR group had easy access to an instructor when completing the worksheets and felt more comfortable asking clarifying questions; on the other hand, the VR group’s activities were very individualistic since they were contained within the headsets, and few conceptual questions were asked.

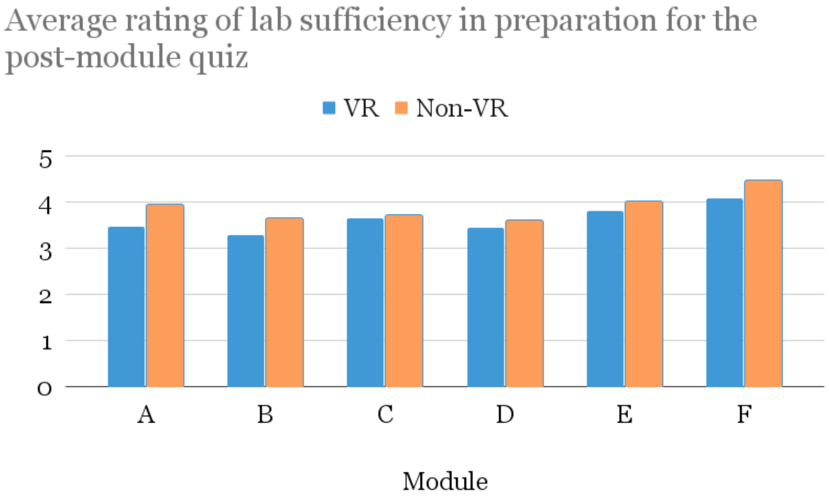


Figure 7: Students assessed how well the lab prepared them for the post-module quiz on a scale from 1- Highly Insufficient to 5- Highly Sufficient.

In terms of enjoyment, half of the labs were deemed more enjoyable in VR as seen in Figure 8. The two learning-based labs, Modules A and C, had a more positive response than the two experienced-based labs B and D. This is not to say that in general, learning-based simulations outperform experience-based simulations, but rather suggests that the experiences chosen for this particular class were better executed in the real world. The largest difference in responses is seen in the averages collected from Module A. As mentioned for this module, the non-VR group was delivered a secondary two-hour lecture on top of the joint one-hour lecture rather than have a traditional lab experience. In this case, the VR group reacted much more positively than the non-VR group, suggesting that an interactive experience is more preferrable to an extended lecture.

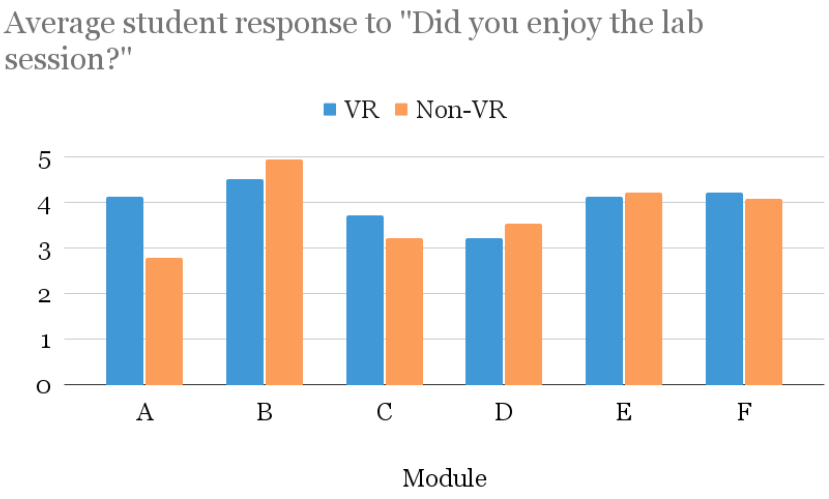


Figure 8: Students assessed how well they enjoyed the lab session on a scale of 1- Not at all to 5- Yes, very much.

Each module had its own set of learning objectives which students assessed in the pre- and post-class surveys, the averages of which are summarized in Figure 9. When comparing the change in confidence levels, as seen in Figure 10, the averages for all modules had a net positive change in confidence after the class. Half of the labs in VR made students feel more confident, of which two of the three were the learning-based labs A and C. The Module B students who used the flight simulator in VR felt the least confident out of all of the modules about meeting the set learning objectives after the class; some students cited that the lack of haptic feedback and sensitivity of the VR controls made flying less intuitive. It is relevant to note that the desktop version of Microsoft Flight Simulator is the primary optimized version of the software, whereas the VR plug-in is an added feature. Moreover, using the flight stick physically limited the non-VR students from accidentally hitting the wrong buttons, a problem that arose in a few instances of the VR students who had unrestricted access to the cockpit controls.

After the last class, an additional question was added to the reflection that asked students what their preference was for learning with VR over learning without VR. The trend in Figure 11 skews positive towards more involvement with VR, with the majority of responses stating that they would prefer learning both modules each week in VR.

Post-Module Assessment Results

The data from the post-module assessments, compared in Table 4, shows that the average score for the VR students was slightly higher than the non-VR students for every module except for Module E and F. Interestingly, this seems to contradict the results from Figure 7; that is, although students in Modules A-D thought that VR prepared them less than their non-VR counterparts, the VR users scored higher on average than the non-VR users for these modules.

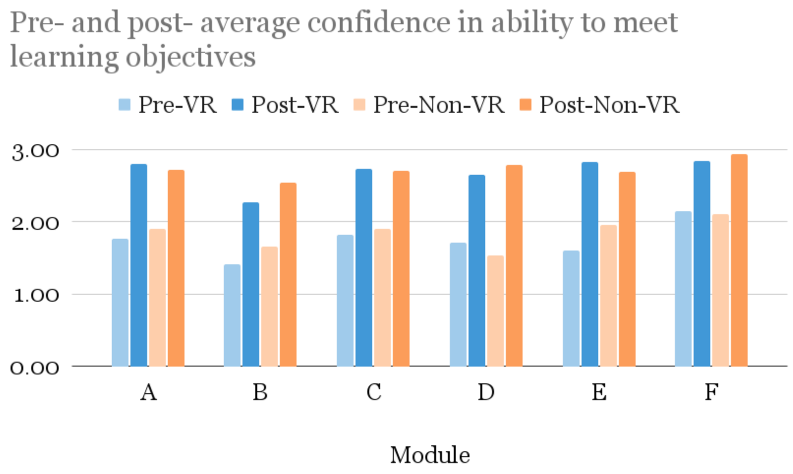


Figure 9: Students assessed their confidence on meeting a set of learning objectives, which varied by module, on a scale of 1- Not at all, 2- Barely, and 3- Fully or almost fully. Students were asked these questions before and after each module.

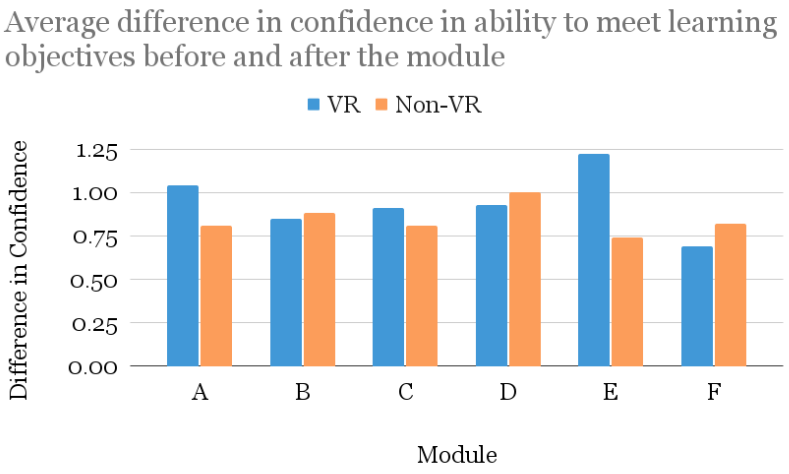


Figure 10: The average difference between the pre- and post-class confidence levels in ability to meet learning objectives for each module.

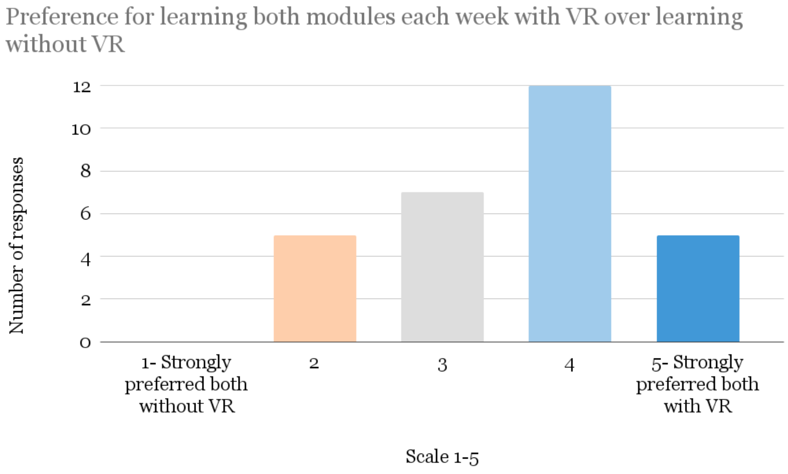


Figure 11: Student preference for learning both modules each week on a scale of 1- Strongly would have preferred both without VR to 5- Strongly would have preferred both with VR.

Table 4: Grade distribution for each module by group.

Post-Module Quiz Grades						
Module	**Group**	**Mean**	**Min**	**1st quart**	**3rd quart**	**Max**
A	A- VR	0.84	0.68	0.8	0.89	0.96
	A- NonVR	0.83	0.64	0.79	0.86	1.00
B	B- VR	0.84	0.64	0.79	0.89	0.96
	B- NonVR	0.84	0.64	0.8	0.88	0.93
C	C- VR	0.95	0.88	0.92	0.98	1.00
	C- NonVR	0.91	0.57	0.93	0.97	1.00
D	D- VR	0.91	0.82	0.87	0.95	1.00
	D- NonVR	0.9	0.69	0.89	0.94	0.98
E	E- VR	0.82	0.46	0.79	0.9	1.00
	E- NonVR	0.88	0.79	0.84	0.92	0.96
F	F- VR	0.89	0.8	0.86	0.92	0.94
	F- NonVR	0.91	0.84	0.87	0.95	0.99

Statistical Results

To statistically evaluate if VR impacted grades, confidence, and enjoyability, t-tests and a non-parametric Kruskal-Wallis test were performed; the results are seen in Appendix B. Though the reported averages are higher for VR users in some of the modules, a one-sided t-test shows that this difference is not statistically significant. In all six modules, there is no significant difference between the average grades of the VR group when compared to the non-VR group. When looking at the change in confidence levels between VR and non-VR, there is no significant difference in averages for every module except for Module E. Module E showed a significant difference in difference in confidence, with the VR group outperforming the non-VR group. Interestingly, although both E and F used Mission: ISS, these results were not repeated for Module F; this may be due to the difference in topics (human-machine interactions vs. humans in space) within Mission: ISS.

The Kruskal-Wallis test on the enjoyability rankings that students had assigned in the post-module surveys had mainly insignificant results. However, both Modules A and B showed a significant difference in median rankings; for Module A, students favored VR, but for Module B, students favored non-VR. An explanation for Module A may again be that students preferred the experience to an extended lecture. For Module B, the flight simulator with the HOTAS flight stick likely made the experience less complicated, therefore more enjoyable.

Additional Statistical Results

Two factors were identified that could complicate our analysis of the effectiveness of VR: student academic level and previous exposure to virtual reality technology. This subsection discusses if student year or previous experience had an effect on grades, difference in confidence, and enjoyability. As such, t-tests (this time two-sided) and Kruskal-Wallis tests were repeated for students that were organized into subgroups based on these two categories. The summary of the results for student year and prior experience can be seen in Appendix C and D, respectively.

Though the topics chosen for the course were introductory level, there is insufficient evidence from the two-tailed t-test to say that the average grade of a senior/grad student was higher or lower than a freshman/sophmore/junior in any of the modules. The same result is true for differences in confidence levels, with the exception of Module B. Module B showed a significant difference in change in confidence levels between upper- and underclassmen, likely due to the fact that most of the underclassmen had never flown a plane before. From the Kruskal-Wallis analysis, the null hypothesis was retained; the difference in median enjoyability rankings is not statistically significant for upper- and underclassmen.

In the pre-course survey, most students had little to no prior experience, while few students had some experience. For Modules A, B, E, and F, there was no significant difference in average test scores for those with some experience and those with little to none. However, in Modules C and D, there was a significant difference in the grade averages. The data suggests that those with little to no experience outperformed those with experience, but the sample size of those with experience is small. Prior VR experience did not have a significant effect on the averages of the students' confidence in meeting learning objectives in any of the modules. Moreover, prior experience did not change the median value for enjoyability in any module. There is insufficient evidence to say that prior experience results in a higher or lower median enjoyability ranking.

It is worth emphasizing that the topics chosen for this iteration of the Aeroverse course were all topics that could have also been taught without VR (which was necessary for the experimental design). A course that only teaches topics suitable for XR that cannot be easily replicated in the real world would likely yield different results than the ones that this study presents.

Reports of Cybersickness

Despite these interesting initial findings, it is important to note that extended reality is not without drawbacks. Cybersickness, also referred to as simulator sickness, is a form of motion sickness caused by the sensory misalignment between the real and virtual world [18]. Individual susceptibility to cybersickness varies on a person-to-person basis, but symptoms can be as mild as eye fatigue and as serious as nausea and vertigo. Within our class, several symptoms of cybersickness were self-reported in the post-class surveys, the results of which are shown in Figure 12. Although students went through a debriefing on cybersickness and mitigation strategies at the beginning of the course, between 27-73% of students mentioned at least mild symptoms depending on the module; some described nausea and headaches that lasted after the class ended for the day. A significant increase is seen in Modules E and F, which was predicted correctly. From Figure 11, three of the five respondents that would have preferred not learning both classes with VR cited cybersickness as the main hindrance to adopting more VR technology. Future renditions of this course or similar courses may benefit from reducing the required amount of time spent in VR or designing longer activities for students to complete outside of the headsets.

When comparing the grades of the healthy VR users to the cybersick VR users, there is not enough evidence to suggest that cybersickness had a significant impact on summative assessment performance within the VR group. A one-tailed t-test was performed to compare healthy and cybersick student grades. A summary of the test results is shown in Table 5. Note that $p > 0.05$ for all mod-

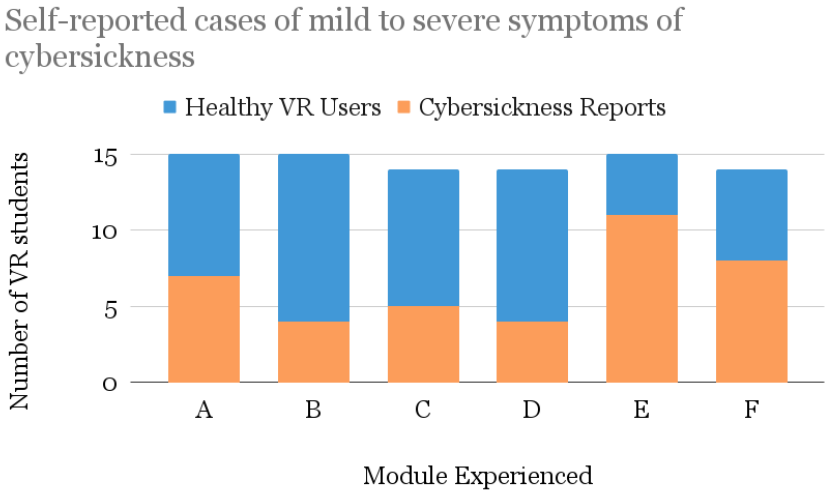


Figure 12: Number of students in the VR group for each module and the reported number of students experiencing cybersickness symptoms.

ules except for B, which seems to suggest that there is a significant difference between healthy and cybersick users (favoring that the cybersickness mean is higher than the healthy mean). However, this result is likely non-representative, since the sample size of the cybersick users for that module is small. For our class, there was no significant difference in performance between healthy and cybersick users in the remaining modules.

Table 5: **Grade performance t-test results for healthy and cybersick students.**

Module A			Module B			Module C		
	Healthy	*Cybersick*		*Healthy*	*Cybersick*		*Healthy*	*Cybersick*
Mean	0.865	0.811	Mean	0.819	0.908	Mean	0.952	0.942
Variance	0.004	0.010	Variance	0.008	0.001	Variance	0.001	0.001
Observations	8	7	Observations	11	4	Observations	9	5
df	13		df	13		df	12	
t Stat	1.260		t Stat	-1.882		t Stat	0.498	
P(T<=t) one-tail	0.115		P(T<=t) one-tail	$p < 0.05$		P(T<=t) one-tail	0.314	
Module D			Module E			Module F		
	Healthy	*Cybersick*		*Healthy*	*Cybersick*		*Healthy*	*Cybersick*
Mean	0.911	0.903	Mean	0.783	0.840	Mean	0.885	0.890
Variance	0.002	0.007	Variance	0.029	0.028	Variance	0.003	0.002
Observations	10	4	Observations	4	10	Observations	6	8
df	12		df	12		df	12	
t Stat	0.251		t Stat	-0.582		t Stat	-0.194	
P(T<=t) one-tail	0.403		P(T<=t) one-tail	0.286		P(T<=t) one-tail	0.425	

Conclusion and Future Work

In conclusion, VR empowers instructors by providing students with unique, engaging opportunities in the classroom. The overall reception of our course, Aeroverse, has been positive, and students have expressed a preference for learning with VR content (Figure 11). The results for the course show that students enjoyed and felt more confident with our learning-based VR labs. Conversely, students felt that our VR labs did not prepare them for summative assessments as well as the non-VR labs did. Despite this, VR users outperformed non-VR users in the post-module quiz for two thirds of the course. The statistical significance of these results was analyzed, and a statistical significance was found in only a few cases between VR users and non-VR users. Additional tests were performed to see if student year or previous experience had a significant effect on the data, which in almost all cases, did not. These results are valid for our course, but more data are needed to expand this conclusion to general aerospace education.

Though the potential benefits of VR in the classroom are encouraging, instructors should consider carefully what types of simulations should be presented in VR, and what topics are more effective in the real world. Additionally, it is important to limit the time spent using a headset and to prepare contingency plans in case students exhibit cybersickness, which may detract from learning on a case-by-case basis.

Future work may include the adoption of AR technology into the Aeroverse curriculum. The content within Modules A, C, and D may be extended and edited according to user feedback. To address concerns of not being able to reference material quickly or not being able take notes in VR, supplementary learning materials such as a PowerPoint summary or written synopsis may be provided to students to reference after the VR experiences. Another remedy to consider would be a voice-to-text notes feature within the simulation that can export personalized notes. For more radical results, additional topics that cannot easily be translated into a non-XR format may be considered, such as interactive model assembly, first-person point-of-view experiences, or modelling system interior processes. With this in mind, the continued exploration and refinement of XR usage in aerospace engineering education holds promise for fostering an enriched learning experience.

References

[1] J. M. Probst and H. Orsolits, “Experts’ view on ar/vr in engineering education at universities,” in *Learning in the Age of Digital and Green Transition*, vol. 634 of *Lecture Notes in Networks and Systems*, pp. 1010–1022, Springer, 2023.

[2] M. Cook, Z. Lischer-Katz, N. Hall, J. Hardesty, J. Johnson, R. McDonald, and T. Carlisle, “Challenges and strategies for educational virtual reality: Results of an expert-led forum on 3d/vr technologies across academic institutions,” *Information Technology and Libraries*, vol. 38, p. 25–48, Dec. 2019.

[3] S. Marshall, “Augmented reality’s application in education and training,” in *Springer Handbook of Augmented Reality* (A. Y. C. Nee and S. K. Ong, eds.), ch. 13, pp. 335–353, Cham: Springer International Publishing, 2023.

[4] M. Safi and J. Chung, “Augmented reality uses and applications in aerospace and aviation,” in *Springer Handbook of Augmented Reality* (A. Y. C. Nee and S. K. Ong, eds.), ch. 20, pp. 473–494, Cham: Springer International Publishing, 2023.

[5] “Virtual reality with real benefits.” Airbus. `https://www.airbus.com/en/newsroom/news/2017-09-virtual-reality-with-real-benefits` (accessed Feb. 8, 2024).

[6] J. Hale, “Applied virtual reality in aerospace,” in *Wescon/96*, pp. 547–550, 1996.

[7] S. Tadeja, P. Seshadri, and P. Kristensson, “Aerovr: An immersive visualisation system for aerospace design and digital twinning in virtual reality,” *The Aeronautical Journal*, vol. 124, no. 1280, p. 1615–1635, 2020.

[8] H. Ardiny and E. Khanmirza, “The role of ar and vr technologies in education developments: Opportunities and challenges,” in *2018 6th RSI International Conference on Robotics and Mechatronics*, (Tehran, Iran), pp. 482–487, 2018.

[9] A. Xiao, K. Bryden, and D. Brigham, “Virtual reality tools for enhancing interactive learning,” in *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*, (Salt Lake City, Utah), pp. 9.1404.1–9.1404.13, American Society for Engineering Education, June 2004.

[10] U. Dakeev, R. R. Pecen, F. Yildiz, I. I. Basith, S. M. Obeidat, and L. E. Sowell, “Development of virtual reality robotics laboratory simulation,” in *2022 ASEE Zone IV Conference*, (Vancouver, Canada), May 2022.

[11] Z. Shi and C. L. R. McGhan, “Affordable virtual reality setup for educational aerospace robotics simulation and testing,” in *Journal of Aerospace Information Systems*, vol. 17, pp. 66–69, American Institute of Aeronautics and Astronautics, January 2020.

[12] F. Castronovo, R. Schaffer, and V. R. Kandi, “Lessons learned from implementing virtual reality in an introductory engineering course,” in *2020 ASEE Virtual Annual Conference Content Access, Virtual*, June 2020.

[13] C. A. Aji and M. J. Khan, “Virtual reality lessons in undergraduate introductory stem courses,” in *2021 ASEE Virtual Annual Conference Content Access, Virtual*, (Vancouver, Canada), May 2022.

[14] A. Marougkas, C. Troussas, A. Krouska, and C. Sgouropoulou, “Virtual reality in education: A review of learning theories, approaches and methodologies for the last decade,” *Electronics*, vol. 12, no. 13, 2023.

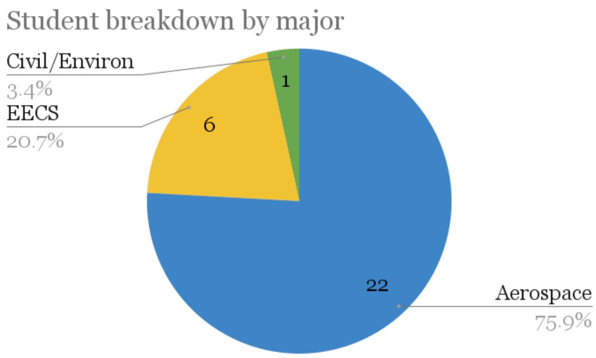
[15] “New Simulation Lab Opens Exciting Chapter in AE’s Rotorcraft Research.” Daniel Guggenheim School of Aerospace Engineering. `https://ae.gatech.edu/news/2018/02/new-simulation-lab-opens-exciting-chapter-aes-rotorcraft-research` (accessed Feb. 6, 2024).

[16] “Flight Simulation & Training Devices.” Embry-Riddle Aeronautical University Daytona Beach Florida Campus. `https://daytonabeach.erau.edu/college-aviation/flight/simulation-training-devices` (accessed Feb. 6, 2024).

[17] “UNO’s Aviation Institute Adds Boeing 737 Flight Simulator.” University of Nebraska Omaha. `https://www.unomaha.edu/college-of-public-affairs-and-community-service/news/2023/02/uno-aviation-institute-adds-boeing-737-flight-simulato.php` (accessed Feb. 6, 2024).

[18] O. Hein, P. Rauschnabel, M. Hassib, and F. Alt, “Sick in the car, sick in vr? understanding how real-world susceptibility to dizziness, nausea, and eye strain influences vr motion sickness,” in *Human-Computer Interaction – INTERACT 2023* (J. Abdelnour Nocera, M. Kristín árusdóttir, H. Petrie, A. Piccinno, and M. Winckler, eds.), (Cham), pp. 552–573, Springer Nature Switzerland, 2023.

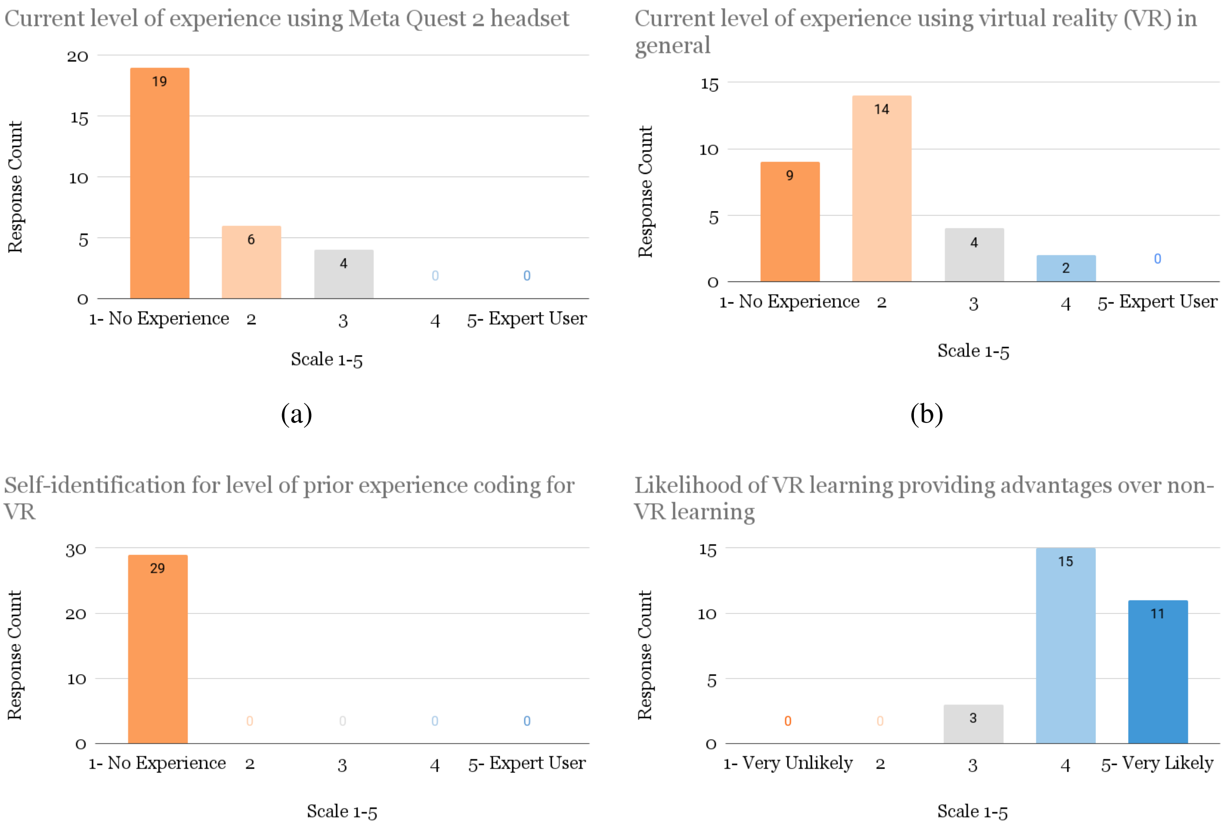
Appendix A



(a) (b)

Figure A1: (a) Breakdown of students by major. (b) Breakdown of students by year and affiliation.

Note that electrical engineering and computer science (EECS) is considered as one major, civil and environmental engineering is also considered as one major, and double majors and/or concentrations are not represented. Moreover, not all graduate students have undergraduate degrees in aerospace.



(a)

(b)

(c)

(d)

Figure A2: (a) Students rated their level of experience using the Meta Quest 2. (b) Students rated their experience using VR of any type. (c) Students rated their experience with coding for VR applications. (d) Students predicted the likelihood of VR having an advantageous impact on learning.

Appendix B

Table B1: **Statistical results when comparing VR and non-VR student groups.**

t-Test: Grades, VR vs. Non-VR								
Module A- Grades			**Module B- Grades**			**Module C- Grades**		
	VR	*NonVR*		*VR*	*NonVR*		*VR*	*NonVR*
Mean	0.840	0.829	Mean	0.843	0.835	Mean	0.949	0.913
Variance	0.007	0.008	Variance	0.008	0.006	Variance	0.001	0.013
Observations	15	14	Observations	15	14	Observations	14	15
df	27		df	27		df	27	
t Stat	0.328		t Stat	0.250		t Stat	-1.143	
P(T<=t) one-tail	0.373		P(T<=t) one-tail	0.402		P(T<=t) one-tail	0.132	
Module D- Grades			**Module E- Grades**			**Module F- Grades**		
	VR	*NonVR*		*VR*	*NonVR*		*VR*	*NonVR*
Mean	0.909	0.901	Mean	0.824	0.877	Mean	0.888	0.914
Variance	0.003	0.006	Variance	0.025	0.003	Variance	0.002	0.002
Observations	14	15	Observations	15	14	Observations	14	15
df	27		df	27		df	27	
t Stat	-0.322		t Stat	-1.197		t Stat	1.531	
P(T<=t) one-tail	0.375		P(T<=t) one-tail	0.121		P(T<=t) one-tail	0.069	
t-Test: Diff. Confidence, VR vs. Non-VR								
Module A- Diff. Confidence			**Module B- Diff. Confidence**			**Module C- Diff. Confidence**		
	VR	*NonVR*		*VR*	*NonVR*		*VR*	*NonVR*
Mean	1.040	0.814	Mean	0.821	0.875	Mean	0.908	0.754
Variance	0.361	0.520	Variance	0.158	0.603	Variance	0.739	0.336
Observations	15	14	Observations	14	14	Observations	14	14
df	27		df	26		df	26	
t Stat	0.918		t Stat	-0.230		t Stat	-0.554	
P(T<=t) one-tail	0.183		P(T<=t) one-tail	0.410		P(T<=t) one-tail	0.292	
Module D- Diff. Confidence			**Module E- Diff. Confidence**			**Module F- Diff. Confidence**		
	VR	*NonVR*		*VR*	*NonVR*		*VR*	*NonVR*
Mean	0.929	1.250	Mean	1.222	0.737	Mean	0.691	0.822
Variance	0.437	0.250	Variance	0.329	0.686	Variance	0.914	0.474
Observations	14	15	Observations	15	14	Observations	14	15
df	27		df	27		df	27	
t Stat	1.484		t Stat	1.843		t Stat	0.427	
P(T<=t) one-tail	0.075		P(T<=t) one-tail	$p < 0.05$		P(T<=t) one-tail	0.337	
Kruskal-Wallis: Enjoyability, VR vs. Non-VR								
Module A- Enjoyability			**Module B- Enjoyability**			**Module C- Enjoyability**		
	VR	*NonVR*		*VR*	*NonVR*		*VR*	*NonVR*
Median	4	3	Median	5	5	Median	4	3
Total N	29		Total N	28		Total N	28	
Test Statistic	13.369		Test Statistic	3.363		Test Statistic	1.57	
df	1		df	1		df	1	
Asymptotic Sig.	$p < 0.05$		Asymptotic Sig.	$p < 0.05$		Asymptotic Sig.	0.105	
Module D- Enjoyability			**Module E- Enjoyability**			**Module F- Enjoyability**		
	VR	*NonVR*		*VR*	*NonVR*		*VR*	*NonVR*
Median	3.5	4	Median	4	4.5	Median	5	4
Total N	29		Total N	29		Total N	29	
Test Statistic	0.67		Test Statistic	0.055		Test Statistic	0.347	
df	1		df	1		df	1	
Asymptotic Sig.	0.207		Asymptotic Sig.	0.407		Asymptotic Sig.	0.278	

Appendix C

Table C1: **Statistical results when comparing little to no VR experience and some experience.**

t-Test: Grades, Some Experience vs. Little/None								
Module A- Grades			**Module B- Grades**			**Module C- Grades**		
	Little	*Some*		*Little*	*Some*		*Little*	*Some*
Mean	0.840	0.817	Mean	0.834	0.858	Mean	0.949	0.857
Variance	0.009	0.002	Variance	0.007	0.006	Variance	0.002	0.025
Observations	23	6	Observations	23	6	Observations	23	6
df	27		df	27		df	27	
t Stat	0.571		t Stat	-0.651		t Stat	2.606	
P(T<=t) two-tail	0.573		P(T<=t) two-tail	0.521		P(T<=t) two-tail	$p < 0.05$	
Module D- Grades			**Module E- Grades**			**Module F- Grades**		
	Little	*Some*		*Little*	*Some*		*Little*	*Some*
Mean	0.919	0.850	Mean	0.855	0.830	Mean	0.897	0.918
Variance	0.002	0.011	Variance	0.014	0.020	Variance	0.002	0.001
Observations	23	6	Observations	23	6	Observations	23	6
df	27		df	27		df	27	
t Stat	2.512		t Stat	0.442		t Stat	-0.991	
P(T<=t) two-tail	$p < 0.05$		P(T<=t) two-tail	0.662		P(T<=t) two-tail	0.330	
t-Test: Diff. Confidence, Some Experience vs. Little/None								
Module A- Diff. Confidence			**Module B- Diff. Confidence**			**Module C- Diff. Confidence**		
	Little	*Some*		*Little*	*Some*		*Little*	*Some*
Mean	0.852	1.233	Mean	0.804	1.050	Mean	0.813	0.914
Variance	0.364	0.695	Variance	0.278	0.888	Variance	0.504	0.749
Observations	23	6	Observations	23	5	Observations	23	5
df	27		df	26		df	26	
t Stat	-1.275		t Stat	-0.816		t Stat	-0.278	
P(T<=t) two-tail	0.213		P(T<=t) two-tail	0.422		P(T<=t) two-tail	0.783	
Module D- Diff. Confidence			**Module E- Diff. Confidence**			**Module F- Diff. Confidence**		
	Little	*Some*		*Little*	*Some*		*Little*	*Some*
Mean	1.130	0.958	Mean	0.898	1.333	Mean	0.667	1.112
Variance	0.300	0.635	Variance	0.509	0.626	Variance	0.697	0.475
Observations	23	6	Observations	23	6	Observations	23	6
df	27		df	27		df	27	
t Stat	0.624		t Stat	-1.304		t Stat	-1.199	
P(T<=t) two-tail	0.538		P(T<=t) two-tail	0.203		P(T<=t) two-tail	0.241	
Kruskal-Wallis: Enjoyability, Some Experience vs. Little/None								
Module A- Enjoyability			**Module B- Enjoyability**			**Module C- Enjoyability**		
	Little	*Some*		*Little*	*Some*		*Little*	*Some*
Median	4	4	Median	5	5	Median	4	3
Total N	29		Total N	28		Total N	28	
Test Statistic	0.236		Test Statistic	0.016		Test Statistic	0.61	
df	1		df	1		df	1	
Asymptotic Sig.	0.627		Asymptotic Sig.	0.9		Asymptotic Sig.	0.805	
Module D- Enjoyability			**Module E- Enjoyability**			**Module F- Enjoyability**		
	Little	*Some*		*Little*	*Some*		*Little*	*Some*
Median	4	4	Median	4	5	Median	4	5
Total N	29		Total N	29		Total N	29	
Test Statistic	0.021		Test Statistic	0.915		Test Statistic	2.647	
df	1		df	1		df	1	
Asymptotic Sig.	0.885		Asymptotic Sig.	0.339		Asymptotic Sig.	0.104	

Appendix D

Table D1: **Statistical results when comparing upperclassmen and underclassmen.**

t-Test: Grades, Upper vs. Underclassmen								
Module A- Grades			**Module B- Grades**			**Module C- Grades**		
	Upper	*Under*		*Upper*	*Under*		*Upper*	*Under*
Mean	0.817	0.854	Mean	0.833	0.846	Mean	0.931	0.929
Variance	0.011	0.003	Variance	0.009	0.005	Variance	0.004	0.011
Observations	15	14	Observations	15	14	Observations	15	14
df	27		df	27		df	27	
t Stat	-1.179		t Stat	-0.427		t Stat	0.086	
P(T<=t) two-tail	0.249		P(T<=t) two-tail	0.673		P(T<=t) two-tail	0.932	
Module D- Grades			**Module E- Grades**			**Module F- Grades**		
	Upper	*Under*		*Upper*	*Under*		*Upper*	*Under*
Mean	0.911	0.897	Mean	0.847	0.853	Mean	0.893	0.910
Variance	0.003	0.005	Variance	0.018	0.012	Variance	0.002	0.003
Observations	15	14	Observations	15	14	Observations	15	14
df	27		df	27		df	27	
t Stat	0.580		t Stat	-0.136		t Stat	-0.952	
P(T<=t) two-tail	0.567		P(T<=t) two-tail	0.893		P(T<=t) two-tail	0.350	
t-Test: Diff. Confidence, Upper vs. Underclassmen								
Module A- Diff. Confidence			**Module B- Diff. Confidence**			**Module C- Diff. Confidence**		
	Upper	*Under*		*Upper*	*Under*		*Upper*	*Under*
Mean	0.787	1.086	Mean	0.633	1.096	Mean	0.647	1.043
Variance	0.306	0.558	Variance	0.293	0.360	Variance	0.480	0.528
Observations	15	14	Observations	15	13	Observations	15	13
df	27		df	26		df	26	
t Stat	-1.231		t Stat	-2.146		t Stat	-1.474	
P(T<=t) two-tail	0.229		P(T<=t) two-tail	$p < 0.05$		P(T<=t) two-tail	0.152	
Module D- Diff. Confidence			**Module E- Diff. Confidence**			**Module F- Diff. Confidence**		
	Upper	*Under*		*Upper*	*Under*		*Upper*	*Under*
Mean	0.950	1.250	Mean	0.866	1.119	Mean	0.644	0.881
Variance	0.314	0.375	Variance	0.601	0.489	Variance	0.848	0.489
Observations	15	14	Observations	15	14	Observations	15	14
df	27		df	27		df	27	
t Stat	-1.377		t Stat	-0.919		t Stat	-0.777	
P(T<=t) two-tail	0.180		P(T<=t) two-tail	0.366		P(T<=t) two-tail	0.444	
Kruskal-Wallis: Enjoyability, Upper vs. Underclassmen								
Module A- Enjoyability			**Module B- Enjoyability**			**Module C- Enjoyability**		
	Upper	*Under*		*Upper*	*Under*		*Upper*	*Under*
Median	3	4	Median	5	5	Median	3	4
Total N	29		Total N	28		Total N	28	
Test Statistic	1.339		Test Statistic	2.706		Test Statistic	1.461	
df	1		df	1		df	1	
Asymptotic Sig.	0.247		Asymptotic Sig.	0.1		Asymptotic Sig.	0.227	
Module D- Enjoyability			**Module E- Enjoyability**			**Module F- Enjoyability**		
	Upper	*Under*		*Upper*	*Under*		*Upper*	*Under*
Median	4	4	Median	4	4.5	Median	4	5
Total N	29		Total N	29		Total N	29	
Test Statistic	0.005		Test Statistic	0.055		Test Statistic	0.844	
df	1		df	1		df	1	
Asymptotic Sig.	0.944		Asymptotic Sig.	0.814		Asymptotic Sig.	0.358	