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Near Transfer After Direct Instruction: An Experimental Inquiry within Aviation Technician Training

Francis Eamonn Powers
Old Dominion University, eamonnpowers@gmail.com

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NEAR TRANSFER AFTER DIRECT INSTRUCTION: AN EXPERIMENTAL INQUIRY WITHIN AVIATION TECHNICIAN TRAINING

By

Francis Eamonn Powers
B.S. May 2007, Florida Institute of Technology
M.B.A. May 2018, University of North Dakota

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Approved by:

John Baaki (Director)

Helen Crompton (Member)

Noah Glaser (Member)

ABSTRACT

NEAR TRANSFER AFTER DIRECT INSTRUCTION: AN EXPERIMENTAL INQUIRY WITHIN AVIATION TECHNICIAN TRAINING

Francis Eamonn Powers
Old Dominion University, 2023
Director: Dr. John Baaki

This study put forth two instructional interventions set within a direct instruction (DI) framework specific to an aviation maintenance context. To evaluate the effectiveness of these two training interventions a criterion was established to measure near transfer during a performance evaluation on a live aircraft. Information learned within this study indicates that DI can be highly effective in technical training environments. This study also articulates how VR experiences may be included within these types of training contexts and discusses the factors and affordances that come with utilizing VR in instructional activities.

Additionally, this study revealed experiential characteristics of a DI training experience from the learner perspective. Most notable among them was how much emphasis learners placed on the Present phase of the direct instruction framework, oftentimes discussing the quality, usefulness, and preference of the study's training videos comparative to other forms of instructional media, including even the study's VR experience itself.

Finally, this study leveraged a novel research design for both the instructional context and the study's unit of measurement in near transfer. This study exemplifies how within-subject repeated measure design may be an ideal framework for researchers looking to address long-standing critiques of experimental research within the field of instructional design.

In all things, there are three paths.

I dedicate this work to my family, the whole of it, the wide crisscrossing web of members chosen, and members born. I dedicated it to my wife, my children, and my children’s children; may they always know the secret power of words. And finally, I dedicate this work to the Irish, the people to whom the ideals of my own existence were inextricably forged through generations of creativity, pain, and above all love. *Tiocfaidh ár lá!*

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Time is, of course, our most precious resource. It is a thing of fleeting reality passed along in both the terrific and the mundane. As such, in this vast and complicated work that I have endeavored upon, I have used much time. Time of both myself, and time of many others to which that debt should be duly acknowledged.

First, I wish to acknowledge my wife Shannon who dutifully dealt with this never-ending hobby of mine. So too do I wish to acknowledge my children: Piper, Maximus, and Saoirse, the last of which was born during my doctoral studies. I specifically would like to thank both my wife and children for being the well spring of my focus, my self-declared reason for pushing the load into the long night with a smile on my face and memories of a warm hearth.

Next, I would like to acknowledge my parents. My mother, Madonna, a woman of unquestionable resolve and wisdom, and my late father Fran, a man who knew the true harmony of the wind's songs. These two tremendously beautiful individuals literally made me, they brought me up with care, and provided me every opportunity to succeed and fail. I could never possibly acknowledge them enough.

I'd like to acknowledge my brother, Rory. We have in truth been estranged for some time, likely the byproduct of my own myopic endeavors of family and self. Perhaps with this work set behind me, I will take up the work I know necessary to learn to be a better brother in now our middle years.

With my blood and kin, appropriately recognized I wish to turn my acknowledgements to those who helped me throughout this work and the work which led up to its completion.

As is fitting, I first wish to acknowledge Dr. John Baaki, my advisor and chair of my committee. I have liked him from the first day we spoke. He speaks with passion, with humility, and with the sound of knowledge truly earned. I appreciate his guidance, I appreciate his effort, and perhaps most importantly I appreciate his patience.

I'd also like to acknowledge Dr. Robert Moore, who was my first true advisor at Old Dominion. He helped me understand the game that is academia, the dance that is this way of life, and the position from which to take a stand. Without him, it is entirely possible I would not be writing this today.

I'd like to acknowledge the friendship and scholarship of my peers, Jeremy McLaughlin and Heidi Kirby. I have spent many hours with these gorgeous specimens of humanity, they are both incredibly honest, incredibly caring, and incredibly talented. I feel truly blessed to know them and honored that they chose to ally with me on the various wins and follies of this self-righteous pursuit.

In friendship, there is no group equal to the collective steadfast meanderings of my greatest companions. I wish to acknowledge; Matthew Reffett, Kristin Parker, Matthew Corriell, and Dr. Kurt Stein. We have walked through the rains of misery, we have run through the last golden rays of sunlight, and we have laughed with the deep breaths of people who have touched true happiness.

In the workings of this project (and many others) I wish to acknowledge the brilliance of Clarke Dale, a longtime friend and colleague who burns bright with the red flame of artistry and the blue flame of virtue. So to, I wish to acknowledge Adam Rush, who was completely essential to the very reality of this work's existence. He is an unabashedly good man, to which the world knows too few. Clarke and Adam provided much and in some cases all the effort to bring forth this study's training materials. There is no amount of time I could spend to thank them enough.

In that regard, I would also like to acknowledge the esteemed efforts of Eric Larson, one of the most humbly brilliant people I know. He is the man that made our virtual world look, act, and feel. I also wish to acknowledge Trey Dunlap, Peter Martinez, and Derek Burns, who worked alongside Adam and Eric to make my whiteboard and pen drawn meanderings into a very real virtual thing.

Finally, but in no way least among my acknowledgements I wish to acknowledge Travis Billet and Christopher Piccone who took a chance on making my project a reality. They could have easily just ignored a meeting request, or said they were too busy (which they undoubtedly were) or come up with any other of the 10,000 reasons not to help a guy from another school perform his PhD study. But they didn't, they put forth effort for no other reason than to help me, and for that I will forever be grateful and humbled.

Sincerely, thank you all.

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CHAPTER I – INTRODUCTION

Introduction

Boeing has forecasted the need for close to 800,000 new aircraft technicians globally over the next 20 years (Boeing, 2020). This number is corroborated by the US Bureau of Labor Statistics projecting a higher-than-average growth in employment demands for aircraft mechanics and technicians between 2019-2029 (Bureau of Labor Statistics, 2021). Both statistics account their numbers largely to attrition rates throughout the current industry setting with neither including the potential increased demand for aircraft technicians necessary to maintain emerging aircraft types like autonomous urban air mobility and electronic vertical takeoff vehicles, itself a burgeoning market segment. Paradoxically, while these statistics clearly show a growing demand for aircraft technicians, other industry indicators show that training new technicians is occurring at a disturbingly low rate (Ley & Organ, 2020). Corroborating these findings, the industry trade group Aviation Technician Education Council, posits that if enrollments within technician schools do not markedly improve the US will fall 12,000 mechanics short of meeting projected commercial aviation needs in 2041 (Aviation Technician Education Council, 2021).

There are 170 Federal Aviation Administration (FAA) Part 147 aircraft technician schools throughout the country. These schools are quite often associated with colleges and universities or for-profit training organizations (FAA, 2022a). The length of time required to become a certificated aircraft technician is considerable, requiring an 1800-hour long largely instructor-led training curriculum (FAA, 2022b) which closely follows the tasks outlined within the FAA’s Airman Certification Standards (ACS). This training curriculum currently requires the use of expensive tool sets, including actual aircraft components and increasingly complex consumable materials like carbon fiber and titanium (Hannon, 2007).

These two factors, the length of time to train coupled with the high cost of training materials, create a systemic challenge for the aircraft technician training landscape at large, which subsequently results in low class numbers, high course costs, and a learner makeup that does not reflect that of American society (Alba, 2020).

Aircraft Technician Training Programs

Research within Part 147 schools, and the aircraft maintenance industry at large is extremely limited, but by including elements of the regulation, industry findings, and training program curriculums we are left with a clearer picture of the challenges these schools face today.

FAA approved aircraft technician training programs must align with the regulatory guidance put forth for their certification found in the code of federal regulations Part 147 (FAA, 2022c). That guidance creates an overall framework for each individual school to build out an acceptable training curriculum from a regulatory standpoint. As such, there is significant parity between differing Part 147 schools in terms of curriculum and lesson content in that the approving authority is actively perusing standardized training practices across the industry (Rardon, 1985). As such, many programs feature the same or at least very similar overall training unit structuring.

The methodology for training aircraft technicians has gone largely unchanged since the early 1970’s when the FAA carried out a study of the aviation maintenance occupation. This study set out to address that generation’s aircraft technician shortages and issued in a new curriculum for FAA Part 147 Schools (Allen, 1970). Since then, the Part 147 Curriculum requirements have gone largely unchanged creating challenges for schools seeking out better training methodologies and practices (Hannon, 2007; *National Training Aircraft Symposium Conference Topics*, 2022).

In a typical curriculum training unit, there exist three distinct components. The first is a theoretical portion where learners participate in a typical classroom setting (Embry Riddle University, 2022; Miramar College, 2009). Within the theoretical portion of the individual lesson module, the instructor generally provides a 1-to-2-hour lecture, specific to the individual aircraft or engine subcomponent (Embry Riddle University, 2022; Miramar College, 2009). The content is generally standardized into the following flow: material is initially presented at a general level and then progresses to be more operationally minded, taking the learner through technical operational considerations. Typically, this involves instructor-led discussion pertaining to when and how individual aircraft or engine subcomponent affect other subcomponents, the specific controls and indications a technician can expect to see upon operation, and considerations for when control characteristics indicate optimal or suboptimal performance. These lecture/discussion style interventions are often assisted by various multi-media elements including PowerPoint slide presentations, photographs, engine manufacturer publications, video, and whiteboard drawings.

Sometime after the theoretical lesson content, the learners then participate in a lab exercise within the maintenance shop (Hammer, 2019). In the lab exercise, learners are brought to a physical system mockup known as a part task trainer or PTT. The PTT acts as a means for the learners to individually practice elements of the practical training tasks relevant to the theoretical portion of the individual unit of instruction. During this session participants are generally put into groups (Embry Riddle University, 2022; Miramar College, 2009). These groups will work and observe others working on the PTT with general guidance provided by the instructor on who should be doing the primary work and for how long. Research specific to 147 Schools has indicated the class size and timing of these lessons have a considerable impact on training effectiveness, with a preferences towards smaller class size and adequate time for individual participants to practice on the PTT device (Hammer, 2019).

Following the work on the PTT, learners are then evaluated against regulatory approved Airmen Certification Standards (ACS). This is done by an instructor via a module specific instructor grading sheet known to the FAA and other aviation regulators as the Practical Task Assessment Log (PTAL). Where available programs occasionally use a ‘live aircraft’ trainer, where an aircraft or engine is presented in a real-world context (Hammer, 2019; Rardon, 1985), rather than a PTT. The specific scoring of the evaluation element of these tasks has been a subject of research. Berentsen (2005) outlined how performance goals might be well suited to fit within a typical rubric structure used throughout educational contexts. However, the researcher notes that considerable challenge within the field to this practice as program instructors are not always proficient in designing appropriate performance evaluation levels.

The overall process described above is then repeated several times for each aircraft component subcategory, categories like sheet metal, composites, and hydraulics. Ultimately the ACS requirements list 40 topics in total (FAA, 2022b). These 40 topics make up the basis of all approved aircraft technician training programs throughout the United States and represent what is to be covered within the 1800-hour minimum requirements set forth by regulation.

While there is little to be done about the hour requirements set forth by the FAA, that represents only one half of the systematic challenge facing the industry. The other is the tremendous cost of training materials for these practical task items (Dyen, 2017). Take for instance the training of turbine engine air systems, a required element every Part 147 school must provide within their curriculum per the regulation. Several tasks defined within the ACS for this training topic explicitly require a functioning representation of a turbine aircraft engine. Because the cost of materials such as these are so high, there is a cascading effect which impacts not just a school's financial capabilities but also even the instructional experience (Hammer, 2019). As previously described, sometime after a unit of instruction's theoretical lesson students participate in lab exercises within the maintenance shop. Due in part to the scarcity of certain resources, such as a turbine engine or PTTs, the students may not have access to the engine for days if not weeks following the theoretical portion of the unit and when they do eventually gain access they are often asked to work as a collective group to complete the exercise (Hammer, 2019).

The Instructional Design Opportunity

These practices are apparent to observers within the industry, yet they do not represent a practice which has been specifically mandated by regulation (Rardon, 1985; Williams & Rhoades, 2006). Unlike the strict adherence to the time-based requirements, the instructional guidance is left to the interpretation of the industry in collaboration with regulators. The FAA will work with Part 147 schools and industry partners to establish acceptable means of instruction on a case-by-case basis based off the stated ACS task requirements (Rardon, 1985). As in, there are no specific requirements set forth by the regulators on how a school must carry out an established curriculum via their instructional methods and materials.

This includes perhaps even somewhat glaring omissions like specific tooling requirements or even the use of actual aircraft components. Meaning, for example, it is possible that regulators could technically approved a Turbine Engine Training course, without the use of an actual aircraft engine. To do so the training provider would have to provide evidence to the assigned regulatory inspector that the ASC task requirement could be trained and evaluated effectively, consistently and with reasonable assurance the learned task could be transferred into a real-world setting (FAA, 2022c). This possibility has tremendous potential for not only addressing the cost of materials issue within the industry, but also potentially improving the overall instructional experience for a new generation of aircraft technicians.

In its current state, the industry essentially requires the use of these expensive part task trainers due to lack of other acceptable option (Alba, 2020; Dyen, 2017; Vaitiekunaite, 2020). These trainers perpetuate instructional practices which take away from a student’s individual path to discovery, robs them of the opportunity to practice, and limits the available time a student has to develop their skills at their own pace, all of which are hallmark elements of a modern understanding of instructional design and training development. I believe these various factors culminate into an opportunity which is largely a matter of instructional design. Morrison et al., describe that, “the goal of instructional design is to make learning more efficient, more effective, and less difficult.” (Morrison et al., 2019, p. 2). They go on to say that it is the instructional designer’s purpose to improve human performance and solve instructional problems. It would appear, the aviation technician training industry has such a problem to be solved and it is the intention of this work to provide evidence to help do so.

To address this problem, I first considered the current instructional approach which has been outlined above. To do so I utilized curriculum documents from two fully accredited FAA approved Part 147 programs (Embry Riddle University, 2022; Miramar College, 2009). In the current paradigm, students first participate in a classroom style lecture or multimedia presentation which introduces and establishes the base line contextual and procedural knowledge necessary to carry out the lab activity within the shop. Sometime after this introductory step, students then go through a hands-on activity on the PTT, generally in a group, where they practice and perform the tasks discussed within the introductory training module while also observing the practice and performance of their peers.

From an instructional standpoint, this type of learning activity fits within the instructional framework of Direct Instruction (DI). Joyce et al. (Joyce et al., 2003) specify that DI frameworks include: framing learner performance into goals; breaking these various goals into smaller component tasks; designing training activities to master these tasks, and then arranging the learning events into a sequence which promotes transfer. Gagné identified that DI model works well in situations where motor skills and hands-on activities are involved (Gagné et al., 2005; Reiser & Gagné, 1983) and DI has been a strategy of choice when learning objectives require direct practice in what must be done, or said, or written (Cazden & Cordeiro, 1992). Often the sequence of events which occur in a training experience designed within the DI framework will be referred to in simple terms like Present, Practice, and Perform.

Figure 1

Current State Instructional Sequence

Present	***Practice***	***Perform***
Lecture and multimedia presentation	Hands-on work within the shop environment using the PTT	Hands-on performance evaluation using the PPT

Using the DI framework to break up the current state instructional experience (Figure 1), we can see the challenge is not in addressing the totality of the instructional experience, but just addressing the elements which require the use of the costly and instructionally limiting equipment and toolsets; the Practice and Perform phases.

How then may an instructional designer develop hands-on training experiences without hands-on tools and equipment? One option which has become increasingly popular in hands-on contexts in recent years is the use of virtual reality (Ismail & Groccia, 2018).

Virtual Reality

Virtual Reality (VR) commonly refers to the use of computer-generated real-time representations of real or fictional environments that utilize three-dimensional objects and symbols (Moreno & Mayer, 2001). VR is generally expected to be highly interactive and routinely leverages some type of physical or graphical human to computer interface (i.e., touch screens, mouse and keyboard, game controller etc. (Berg & Steinsbekk, 2020)). Additionally, VR's use of Head Mounted Displays (HMDs) and similar devices are often implemented to allow users to fully "immerse" themselves within virtualized environments (Freina & Ott, 2015).

VR has been used to simulate situations that would be excessively dangerous or expensive under physically real conditions and has been found to make training possible without the need for real machines or equipment to be physically present (Pletz & Zinn, 2020). This last element is an especially relevant point for the stated problems above as often aviation technician training providers are required to cover a litany of tasks requiring the specific use of unique aircraft components which are often quite expensive, challenging to gain access to, or perhaps even dangerous to work with.

There do, however, exist several challenges holding VR back from addressing the needs within this industry. Firstly, VR training experiences vary widely, ranging from highly realistic representations of virtual worlds with high levels of interactive content, to abstract conceptual experiences which may or may not include any interaction, with a multitude of options in between based off specific hardware, software, and experiential considerations and affordances (Wu et al., 2020). Secondly, at the current time, there exists an overall lack of consensus in the effectiveness of VR as a training tool (Bower & Jong, 2020) and very few studies have been accomplished which attempt to ascertain how skills learned during VR training exercises transfer to real world skill application within an aerospace context (Rupasinghe et al., 2011).

VR and Maintenance Training

Aviation training at large has been a long-time user of immersive forms of media like VR, especially in the training of pilots. Full-motion Flight Simulators (FFS) have been utilized since the 1960's to assist pilots in improving instrument proficiency (the ability to fly an aircraft without the use of the external horizon), achieve advanced pilot ratings, and receive aircraft specific type training (Hays et al., 1992; Martinussen & Hunter, 2017). Nearly all FFSs utilize advanced simulation to recreate the aircraft's various systems and avionics while coupled with real-world aerodynamic flight models (FAA, 1991). Additionally, FFS are required to utilize advanced wrap-around displays featuring highly detailed visual graphics to represent the outside world in and around airports (FAA, 1991). These elements allow pilots to operate at a level of fidelity that so closely mimics the real-world that nearly every aviation regulatory authority on the planet has accepted FFS training in lieu of in-aircraft flight training for passenger cabin and large body aircraft (i.e., Airbus A-320, Boeing 747), rotorcraft, and other aircraft types.

These exploits are only possible due to the tremendous focus of industry and researchers during the 1980's to address the specific training task needs and required simulation fidelity levels necessary for pilot training, which ultimately paved the way for modern pilot training's heightened use FFS (Casner et al., 2013; Homan & Williams, 2019). No such effort has as of yet been taken on behalf of the aircraft technician, and as such, the FAA have yet to provide guidance on to what parameters and methods these various offerings would need to employ to be satisfactorily comparative to the current ‘on-aircraft’ training tasks. This study endeavors to help directly address this challenge.

An important element of note relative to this study is that the FFS use mentioned above does not constitute the only element of a regulatory approved pilot training program. Rather the FFS is an instructional element utilized at a specific point during pilot training, sequenced in a way to ensure performance will transfer to real world contexts. This is quite similar to the paradigm we face within the already described instructional opportunity. In much the same way, the VR experience described within this study does not stand alone, but rather represents an appropriate component of an overall instructional experience. As such, I have made adjustments to the existing DI framework to set the VR intervention up to stand as a potential appropriate alternative during the Practice and Performance phase (Figure 2).

Figure 2

First Iteration of DI Instructional Sequence with the PTT or VR

	Present	***Practice***	***Perform***
With PTT	Lecture and multimedia presentation	Hands-on work within the shop environment using the PTT	Hands-on performance evaluation using the PPT
With VR	Lecture and multimedia presentation	Hands-on work within a virtualized environment using VR	Hands-on performance evaluation using the PPT

Industry groups and professional training providers appear motivated to push forward with VR as a suitable tool for aviation maintenance training (W. C. Wu & Vu, 2022) without the presence of instructional research found within the field. At the writing of this work, scholarly work within the Part 147 context and connected to an instructional framework was extremely limited. Rupasinghe et al. (2011) is one such work. Within it, the researchers' goals were similar to this study's own, in that they sought to reduce the gap between high-end technology requirement in the hangar (work environment) and the classroom. They leveraged Bloom's taxonomy (Bloom & Krathwohl, 2020) to design and develop two VR technology-based simulators to address two specific ASC tasks. Their study found the interventions to be successful, in that participants across experimental training interventions scored similarly in cognitive pre and post-tests. While these results are of considerable interest for the purpose of this study, it should be noted that there exist several limitations identified both within the work and upon its review.

For one, the Rupasinghe's developed VR implementation did not include an HMD, instead featuring a conventional desktop display to interact within the simulated environment. While this still a viable approach, it does not necessarily represent the current state of VR technology available to schools. Next the study employed a typical experimental design, with three groups each receiving different instructional interventions followed by a cognitive post-test. Within the field of instructional design this type of experimental inquiry would likely not meet the expectations of the academic community in light of the critiques put forth against media comparison studies (R. B. Kozma, 1994). Finally, this study calls for a more comprehensive analysis into VR's training effectiveness with specific interest in "training transfer studies." (Rupasinghe et al., 2011, p. 12).

Training Effectiveness

For any new training methodology to be accepted as a potential element for regulatory approved training, researchers and industry partners will undoubtedly be tasked with validating the effectiveness of its inclusion per specific training tasks. While this study serves as one of the few inquiries into VR training effectiveness for aviation contexts, there do exist several examples of work put forth in other vocational fields which may shed light on potential pathways for Part 147 schools to leverage.

While there are a multitude of ways to measure training effectiveness, this study's focus rests in the concept of training transfer. Within vocational training, current research suggests that hands-on experience is still seen as the gold standard of training, accounting for close to 80% of learned content which is applicable for a given set of job tasks (Lee et al., 2019; Marsick, 2009;

Yoon et al., 2018). This has also been found to be the case within aviation maintenance specific contexts (Walter, 2000). Training experiences which feature hands-on engaged activities provide students opportunities to practice and apply their understanding under real-life or simulated environments and have been shown to result in easier and longer-lasting retention of information (Ismail & Groccia, 2018). These findings are corroborated by Makransky and Lilleholt (2018) who specifically discuss industry's consistent needs for highly skilled employees who possess acquired skillsets best acquired through intensive repeated practice, training, and hands-on practical experience, all of which are time-consuming and expensive, much like the problem which faces the aviation industry today. What this ultimately leads up to is a question of how to ensure VR's effectiveness in transferring hands-on skills into real life contexts.

One consistently identified element of interest within the study of VR has been the investigation and discovery of how such experiences may lead to better transfer of learned skills to real scenarios and conditions (Renganayagalu et al., 2021). Transfer as a concept has been defined several ways over the years. Nokes (2009) defines transfer as the process in which knowledge acquired from one task or situation can later be applied to a different one. The ability to transfer knowledge from training experiences into real world applications is inherently a central tenent of instructional design and education in general. Appropriately, the study of transfer has been of interest to researchers for more than a century with Thorndike and Woodworth (1901) coining the term *transfer effect* as a representative measurement of magnitude in the comparison of functions trained comparative to identical functions tested.

In a more contemporary example, Dohn et al., (2020) mention the explicit need to align functional training tasks with real-world situations, going on to discuss how practitioners may accomplish desired levels of transfer through the use of high-fidelity interventions. This viewpoint of transfer has proven to be of particular interest to those designing instructional interventions with specific performance goals, as is often the case in vocational education and training (Cornford, 2002; Kilbrink et al., 2018). I have highlighted this particular conceptual take on transfer because I feel it uniquely represents the goals of the aviation maintenance training industry. Even in its current state, the PTTs used ubiquitously across schools are functionally built to replicate real-world situations in closely aligned training tasks aimed at promoting transfer.

For this study, I highlight a specific definition of transfer known as near transfer. Near transfer has been described as the application of learned skills and knowledge from a dedicated training experience to an almost identical real-world situation (Barnett & Ceci, 2002; Blume et al., 2010; Bossard et al., 2008). Pletz and Zinn (2020), whose study provides much of the methodological underpinning of this study, highlight how near transfer is an appropriate means to evaluate a designed immersive VR training experience relative to the learned actions applied to a near to identical situation based in reality.

To evaluate the effectiveness of the VR training intervention Pletz & Zinn observed the physical performance of training participants within a real world setting after having gone through the training. As part of this evaluation process, they utilized a criterion which was accepted within their specific vocational context.

Inspired by this approach, I made an adjustment to the Perform element within the overall training intervention (Figure 3). By placing an actual aircraft component into the Perform step, we effectively create a situation where real-life application of the learned skill can be evaluated based off of the existing industry verified performance criteria.

Figure 3

Second Iteration of DI Instructional Sequence with the PTT or VR

	Present	***Practice***	***Perform (Near Transfer Evaluation)***
With PTT	Lecture and multimedia presentation	Hands-on work within the shop environment using the PTT	Hands-on performance evaluation using actual aircraft
With VR	Lecture and multimedia presentation	Hands-on work within a virtualized environment using VR	Hands-on performance evaluation using actual aircraft

Designing the Interventions

Armed with a framework to evaluate two differing training interventions I set out to build the training materials necessary to carry out the various elements of the study's overall design.

First off, the tasks featured within this study include two different maintenance tasks on the Pratt and Whitney PT-6 Turboprop engine. The PT-6 is a common engine found within general aviation and contextually relevant to the study's participants and capable of meeting several of the curriculum requirements set forth in the ASC. The tasks discussed throughout this work include an Oil Filter removal and replacement and an ignition lead test.

Within the context of this study, I adjusted the initial *Present* portion of the training experience from the typical instructor-led lecture format to a standardized web-based eLearning approach for each of the tasks featured within the study. Within this eLearning session, learners were presented information via interactive video content. This content showed the procedural elements required to correctly perform the two maintenance tasks and prompted the participants to interact in basic, module specific, knowledge check activities.

Next came the *Practice* step. A VR training intervention was purpose built for one of the two tasks featured within this study while the other task used a conventional PTT. The design choices included within this VR instructional design process are central to this study’s purpose and are subsequently described extensively later in this work.

Finally, so as to measure near transfer in a real-world context, the *Perform* phase activities were conducted on a functional live engine and evaluated upon via an existing, specific, industry and regulatory accepted, performance criterion. Thus, when compared to the current state training experience in Figure 1, we see that Figure 4 represents two new fully formed instructional experiences set to be evaluated for the first time.

Figure 4

Final Iteration of DI Instructional Sequence with the PTT or VR

	Present	***Practice***	***Perform (Near Transfer Evaluation)***
With PTT	eLearning interactive video content	Hands-on work within the shop environment using the PTT	Hands-on performance evaluation using actual aircraft
With VR	eLearning interactive video content	Hands-on work within a virtualized environment using VR	Hands-on performance evaluation using actual aircraft

Study Overview

The study took place at an aerospace specific university setting located in the southeastern United States. Participants were enrollees of an Aircraft Maintenance Science undergraduate degree who had not taken the course Turbine Transition. The reason for this exclusion was that the two tasks covered within this study’s design are also covered within that course.

The study itself largely follows along with previous work put forth evaluating the effectiveness of immersive media experiences in training contexts (Klingenberg et al., 2020; Meyer et al., 2019; Pletz & Zinn, 2020). Uniquely, this study utilizes a within-subject repeated measure design (Creswell & Creswell, 2017; Farra et al., 2018).

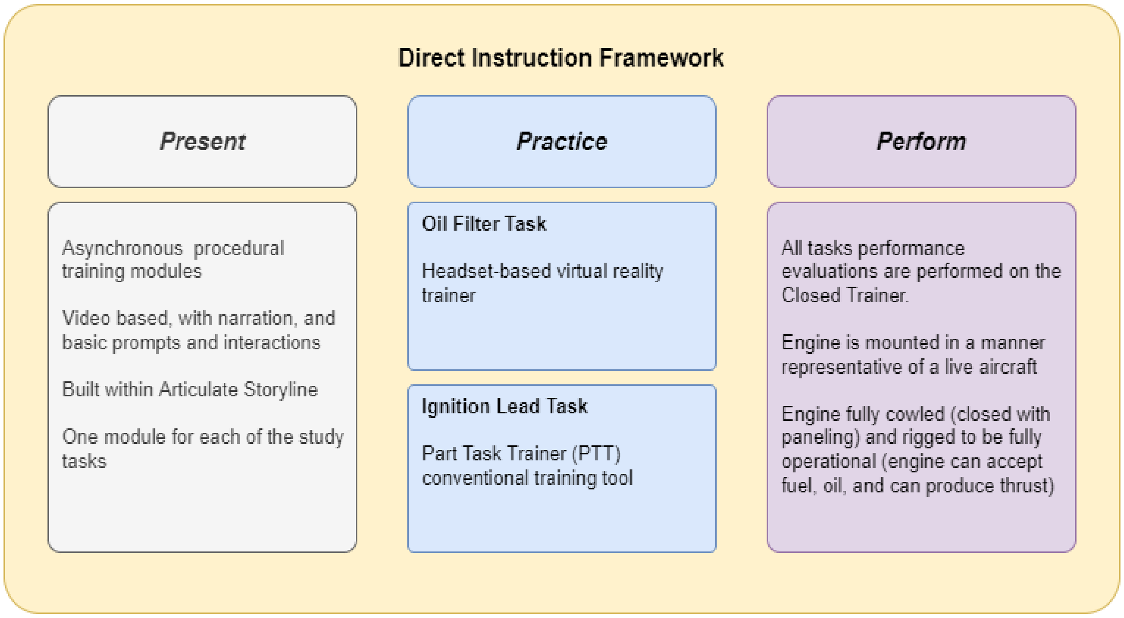
Central to the within-subject repeated measure research methodology, each participant went through each of the instructional experiences, providing the means for the students themselves to serve as their own control variable (Verma, 2016). Thus, the only designed differences between the two instructional experiences occurs during the Practice phase.

At the conclusion of these practice training events each participant participated in a performance evaluation on a live aircraft engine graded by a program instructor. The participants' performance was assessed based upon performance criteria set forth by both existing regulatory authority specifications and certification standards. This assessment led to a nominal value known as Performance Score (PS)

At the completion of this exercise the participants were then asked to take a short questionnaire centered around technological preference and instructional preferences. This was followed by a short follow up one-on-one open-ended interview protocol leveraged to gain context to participant survey responses and ascertain any reflections made during the study's training experiences.

Figure 5

High-level breakdown of study's DI interventions



Asynchronous procedural training modules

Video based, with narration, and basic prompts and interactions

Built within Articulate Storyline

One module for each of the study tasks

Headset-based virtual reality trainer

Part Task Trainer (PTT) conventional training tool

All tasks performance evaluations are performed on the Closed Trainer.

Engine is mounted in a manner representative of a live aircraft

Engine fully cowled (closed with paneling) and rigged to be fully operational (engine can accept fuel, oil, and can produce thrust)

Purpose of Study

The purpose of this study was multifaceted. At the highest most abstract level, this study set out to find a way to address the industry's technician shortage problem (Aviation Technician Education Council, 2021; Boeing, 2020). One way identified by the industry at large (Alba, 2020; Vaitiekunaite, 2020) is to increase the volume and speed of technicians participating in and graduating from Part 147 schools. Unfortunately, 147 Schools are challenged by antiquated training methods and costly training materials and are thus currently ill-suited to address the industries growing demands (Hannon, 2007). As such, research into the improvement of instructional practices and methods seems warranted.

The primary purpose of this study is to determine how well an aircraft technician performs in a series of real-world tasks after two DI training experiences. These training experiences were designed in a way which directly address some of the systematic challenges which exist within the Part 147 landscape. Specifically, each of these experiences feature a unique instructional element during the Practice phase.

This study set out to evaluate the effectiveness of these two training interventions by quantifying the level of near transfer into a real-world task. By doing so this study addresses several long-standing calls from across the literature to identify and leverage new forms of empirical research to evaluate transfer of training (Broad, 1992; Schoeb et al., 2021).

Secondarily, within the literature there exists considerable interest in finding better ways to better evaluate training effectiveness of VR interventions (Bower & Jong, 2020; Pletz & Zinn, 2020). As this study includes a VR element within its instructional design it stands to reason that the evaluation of transfer as put forth by this study's methodology may also be appropriate in determining the effectiveness of VR training interventions.

Finally, much has been said in the literature regarding the perception of new training methodologies and how those perceptions effect training effectiveness (Makransky, Wismer, et al., 2019; B. Wu et al., 2020) and training transfer (Arasanmi & Ojo, 2021; Nietfeld, 2020a; Sakkal & Martin, 2019). Because of the relatively unexplored context of Part 147 programs, this study set out to understand how technicians perceive this study's instructional methodology and training interventions relative to both their previous experiences as well as future professional expectations.

Research Questions

To align with this study's purpose statement, two research questions were devised. First to quantitatively evaluate the effectiveness of the study's two parallel training interventions the first research questions centers on specific performance as measured by near transfer. As such, Research Question 1 directly asks how aircraft technicians perform on near transfer tasks after each of the study's DI experiences?

Secondly, as the two DI experiences designed for this study represent a departure from the current Part 147 training it seemed critical to investigate the factors and experiences participants brought to and took away from the study's designed instructional intervention. Thus, study's Research question 2 investigates the perceptions, preferences, and expectations of the study's participants relative to the study's overall instructional experiences.

In summary, this study's research questions are as follows:

RQ 1 - How do aircraft technicians perform on near transfer tasks after each of the study's DI experiences?

RQ 2 – What perceptions, preferences, and expectations do participants bring into and take away from the study's instructional experiences?

CHAPTER II – LITERATURE REVIEW

Introduction

This section has been drafted to show how the study's purpose and subsequent research questions are based within the current literature. First and foremost, this literature review discusses the study's central conceptual and instructional framework, direct instruction. Next, as the study leverages VR in one of its training interventions, a discussion on the specific definition of VR and the documented challenges associated with measuring its effectiveness as a training tool is provided. With DI and VR scoped and defined I then provide a breakdown of this study's key component of measurement, transfer of training which is used in the evaluation of the study's first research question. Next, as this study involves differing forms of instructional media within the Practice phase of the instructional experience, I outline the some of the pitfalls of the much-maligned media comparison study, while outlining how this study's experimental framework falls outside of the trope. Finally, to address the study's second research question, I have provided a review of previous research diving into the perceptions, preferences, and expectations of students experiencing new instructional technologies and practices. These characteristics span across elements which may impact training transfer, like previous experience, technological acceptance, and comfort with VR, among others. Finally, this section concludes with a narrative section outlining how this study will provide unique significance to the field of aviation maintenance training and instructional design.

Direct Instruction

Central to this study's purpose is an evaluation of two differing instructional experiences, each of which fit within the same instructional framework; Direct Instruction (DI). DI uses several elements set within the behavioral underpinning of instructional design. Some of DI's major tenets include scripted lessons, active student response, rapid feedback, self-pacing, student-oriented objectives, and mastery learning (Burton et al., 2004). DI is not a new instructional design concept, it was coined by the behavioral researchers Bereiter and Engelmann in an attempt to discover “the most efficient way to teach each skill” (Engelmann, 1980, p. xi). The researchers built their initial DI framework with the understanding that learners were expected to derive learning in a consistent manner via the presentation of information provided by a teacher or facilitator (Bereiter & Engelmann, 1966). This placed particular emphasis on the teacher’s role in identifying the appropriate interventions to which they might receive the appropriate response from the learner. Rapid questioning, frequent testing, continuous interaction, and positive reinforcement were among the instructional tools utilized to promote learning within the initial trappings of the DI framework.

In order to assist teachers in designing such a framework, Bereiter and Engelmann put forth their first iteration of a DI model. Their model established a three-stage systematic design driven by continuous assessment during any learning event. The three stages included: (a) an introduction to the lesson content, (b) the presentation of said content, and (c) the practice of said content with immediate feedback. Since Bereiter and Engelmann, there have been many iterations of this DI model including Rosenshine’s explicit teaching model (Rosenshine, 1987), Good and Grouws’ Strategies for Effective Training Model (Good & Grouws, 1979), and Hunter’s Design of Effective Lessons Model (Hunter, 1976)Click or tap here to enter text.; all of which, to varying degrees, continue Bereiter and Engelmann’s three primary stages.

Despite the general departure in acceptance of behavioral frameworks within the field and study of instructional design, in favor of cognitive, constructive, and generative paradigms, many DI principles continue to find presence within models routinely used today. There is likely no better example of this than Gagné’s Nine Events of Instruction (Gagné, 1985; McKivigan, 2019), often seen as the preeminent model of instructional design within the field. Gagné’s nine event model maintains much of Bereiter and Engelmann initial work albeit with greater detail, and more emphasis on the needs and interest of the learner with less emphasis placed on the physical demands of the instructional environment (Magliaro et al., 2005).

More recently, DI based concepts have seen somewhat of a resurgence during the advent of computer-based instruction where demands for data driven performance-based objectives remain prevalent. Set within the context of the modern age of instructional design, Joyce et al., (2003) specify how DI’s instructional design principles can be used in self-guided computer based learning. Insights into this approach include the framing of learner performance into specific goals and/or tasks with emphasis on breaking those tasks into smaller more modularized component tasks for which specific performance measures can be more properly considered. In doing so, it becomes clearer for instructional designers to not only derive where feedback and assessment may be appropriate, but also provide a framework towards critical practice elements found to lead to mastery of a given skill or task. Ultimately, the sequencing of these collective components are then designed into specific learning events with the intention to promote transfer. The researchers go on to state, within the specific context of computer-based learning environments, that while DI is not necessarily the prominent instructional framework it once was, it is still the strategy of choice when a series of learning objectives require direct practice in what must be done, or said, or written.

DI principles are also being closely applied to instructional environments and circumstances which feature high levels of guided interaction. In a recent work put forth by Rolf and Slocum (2021) they highlight how DI in its current iteration includes a broad and complex series of systems and concepts aimed to assist in maximizing learning potential. These systems include instructional formats that specify the interactions between teacher and student, flexible skills-based groupings, active student responding, responsive interactions between students and teachers, ongoing data-based decision making, and mastery teaching. In several of these systems we again see a need to adhere to certain controls within the learning environment, the clear presentation of information to the learner, an emphasis on data-driven immediate feedback, and ultimately a clear pathway to task or skill mastery.

There are considerable factors which suggest DI as appropriate for instructional experiences set within specific contexts. One of these contexts, and the reason for DI's use within this study, is that of vocational training. Gagné himself identified that the DI model works well in situations where motor skills are specifically involved (Gagné, 1985) and DI has been a strategy of choice when specific learning objectives require learners having direct practice in what must be done, or said, or written (Cazden & Cordeiro, 1992). Gunter et al., (1990) specifically reference automotive tasks like carburetor overhaul, in their work describing appropriate uses of DI in practice.

As has been discussed there are many iterations of the DI framework, for the purposes of this study I have chosen to utilize DI's basic architecture as described by Magliaro et al. (2005). These steps include presentation, practice, and performance. These basic steps appear in every available DI framework with various details and expansion to accommodate different learning contexts. As such each time the terms Present, Practice, and Perform are used to delineate training phases within the instructional experience, it should be assumed that these are meant to directly indicate the aforementioned phases of the DI model.

Virtual Reality

Definition

This study features the use of Virtual Reality (VR) in one its two training interventions. In investigating the terminology necessary for this work, I found that VR appears as somewhat of a catchall term, representing a broad number of technologies and experiences. These experiences range from personal computer based simulations (Coxon et al., 2016) to room scale projected activities (Halabi et al., 2017) among others. This poses a challenge to researchers hoping to leverage VR as it is possible the use of differing elements and methods can potentially affect the instructional experience (Mayer, 2021). As such, this study has identified a number of elements which appear to have broad consensus in the literature's definition of VR and are thus featured prominently within this study's work.

One element that nearly every VR intervention includes is the use of three-dimensional renderings (3D). Almousa et al. (2019) define VR technology as providing a multisensory three-dimensional (3D) environment which enables participants to immerse themselves in a simulated world. This simple definition is ubiquitously used throughout much of the literature identifying virtual reality as a means to immerse the learner within a synthetic environment or world. Sometimes this 3D element is explained more technically, featuring descriptions of the physical means in which the synthetic environment is rendered. Lanier et al. (2019) specifically define VR as a digital technology which utilizes stereoscopic displays to create three-dimensional content.

The second element where there appears to be broad consensus is in the explicit need for interaction. Lanier et al.'s (2019) contends that VR is inherently interactive, this is corroborated by Bun et al. (2017) who indicate VR experiences enable users to interact in real time with elements of an artificially rendered three-dimensional world. Freina et al. (2017) extend these two concepts further by defining the artificial 3D environment provided by VR, as a multi-sensory experience making it possible to interact in a natural manner using electronic tools. This is echoed by Parong and Mayer (2020) who go so far as to add the descriptive term ‘immersive’ to their definition of immersive virtual reality (IVR), identifying IVR as a technology which allows participants to experience and interact with both physical and/or behavioral simulations.

The final element which appears in much of the VR literature is the use of a Head Mounted Display (HMD) and handheld controllers. Renganayagalu et al. (2021) define VR as a computer-generated three-dimensional graphical representation of a real or imaginary place in which participants are immersed through a headset display, where the rendered environment is augmented using wearable sensors, audio, and controller based haptic feedback.

This concept of a multi-sensory interactive experience is further highlighted by Makransky and Lilleholt (2018) in their description of VR which includes design considerations for a multiple sensorial user interface which leverages real-time simulation and interaction. Along these lines, many researchers make the conceptual jump from simulation and behavioral interactions to reality replication. Schmid Mast et al. (2018) and Hite et al. (2019) position VR as a means to engage learners in hyper-realistic spatial interfaces which are both innately immersive and interactive, including elements beyond the visual and tactile senses aimed to ensure faithful reflection of reality.

For the purposes, VR shall be considered a headset mounted experience in which a completely immersive three-dimensional synthetic environment is represented to various levels of fidelity through a form of headset driven stereographic projection. This environment includes varying levels of human to computer interface aimed at providing a multi-sensory immersive experience.

Effectiveness

In recent years there has been a proliferation of research into the use of VR across contexts, subject matters, and use cases. This has been in large part due to the increased availability of affordable VR applications and hardware (Bower & Jong, 2020).

The accessibility of these new tools has provided opportunities for students to experience VR environments in learning contexts without there necessarily being clear instructional frameworks in place providing guidance for VR's appropriate use in providing instruction (Makransky, Terkildsen, et al., 2019). Largely educators and researchers alike currently lack the evidence base they need to determine the "when," "why" and "how" of using VR for learning and teaching (Bower & Jong, 2020).

As such, there exists a considerable amount of interest within the literature regarding the effectiveness of VR training in educational setting. In a recent work put forth by Wu et al, (2020) the researchers performed a meta-analysis of the extant literature regarding the effectiveness of VR based training interventions. They specifically set out to review studies which featured experimental designs to determine the effect size of VR comparative to non-immersive forms of training. They found that VR was most effective in the fields of science education; specific abilities development; when representing a simulated or virtual world; and when compared to lectures or real-world practices.

Significantly relevant to this study's focus of inquiry is how the studies featured within this meta-analysis specifically measured effectiveness. Assessment via knowledge test score represented most measures of effectiveness (68.6%) with the remainder being assessed via performance-based evaluation of tasks (31.4%). Previous meta-analysis on the topic have found similar breakdowns between knowledge-based or skill-based measures (Merchant et al., 2014; Radianti et al., 2020) Within studies investigating effectiveness via skills or performance based measures there appears to be a somewhat unified understanding that the most ideal measure for testing VR applications is that of retention or transfer effect (B. Wu et al., 2020).

Transfer of Training

Transfer as a concept has been defined in several ways over the years. Nokes (2009) defines transfer as the process in which knowledge acquired from one task or situation can later be applied to a different one. The ability to transfer knowledge from training experiences into real world applications is inherently a central tenet of instructional design and education in general. Appropriately, the study of transfer has been of interest to researchers for more than a century with Thorndike and Woodworth (1901) coining the term *transfer effect* as a representative measurement of magnitude in the comparison of functions trained comparative to functions tested. Bossard et al. (2008) put forth that transfer of training accounts for the retention and application of knowledge, skills and attitudes from the training event to the workplace environment.

While these definitions highlight some of the more behavioral elements of training transfer there do exist approaches which lean more heavily into the cognitivist paradigm. These definitions tend to focus less on the fidelity of representation between physical and task environments, but rather on information processing. Pletz and Zinn (2020) put forth that previous approaches to transfer tend to see mental symbolic representations and cognitive schemata as the basis for transfer but note that from within this paradigm, research surrounding transfer has been inconsistent.

As such a third approach, beyond behavioral and cognitive has been more recently put forth. This approach views transfer from a situated cognitivist perspective. Situated cognition considers the situated nature of learning experiences, emphasizing that individuals learn not necessarily just from the learning content and message design but also from being part of an activity, a context, and even a culture (Brown et al., 1989; Day & Goldstone, 2012; Schott & Marshall, 2018). Greeno (1997) described situated cognition as the acts of knowing, rather than simply knowledge; that knowledge could be specified in accordance with situational demands. In terms of transfer, this posits that knowledge and skill are inextricably tied to the specific context in which they were acquired. This last part is particularly relevant for this study's inquiry of transfer in vocational settings, as vocational workers are often thrust into contexts and situations which differ from initial training exercises and scenarios (Li et al., 2009; Watkins et al., 2013).

Regardless of the theoretical paradigm, the objective measurement of transfer has been elusive for many within the field (Kontoghiorghes, 2014) and calls for better methods for evaluating transfer of training abound throughout the literature (Broad, 1992; Conley et al., 2020; Dohn et al., 2020). These calls are especially prevalent within scholarship surrounding vocational training. Within their work, Kilbrink et al., (2018) identify that little agreement exists amongst researchers regarding the conceptualization and empirical study of transfer of learning. This is echoed by an extensive systematic review put forth by Schoeb et al. (2021) which highlighted 51 studies on the topic within vocational contexts. In one of their findings, the researchers posit a divergence between the definitions of transfer. As an example, there is differentiation between so called far transfer and near transfer. With far transfer being the performance of a task that is seemingly remote from the tasks that were initially trained (Melby-Lervåg et al., 2016); and near transfer being defined as the performance of task which are similarly structured to problems and contexts represented within the learning environment (Nokes-Malach & Mestre, 2013). Aside from various definitions, Schoeb found that while there exist a considerable number of measurement instruments within the field, their lacks evidence surrounding forms of empirical evaluation of transfer. This is noted as a particular problem within the study of transfer as it makes experimental rigor and the generalization of findings more challenging. Schoeb et al. point out the preponderance of participant driven self-reported scales used throughout the literature as evidence and call for better "objective or numerical indicators to measure transfer" (Schoeb et al., 2021, p. 26).

As such, this study puts forth a methodology aimed at answering this call by providing a framework for objectively evaluating the effectiveness of two training experiences via transfer. This study leverages elements of the research design put forth by Pletz & Zinn (2020) in their investigation of near transfer within a vocational context. In their study, the research team evaluated the effectiveness of both a VR training experience and a real machine training experience within a manufacturing setting.

Avoiding the pitfall of media comparison

As described within the introduction section, the context in which this study finds itself is one in which there is a prescient need for new aircraft technicians to meet high industrial demand for qualified personnel (Aviation Technician Education Council, 2021; Boeing, 2020). Among the largest challenges in addressing this need is the length of time necessary and the types of methodologies utilized within the initial training of aircraft technicians within FAA Part 147 schools (Hannon, 2007; *National Training Aircraft Symposium Conference Topics*, 2022). As has been introduced and will subsequently be described in the following sections, this study aims to address this challenge by putting forth two new instructional experiences set within the DI framework.

While the details of this study's experimental inquiry are covered extensively in future chapters of this work, it is important within this chapter to clarify elements of this study's design relative to the broader discourse of instructional design. Specifically, as this study leverages experimental inquiry to evaluate two differing instructional experiences it becomes critical to address common critiques often laid upon practices of this sort.

One of the preeminent critics of experimental inquiry within instructional design is Richard Clark. His primary challenge to the field at large is centered around the comparison of media within questionable experimental research practices. He posits that experimental studies which indicate specific media use leading to superior learning for individuals are requite with confounding variables like specific instructional emphasis, novelty effects, and lack of appropriate experimental controls (Clark, 1994; Clark & Feldon, 2014; Clark & Salomon, 1986). Clark goes on to say studies focused on new forms of media simply rehash old research questions about the new media's instructional effectiveness. He notes that the newer training methodology usually gets the primary interest of the researcher, and that the instructional intervention is inherently adapted to represent the new media more appropriately. This practice has also been described by Cunningham (1986) as pitting good guys (new media) versus bad guys (traditional media). Despite this critique being well known, even often defined as the great media debate (Tennyson, 1994), this experimental methodology is still widely practiced today with instances encompassing digital games (Hwang et al., 2020), immersive virtual reality (Parong & Mayer, 2020), augmented reality (Buchner & Kerres, 2023) and desktop medical simulation (Dubovi et al., 2017). In a recent work put forth by Honebein and Reigeluth (2021) the authors go so far as to say the practice of so-called media comparison studies is on the rise since 2010, noting that the critiques laid back at the onset of the great media debate are still present and largely unaccounted for even today.

Considering these findings, note that Clark's primary element of critique within his initial work and the subsequent works produced by the field at large, is primarily focused on experimental design of such studies. Kozma (2000) sums up the critique by stating "traditional experiments often are not able to accommodate the complexity of real-world situations" and "this confounding makes it difficult, if not impossible, to disentangle one component of a design from another because the various components are designed to work together (p. 10).

But what of non-traditional experiments? Clark himself, within his seminal 1983 work, outlines how an experimental inquiry including various forms of media may be accomplished with appropriate rigor. In these types of studies, something other than the media itself is being evaluated. His specific examples include an experimental evaluation of instructional sequencing, the perception of learning, sense of achievement, and attitudes toward specific instructional media. He calls this form of inquiry "research *with* media" (1983, p. 446). Going on to say that in these types of studies media acts as a mere conveyance for the experimental treatments being examined and are thus not the true focus of the study. This very closely relates to the research design later described within this study.

Finally, Clarke also mentions within his 1983 work that despite media never leading to better learning, media may address instructional problems other than learning. He describes these instructional problems to include "costs, distribution, the adequacy of different vehicles to carry different symbol systems, and equity of access to instruction." (1983, p. 454). While these variables did not meet Clark’s specific focus, each of these variables are among the very things the aviation maintenance industry is interested in at large (Hammer, 2019). As such, in putting forth a study which present differing forms of media, regardless of the fact that they exist as mere conveyance, answers the broader call from the aviation industry at large to address the instructional opportunity which currently exists within the field of aviation maintenance.

Ultimately, regardless of my intent, this study’s first research question and the methods used to evaluate it may be construed as falling into the familiar pitfalls of a media comparison study. Additionally, readers of this study who come from outside the field of instructional design, which is to be expected given the study’s subject matter, may construe the results of the study’s first research question as conclusive evidence or even proof. In a recent work Honebein and Reigeluth (2021) outline how research studies could be presented or received in this way. One such way highlighted by the researchers is called research to prove. Research to prove is separated into two subcategories, descriptive theory and design theory. In regards to the later form, design theory research aims to prove advances in design theories and instructional methodologies including but not limited to the comparison of media. The aim of these studies is to prescribe which method(s) are preferable in achieving a specific instructional goal. These types of studies are performed quantitatively and provide readers with evidence suggesting one method is better than another, often concluding clear winners and losers within the study’s target of inquiry. While it is the experimental goal of my study to provide empirical evidence relative to my study’s two instructional experiences, this evidence should not be construed in any form or fashion as proof.

In fact, this study more appropriately fits within a different category also described by Honebein and Reigeluth (2021): research to improve. This form of research is largely qualitative and often leverages mixed methods of formative evaluation, while being placed firmly within the scope of an existing instructional theory or framework. The goal of such studies is to improve a specific instructional instance or case, be it through newly formed situated understandings of specific models, new methods, or theories. The conclusion sections of these types of studies often discuss possible improvement(s) to the targeted instructional element (method, model, or theory) based on the study's data given a particular set of situation variables.

This study has been designed in this later vein, as a specific inquiry into the improvement of aviation maintenance training, through the lens of an established instructional design model, leveraging differing instructional interventions. But up until this point very little has been described regarding the qualitative elements found within this study's scope of inquiry. Elements necessary to more clearly express the situated reality this study sets out to improve upon. The next section of this literature review aims to accomplish just that.

Perceptions, Preferences, and Expectations

This study's focus of inquiry rest on the introduction of two new instructional interventions set within the DI framework. To be clear I am speaking not of the PTT or VR Practice phases, but the whole of each three step DI experience. As such, in the vein of Clark's (1983) recommendations this section outlines elements which may impact the perception of learning, sense of achievement, and attitudes toward the interventions put forth within this study. Secondarily, as this study fits within the purview of Honebein and Reigeluth's (2021) research to improve conceptual framework, the second research question has been crafted to qualitatively evaluate this study's specific instructional instance through the situated understanding of a specific model (direct instruction) utilizing new methods of instruction. As such, this section outlines the various elements and factors which the literature has consistently identified as levers which may effect participant’s perceptions, preferences, and expectations relative to both training transfer and technological acceptance.

In terms of transfer, much has been written about how participant perceptions and preferences impact level of transfer from training experiences (Arasanmi & Ojo, 2021). These perceptions and preferences are typically generated from a mixture of prior experience and instructional experience (Sakkal & Martin, 2019). Prior experience represents a domain well-trodden within the literature, being a key component of both meaningful learning and schema theory, each of which are foundational pillars within the cognitivist viewpoint of instructional design (Driscoll, 2005). Specifically, within the purview of both new instructional experiences and training transfer, prior experience or prior knowledge has been established as a key indicator in predicting participant success. Within the domain of transfer, Day et al., (2012) highlight that there is likely no greater predictor of learner success in transferring learned skill than prior experience, noting that prior knowledge helps reduce cognitive load when participants are faced with different or novel problem sets (i.e. places where transfer needs to occur). As such, it becomes critical to any study investigating both new instructional methods or transfer to ascertain the level and scope of previous experience to the subject matter.

While prior experience has been shown to be a key predictor of training transfer, the instructional experience itself represents the greatest controllable factor in ensuring transfer will occur. Within the field of instructional design transfer exists to many as the ultimate goal of training (Broad, 1992), and represents to some the true purpose of the field (Schoeb et al., 2021). With that being said, not all experiences had within an instructional intervention are intentional or represent the intent of the designer. These circumstances therefore become mitigating variables within any training intervention and naturally have an impact on training effectiveness and transfer. Several elements can be found throughout the literature as being particularly relevant in this way, the first of which is interest in the subject matter and the instructional experience. Interest in the subject matter and the instructional experience itself is a central element within the Keller's work on motivational design within conditions-based instructional design theory (Keller, 1979, 2009; Richey et al., 2011). These concepts have too been found within the literature surrounding transfer. In recent study put forth by Gegenfurtner et al. (2020) the researchers put forward that motivational influencers are themselves a key predicator of training transfer into the workplace, highlighting that elements like subject matter interest, future professional aspirations, and perceived utility of training each pose as a key element effecting learner motivation within vocational contexts. These findings mirror what Keller would call *Effort*, which constitutes motivational elements that participants bring to any instructional experience. The second mitigating variable of focus prominently found within the literature which also has ties to Keller's motivational theory is the interest and perception of the instructional intervention itself. Motivation to participate with an instructional experience has been shown to be a predictor of transfer (Mohamed AL-Mottahar & Bt Pangil, 2021). Not surprisingly, researchers and practitioners have set out to design novel, engaging instructional interventions which will motivate learners to participate more fully within the instructional experience. This can be clearly seen in transfer studies investigating the use of game-based learning (Collins & Ferguson, 1993; Nietfeld, 2020b), augmented reality (Conley et al., 2020), and VR simulation (Korteling et al., 2017). As such, in investigating both new instructional methods and transfer, it becomes critical to ascertain how subject matter interest and motivational factors associated with instructional content and methodology perhaps mitigate empirical findings. Additional to this, the research indicates that mitigating factors within the instructional experience may also effect expectations for future training experiences (Arasanmi & Ojo, 2021). As this study's specific instructional context has not been covered extensively within the literature it is necessary to understand how participants perceive the study's instructional experiences and how those perceptions may translate into preferences and expectations for future training experiences.

Finally, this study includes a VR training element set within a relatively unexplored training context. Thus, it is appropriate to understand and evaluate the participants' perception of the VR experience so as to arm researchers and practitioners with beneficial insights into the design of future VR interventions and studies. Numerous studies suggest research participants when queried report overall positive attitudes towards both the use of VR and the perception of VR as a training tool (Makransky, Wismer, et al., 2019; B. Wu et al., 2020). Cheng and Tsai (2019), in a study surrounding the use of VR in a K-12 science context, identify that the use of VR had a strong effect toward motivation and attitudes toward the course's learning objectives. In Wu et al.'s meta-analysis they too found a strong relationship between VR, learning attitudes and positive perception of learned content. VR has even been linked to pleasurable experiences like flow state (Bodzin et al., 2021). There are a number of contributing factors which provide some insight into the apparent broad consensus that VR experience result in positive qualitative experiences, some of which include the presence of game-based elements (Bodzin et al., 2021), the novel experience of participating in VR (van Gelder et al., 2019), the experience being enjoyable or amusing (Klingenberg et al., 2020), and ultimately that content matter presented in the VR experience is relevant and thought provoking. Throughout nearly all VR studies reviewed within this study's effort, these positive attributes appear in various levels of clarity, but one negative element persisted in much of the literature – motion sickness.

Researchers have consistently found that some users experience motion sickness when using a head-mounted display during VR activities (Coxon et al., 2016; Munafo et al., 2017; Suh & Prophet, 2018). This has been linked by some researchers to the use of a fully immersive VR environments within HMDs (Hettinger & Riccio, 1992; Sharples et al., 2008). Sharples et al. even provides a possible explanation for this effect in that participants may be suffering from sensory conflicts when they are viewing synthetic visual representations or self-motion in the VR environment while being physically stationary. This has been corroborated recently through the work of Lui, McEwen, and Mullally (2020) who found there to be a relation between comfort and cognitive load when participants differentiated between seated or standing positions.

Recently, however, the rate of motion sickness findings appears to be decreasing somewhat as VR technology improves. During the time of VR’s infancy, Regan and Price (1994) stated that 61% participants felt symptoms of malaise such as dizziness, nausea, and headache during the experience. However, more recently Lovreglio et al. (2018) reported that only 5% participants felt motion sickness in their study, specifically mentioning in their results the benefits of a higher quality internal to VR navigation system.

As VR based factors like user experience, user perception, ease of use, instructional relevance, and motion sickness have not been thoroughly investigated within this study’s context, there is warrant in investigating how they factors potentially effect perception of this study’s complete training experience. Additionally, it is of interest to determine how the VR experience in and of itself affects the expectations for future training experiences, itself a previously described mitigating factor in overall instructional effectiveness and transfer.

As such, to investigate the novel technological component of this study, I opted to use a widely utilized framework for determining the experiences and levels of acceptance for a technology driven learning experience. The Technology Acceptance Model (TAM) has been widely used throughout the literature to determine the acceptance of any technologically based change (Bourgonjon et al., 2013; Hite, Jones, Childers, Ennes, et al., 2019; Shin & Park, 2019). TAM was selected as an appropriate analysis mechanism due to its focus on determining the interventions ease of use, participants' preparedness felt, the interest in using again, preference for future experiences, and whether or not the intervention met their training expectations (Hite, Jones, Childers, Chesnutt, et al., 2019). Also, this study specifically takes from Fokides' (2017) work which utilized TAM to evaluate participants' acceptance of a VR experiences taking into account insights about participant's background in relevant technology use and relative subject matter experience.

Research Questions

This study sets out to evaluate the effectiveness of two parallel training interventions built within a direct instruction framework by quantifying the degree of near transfer. Thus, against the background of the preceding review, the following two research questions were derived to first quantify the effectiveness of the two training interventions through the lens of near transfer, and then collect data on potential mitigating factors to paint a clearer picture of the study's contextual results. While the previous section covered how factors like previous experience and technological acceptance are poised to mitigate experimental findings it is also the intention of the study's second research question to discover new factors which would enhance the contextual relevance of this study.

This study's research questions are as follows:

RQ 1 - How do aircraft technicians perform on near transfer tasks after each of the study's DI experiences?

RQ 2 – What perceptions, preferences, and expectations do participants bring into and take away from the study's instructional experiences?

Significance of the Study

This study has potential significance for the aviation industry, technician training schools, researchers of instructional design, and practitioners across the subsequent fields. For the aviation industry, the results of this study may provide some initial guidance for regulators and authorities motivated to find ways to address the industry's technician shortage problem via training (Aviation Technician Education Council, 2021; Boeing, 2020). Similarly, this study stands to provide some guidance and direction to Part 147 schools interested in ways to increase the volume and speed of technician training (Hannon, 2007) by applying the study's direct instruction framework into existing curriculum.

Industry aside, within the field of instructional design this study is significant for several reasons. One, this study set out to evaluate the effectiveness of two parallel training interventions by quantifying the level of near transfer into real-world task performance. By doing so, this study addresses several long-standing calls from across the literature to identify and leverage new forms of empirical research to evaluate transfer of training (Broad, 1992; Schoeb et al., 2021). Second, as this study includes a VR training element set within a novel context, researchers and practitioners may that take interest in the VR tool's practical design along with its placement within a comprehensive instructional design framework rather than a standalone piece of media. Additionally, while not the explicit goal of the study, there does exists considerable interest within the literature in finding better ways to evaluate training effectiveness of VR interventions themselves (Bower & Jong, 2020; Pletz & Zinn, 2020). As this study includes a VR element within its instructional design it stands to reason that the evaluation of transfer as put forth by this study’s methodology may also prove to be significant in determining the effectiveness of VR experiences set within adequately designed training interventions.

Lastly, as the subject area of this study fits within the relatively unexplored context of Part 147 programs, this study may prove significant in understanding how technicians perceive new instructional interventions relative to both their previous experiences as well as future professional expectations. Future researchers and practitioners within the field will thus likely find the results of this study’s second research question significant in helping to determining how mitigating factors effect both training effectiveness (Makransky, Wismer, et al., 2019; B. Wu et al., 2020) and ultimately training transfer (Arasanmi & Ojo, 2021; Nietfeld, 2020a; Sakkal & Martin, 2019).

CHAPTER III – CONTEXT

Training Task Selection

For the reader, it is important to note the unique nature of this study’s selected training tasks. These tasks have been specifically identified and vetted by subject matter experts associated with the study. Each training task is an individual unit of instruction, meaning the tasks are not linked together in terms of instructional content or sequencing. The tasks are not part of a building block type curriculum and finally, each individual task has no baring or knowledge transfer to the other study task.

Significant effort from the subject matter experts, instructional staff, and myself went into ensuring that each task held the same level of difficulty so as to not introduce a complication into the core of the study’s design. As such both training tasks feature a similar number of overall steps and actions, a similar number of tools to be used, require the same level of behavioral interaction with the training equipment, require the same level of subject matter knowledge, and can be accomplished within similar time confines of the study regardless of media choice.

Prior to finalizing the choice of these two tasks a viability study was performed testing six different tasks to validate which tasks most appropriately met the expected threshold, the result of that study led to the selection of the two tasks outlined below. Lastly, which training task got which practice intervention type was randomized.

Training Development

For this study, specific training materials were developed to align with the steps outlined within the direct instruction framework. Each element is discussed within the following section with examples provided to aid in contextual understanding. While the PTT is also a training material, it was not specifically designed by myself and is thus not included within this subsection. Information describing the PTT and its task do appear in a later section.

Presentation Materials

The Presentation materials were developed utilizing a mixture of narrated video and interactive instructional content built within Articulate Storyline. Each of the two modules begin with a presenter outlining the goal of the instructional task (i.e., remove and replace oil filter), a listing of the various tools one would need to complete the job, and a quick orientation as to where the work on the engine is to be accomplished (Figure 6). Next the learner is shown a narrated video presentation which shows the complete procedure step-by-step (Figure 7). After the video presentation the learner then goes through an interactive activity which takes the participant through the very same procedure but at a self-directed pace. Each interactive step requires the learner to select a pertinent portion of the screen relative to the appropriate procedural action (Figure 8). When the participant selects the appropriate location, the step is accomplished showing a short video clip of the action being performed with accompanied audio description of what is happening relative to the procedural step. Occasionally, when there is an element of critical importance a highlighted box appears on the screen to indicate a step which must be handled with particular care to avoid bodily injury or aircraft damage (Figure 9). When the procedure comes to a close, the participant is taken to a short three question multiple choice knowledge check aimed to highlight elements of determined importance towards the successful completion of the task.

Figure 6

Introductory Scene (Oil Filter Procedure)

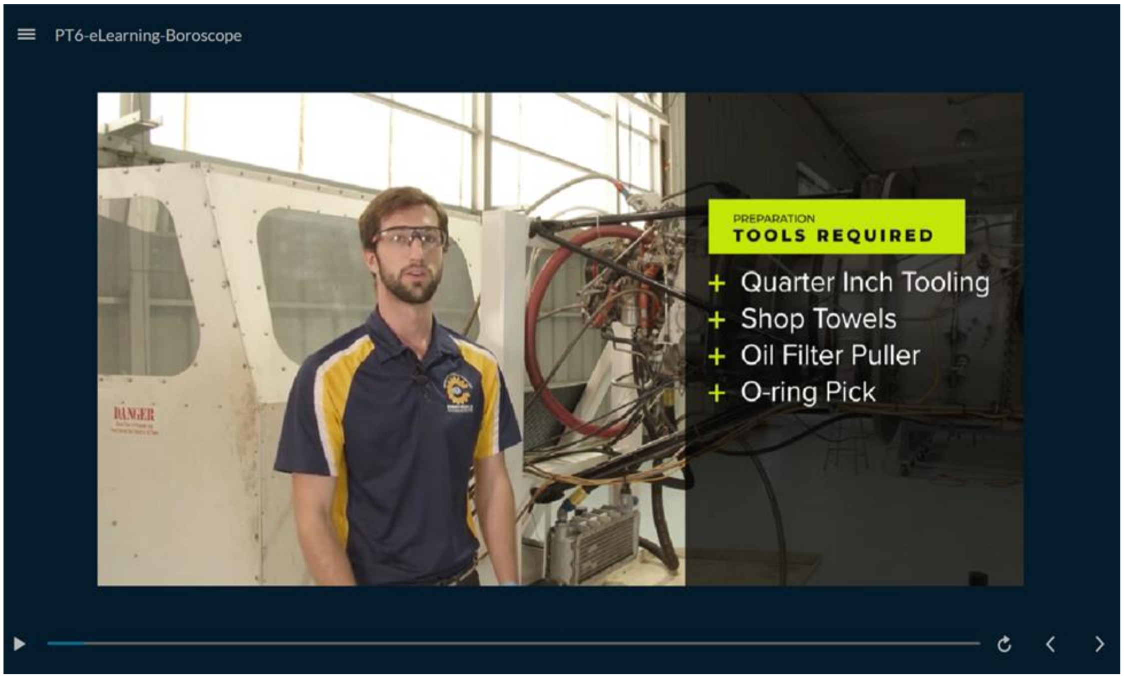
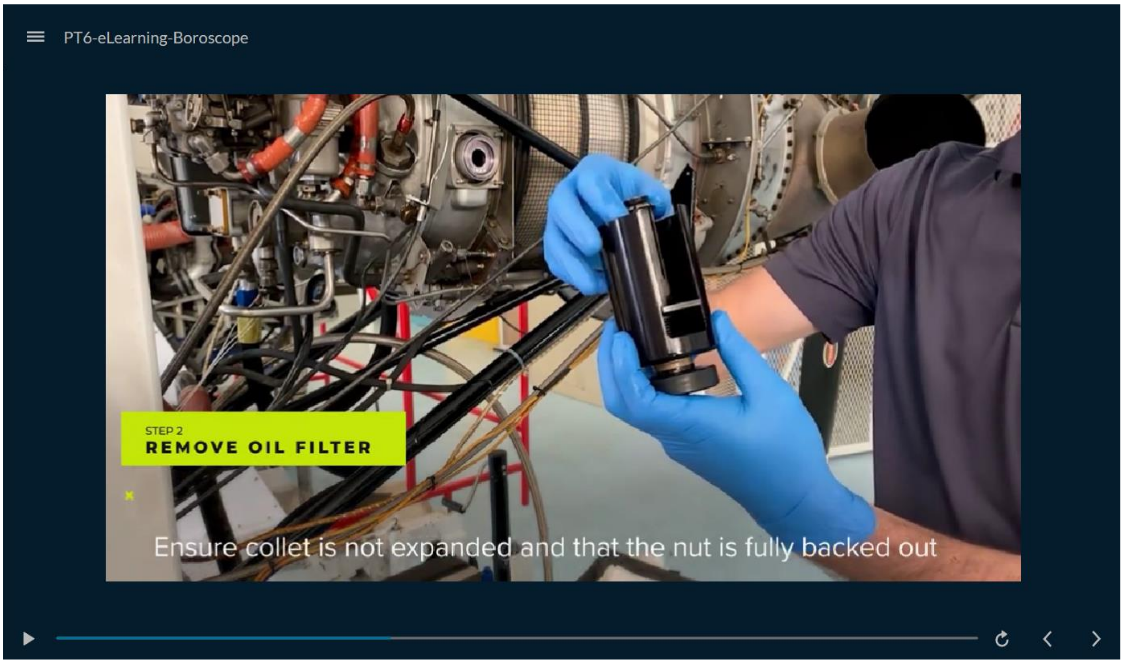


Figure 7

Interactive Step (Oil Filter Procedure)

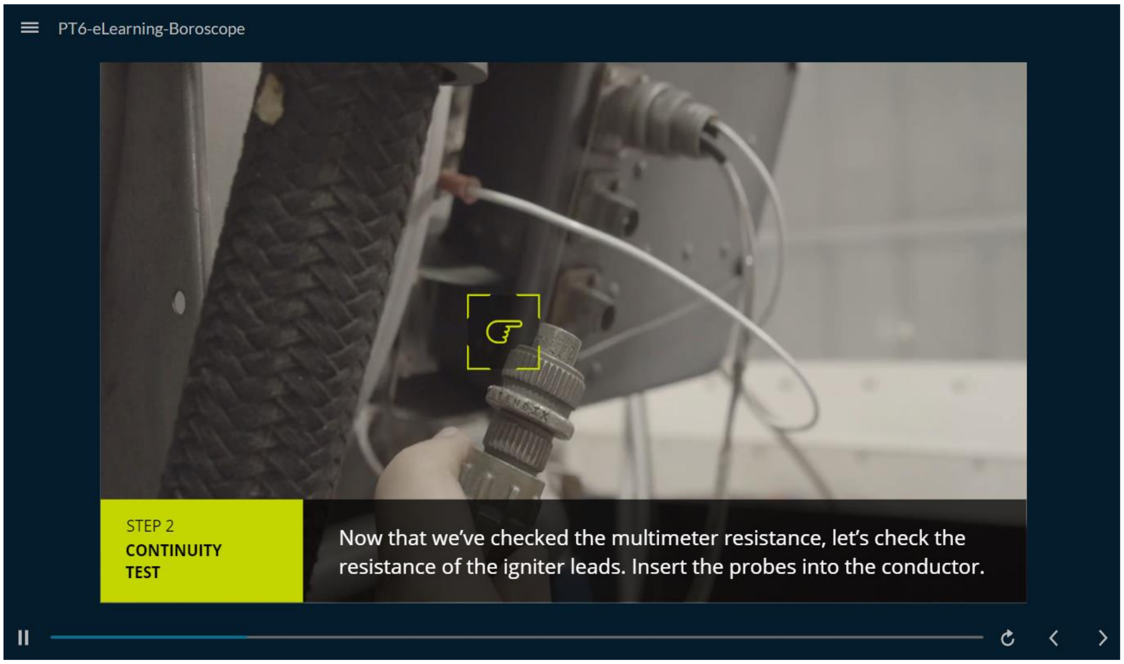


STEP 2
REMOVE OIL FILTER

Ensure collet is not expanded and that the nut is fully backed out

Figure 8

Interactive Step (Ignition Lead Procedure)

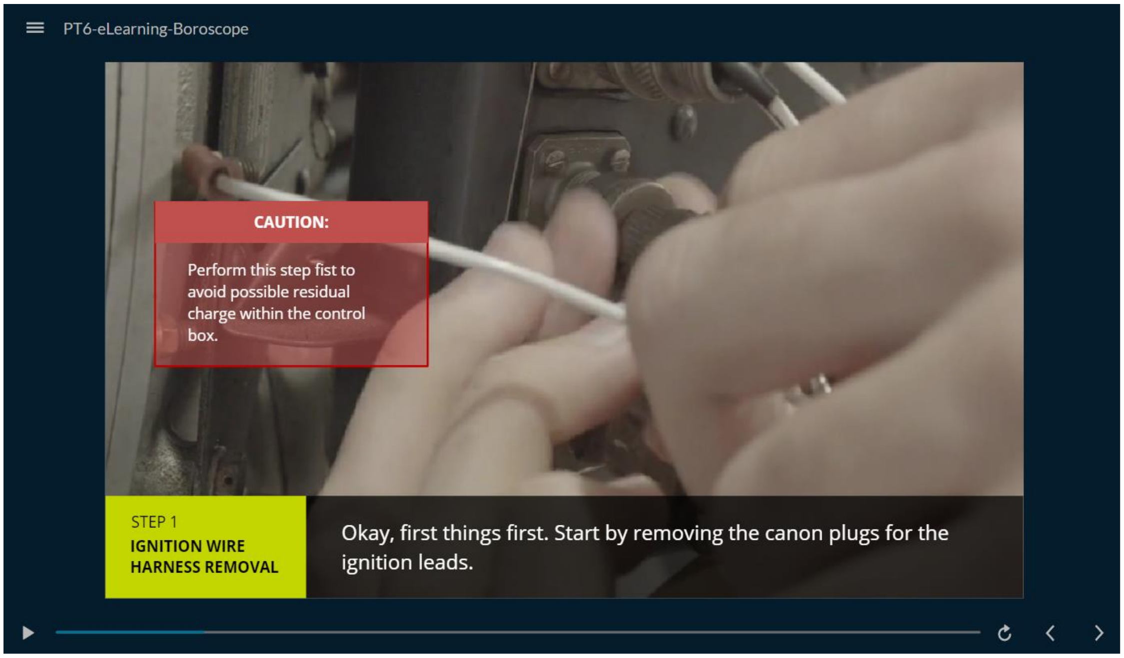


STEP 2
CONTINUITY TEST

Now that we've checked the multimeter resistance, let's check the resistance of the igniter leads. Insert the probes into the conductor.

Figure 9

Cautionary statement upon interaction (Ignition Lead Procedure)



CAUTION:

Perform this step fist to avoid possible residual charge within the control box.

STEP 1
IGNITION WIRE
HARNESS REMOVAL

Okay, first things first. Start by removing the canon plugs for the ignition leads.

VR Task Trainer Development (Practice Task)

In developing any form of training material for an instructional experience there are a number of factors and affordances which go into the media selection process. There are financial factors such as budget and time. There are developmental factors like familiarity with the development process and availability of developmental resources (i.e., software and hardware considerations). And while each of these factors warrant careful consideration and undoubtedly affect the development of the instructional intervention, they do not necessarily relate to the instructional design from the learner’s perspective. How then does one determine when the use of a virtual reality intervention is appropriate for an instructional experience and how then should the VR experience be designed to align with instructional design principles?

First, virtual reality has been said to contain certain *affordances* which align with specific instructional tasks. The term affordance relates to the functional properties which relate to the utility of a specific object or environment (Greeno, 1994). Bower (2008) proposed a methodology for matching technical affordances to learning task requirements to aid in technology selection and instructional design. For the purposes of this study's VR intervention, I have highlighted four affordances put forth by Dalgarno and Lee (2010) as an established criterion for selecting and designing training intervention for a specific instructional task.

Dalgarno's first affordance is that 3-D virtual learning environment (VLE) (including virtual reality experiences) can be used to facilitate learning tasks aimed to enhance spatial knowledge representation. The VR task training experience within this study has been designed in a way to appropriately situate the learner within an appropriate contextual environment, in this case a simulated workshop (Figure 10). The tools, the engine location, and the spatial distances used throughout the experience were designed in a way to simulate reality at a high fidelity. This means the eye location, bodily position, and relative motion related to the real-world task have been considered within the virtual reality experience in a way that aligns directly with the physical performance of the training task.

The next affordance, put forth by Dalgarno considers both the health and safety of the participant within the training environment but also the practicality of specific instructional interventions, stating that 3-D VLEs can be used to train learning tasks which would be impractical or impossible in the real world. As has been previously discussed, a significant portion of the reasoning in designing this VR intervention was to assist with the practicality of training maintenance tasks given the current challenges apparent in the field (i.e., access, availability). Additionally, the VR experience designed within this study allows for learners to peer into the virtual engine to see its internal workings by simply placing their body position into the engine casing itself. This is an impossibility within real world contexts, but something that is commonplace within virtual renderings of real-world objects. Within this study's context this allowed learners to see how the internal workings of the oil filter system connected together giving further context to appropriate tool use and assembly procedures.

Dalgarno's third affordance has been routinely highlighted within the field as a positive attribute of 3D VLEs, the affordance being that 3D VLEs may lead to increased intrinsic motivation and engagement. Within the context of this study, VR was selected in alignment with this affordance for several reasons. First, as has already been discussed, VR has the potential to be delivered anywhere in the world across a wide spectrum of available headset and controller formats. As such this directly relates to the availability of aircraft technician training in new and/or underrepresented populations, demographics, and markets. Availability of these training experiences to a greater population ideally would lead to increasing motivation from participants to participate or enroll in aviation maintenance training curriculum and schools, potentially addressing one of the major challenges the industry faces today. Secondarily, the VR training experience addresses one of the challenges found within the current practice training exercises used within existing aircraft maintenance training programs. In the current state, participants are often placed within small groups to work on a part task trainer, while there are clear benefits to group work there are also considerable drawbacks. Perhaps the most prevalent drawback found within this context is the lack of individuality in the practice exercise, a central element to the direct instruction framework. This lack of individual practice potentially leads to each participant not actually getting a chance to do the entirety of a project by themselves, a requisite of each FAA Part 147 school. Additionally, there are interpersonal factors like self-confidence and willingness to fail publicly which negatively impact potential learning gains within the existing environment. In alignment with Dalgarno's third affordance, the VR task trainer addresses each of these concerns head on given its inherent technological capabilities.

Finally, the fourth affordance put forth by Dalgarno is central to this study's primary purpose statement. Dalgarno posits that 3D VLEs can be leveraged to improve transfer of knowledge and skills to real situations. This is essentially the central focus of this study's experimental design.

Now with the affordance which led to the selection of a VR training intervention considered one must then consider how the VR training intervention was practically developed. Again, Dalgarno provides a well-defined list of distinguishing characteristics to which this study's VR task training intervention closely aligns with. Dalgarno's framework includes two categories: representational fidelity and learner interaction. First focusing on representational fidelity, the VR task trainer intervention used within this study exhibits a highly realistic environmental rendering. This is due to two primary factors, one the headset selection utilized for the study and secondly the visual fidelity of the virtualized world and the objects within.

The virtualized world is set within a fictional workshop (Figure 10). Instead of being modeled from a common maintenance work environment which typically involves limited workspace, occasional loud noises, and at times an overall messy appearance, this fictional workshop has been designed with training in mind. The environment was built to represent what perhaps an ideal workshop would look like, a place of relative comfort and calm, while still including all of the necessary elements of a functional workspace. This design choice was made to aid in the intrinsic motivation to participate within this work environment. The environment is rendered within an HP Reverb 2 headset (Figure 10). The headset provides a 114-degree field of view at a resolution of 2160 X 2160 pixels per eye (4320 x 2160 combined). The virtual environment and virtual objects, colors, textures, and lighting elements were developed in a way to support framerates of up to ninety frames per second within the headset, which within the industry is the baseline expectation for technical tasks and first-person games (Damjan, 2022). The headset and the rendered world both align with not only the realistic display of environment characteristics put forth by Dalgarno, but also allow for the smooth display of view changes and object motion.

The VR training experience utilized within this study was built within the game engine Unity. Within Unity, design elements like movement and control mechanics as well as object and environmental physics (i.e., gravity, weight, mass, etc.) help address object motion and the consistency of object behavior characteristics outlined by Dalgarno. Specific to the VR task training module found within this study, specific behaviors have been built into the simulation parameters used within the instructional experience. Weight of objects is represented by changing the relative effort the participant must use to exert force upon differing objects through linear haptics and object movement speed upon interaction. As the task being trained requires the use of specific tools, naturally ensuring the functionality of those tools align with real-world expectations was paramount. This includes even the kinesthetic feelings associated with utilizing the various tools within the virtual environment.

Kinesthetic and tactile feedback are another characteristic outlined within Dalgarno's framework. Within this intervention's design, I did not have access to equipment which could provide true force feedback (i.e., gloves or control loading interceptors) and thus leveraged the native haptic feedback found within the HP Reverb 2's controllers. Haptics were used throughout the experience in a number of ways, the most common being the ratcheting feel of ratcheting tools. Haptic pulsing was used to mimic the ratchet ‘clicking’ back into a position to apply force on a screw or nut. Additionally, small but abrupt haptic pulses were included when tools made contact with desired fittings and fasteners so as to mimic positive contact with the desired target. Finally, linear haptics were used to simulate tightening, loosening, and breaking torque on fasteners. In these circumstances the haptic vibration increases to a point of near constant vibration at the point in which a fastener cannot be tightened any longer.

During these performance-based interactions, the final two representational fidelity elements described by Dalgarno can be found. Spatial audio is used to mimic tool sounds, these sounds are coupled with the haptic feedback previously described to maintain a high level of realism within the experience. Finally, as the module is designed as a first-person experience, the participants handle tools with a set of gloved hands. Particular effort was put into the simulation parameters of the hands themselves so that the hands would correctly pick up and grab a number of differing sized virtual items while the participant is grabbing the physical controller. Additionally, the key bindings of the controller were configured in a way so as to make both the hand and palm trigger work in a way which would simulate natural actions one does with a hand. Things like pinching a small nut or using scissors (Figure 12).

Dalgarno’s second categorization of distinguished elements within 3D VLE’s include specific considerations for learner interaction. Within the previous paragraphs I have outlined the scripting of object manipulation and behaviors in terms of learner interaction, but I have yet to address the other characteristics. As the training intervention is a VR experience which utilizes a headset mounted display (HMD), view control is fixed to the participant’s viewpoint embodying the person within the virtual environment at the height to which they stand in the real world, adding additional realism to the experience. Navigation is accomplished in two ways, either the participant can walk around the virtual environment by physically walking in the real world, or the participant can teleport utilizing the key binding on the controller.

The final two characteristics within Dalgarno’s framework are largely not accounted for within the intervention. Within the VR task trainer there is very little need for verbal communications, there are no other participants within the virtual environment and there are no non-playable characters to interact with. The only element which could be considered a non-verbal element of communication is use of the tablet checklist used within the virtual workshop which states the checklist steps necessary to accomplish the maintenance task (Figure 13). Lastly, there is very little in the ability to control the environmental attributes of the experience, with the exception of the common functions which appear on the headset (i.e., brightness, contrast, etc.), this is deliberate as my goal in designing the intervention was to simulate an as near to a real-life experience as possible.

Figure 10

Virtual Workshop Environment

Figure 11

HP Reverb 2 HMD and controllers

Figure 12

Hand interaction

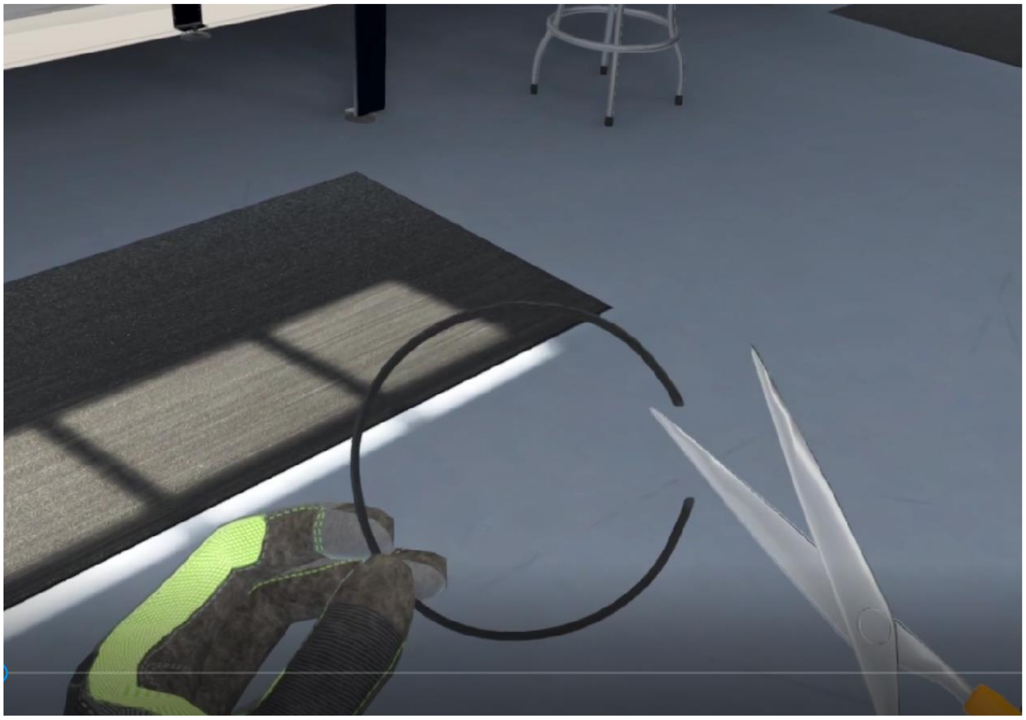
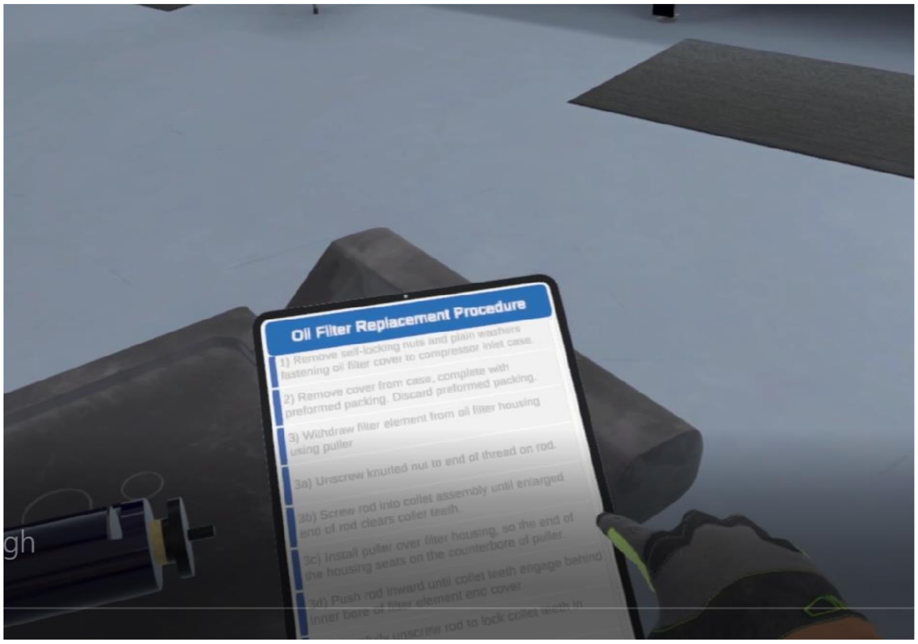


Figure 13

Tablet checklist representation



Oil Filter Replacement Procedure

1) Remove self-locking nuts and plain washers fastening oil filter cover to compressor inlet case.

2) Remove cover from case, complete with preformed packing. Discard preformed packing.

3) Withdraw filter element from oil filter housing using puller

3a) Unscrew knurled nut to end of thread on rod.

3b) Screw rod into collet assembly until enlarged end of rod clears collet teeth.

3c) Install puller over filter housing, so the end of the housing seats on the counterbore of puller.

3d) Push rod inward until collet teeth engage behind inner bore of filter element end cover

unscrew rod to lock collet teeth in

CHAPTER IV - METHODS

Research Design

The quantitative portion of thi study is largely based on research put forth by Farra et al., (2018) who utilized a within-subject repeated measure design to evaluate differing instructional experiences in an experimental setting. Additionally, this study borrows heavily from work recently put forth by Pletz and Zinn (2020) who focused on the use of Immersive Virtual Reality (IVR) within an industrial context, specifically a mechanical and plant engineering setting. In both circumstances I have modified their methodology where appropriate to better suit this study's specific context, this is most evident in my measure of training effectiveness via near transfer.

Secondarily, to seat the study more squarely within Honebein and Reigeluth's (2021) research to improve conceptual framework, this study utilized both questionnaires and open-ended interview questions to evaluate mitigating factors like previous subject matter knowledge, participants' predisposition to specific technological tool sets and their experiences during the training interventions within this study (Hite et al., 2019b; Lanier et al., 2019; Pletz & Zinn, 2020).

Participants & Setting

Participants targeted for this study consisted of undergraduate students enrolled in the aircraft technician vocational education and training program at an aerospace university situated in the southeastern United States.

Due to the nature of the subject matter, the general instructional approach, and FAA Code of Federal Regulation (CFR) Part 147 limitations, class size for aircraft technician courses is limited to 30 participants per semester. As such this study utilized a purposeful sampling of individuals enrolled within this program. Participants within this program are largely male, representing over 80% of enrollees. Participant ages range from 19 to 32 with a median age of 24 years.

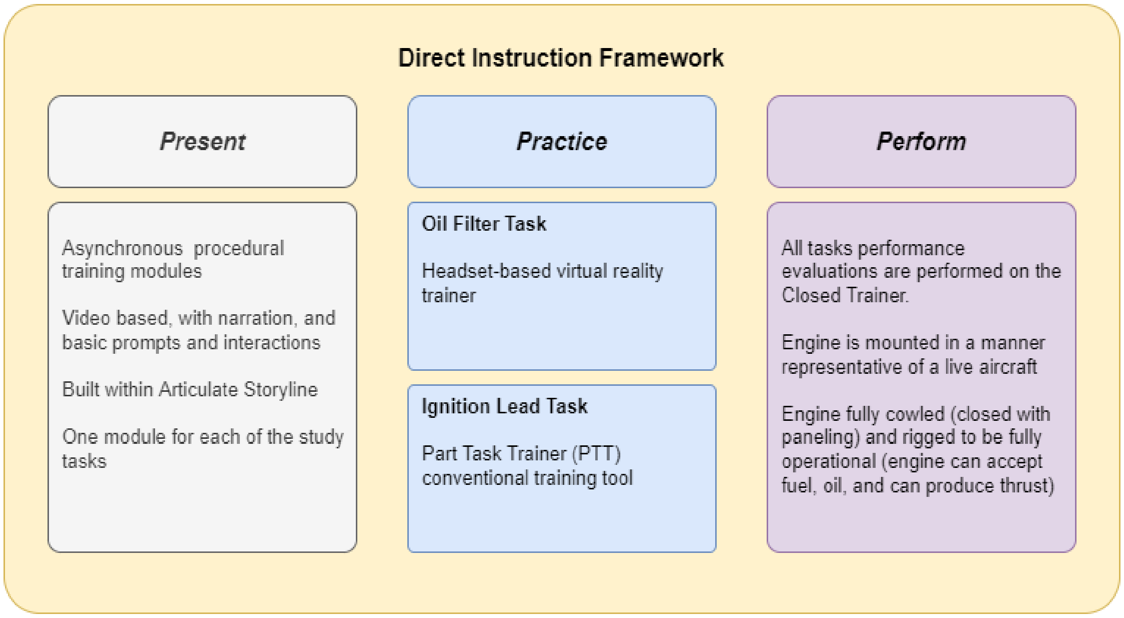
This study took place over two consecutive weekends during the university’s 2022 Spring semester. Enrollees within the curriculum were notified about the study via in class instructor description, email messaging, and signage throughout the schoolhouse building. Students were asked via questionnaire about their willingness to participate in the study. This study was integrated in line with an existing university training curriculum for the course entitled, Turbine Engine Theory and Practice. This course is intended to be an introductory course for aircraft turbine engines and is broken up into individual module units relative to turbine engine subsections (example: low pressure turbine, gear box, fuel, etc.).

Procedures

This study took place over two consecutive weekends during the university’s 2022 Spring semester. Each week seven to ten unique participants went through the whole of the study’s design. On Monday each group was given access to a Canvas site which featured the specific instructional content for the three tasks which were to be performed at the end of the week. This content, described below in the Present phase mainly featured procedural video with narrated instruction and was able to be replayed at the learner’s discretion. At 11:59 on Friday, the Canvas site was then restricted, and no participants were able to access the training materials further. Next, over the weekend each participant arrived for a 2.5-hour training session block. During this block the participant went through each of the training interventions both VR and PTT, as well as performed the transfer training task on the live aircraft mockup. This sequence repeated the following week with the remaining 7 participants.

Figure 14

High-level breakdown of study's DI interventions



Present - Video Materials and Pre-Questionnaire

At the onset of the study, learners were prompted to access a Canvas LMS course which was set up to facilitate the pre-study training materials. This material consisted of three 10-12-minute training videos. These videos were narrated and presented in a manner which broke down the specific steps required to perform each of the study's performance tasks. These materials were accessed via the university's dedicated Canvas instance and were re-playable for the period of time in which the Canvas site was open for each group of participants.

At the end of each video module there existed a three question, multiple choice knowledge check which assessed whether the training objectives set forth in these training videos have been achieved by the learner. This practice aligned with research put forth by Meyer et al. (2019) which indicated pretraining content given prior to immersive media interventions resulted higher levels of knowledge gain, transfer, and self-efficacy along with lower levels of cognitive load during the immersive media intervention.

At the completion of the pretraining module the participants undertook a 10-question background questionnaire aimed identifying potential mitigating factors by assessing the participants' predisposition to VR devices, gaming platforms (interest, previous use, frequency of use), mechanical predisposition, and basic demographic information.

Practical Training Session

Dependent on individual scheduling requirements, each participant signed up and were subsequently assigned to a 2.5-hour Practical Training Session. Within each session each participant went through the two practice training interventions followed by the instructor-led performance evaluation. The sequence of these events occurred in the following order: VR Experience, Conventional Method Exercise, and finally the transfer task with instructor evaluation.

Practice - Virtual Reality (VR) Experience

The VR intervention was designed and built utilizing the game engine platform Unity and features a stylized rendering of the requisite aircraft engine, tools, and user experience elements. From a physical hardware perspective this portion of the study utilized an HP Reverb 2 headset with Omnicept. The headset provides a 114-degree field of view at a resolution of 2160 X 2160 pixels per eye (4320 x 2160 combined). Interaction within the environment was accomplished with two headset specific motion controllers. The headset was tethered to a dedicated desktop computer via a 15-foot cable which was routed from the ceiling so as to avoid a tripping hazard. From a previously accomplished pilot study (Powers, 2021), I had determined the appropriate space requirements for this intervention to be 10 x 10 feet of physical room for participants to walk around in. Additionally, the image depicted from the headset was mirrored onto a monitor for external viewing for technical support.

The procedural elements put forth for VR use within this study align with the methods described in Pletz and Zinn (2020). The VR instructional experience began with a small warm up exercise to ensure the learner could orient themselves within the virtual space, walkaround comfortably and utilize the controllers to accomplish tasks. This was accomplished via an “in-game” tutorial where physical bodily movement, controller buttons and safety interactions were selected and performed to ensure the learner was prepared to participate in the learning task. Once the tutorial is completed the learner was prompted to complete the expected learning task, in the case of the VR experience this was the removal and replacement of the engine’s oil filter.

While experiencing the intervention, the participant had two ways to interact with the general VR experience. The learner had the option to interact with the virtual environment with their body by kneeling, crouching, walking, or leaning as they saw fit for the instructional activity. If, however, the learner did not wish to operate this way they could choose to sit in a seat and utilize the on-screen checklist or the motion hand controllers to navigate the virtual environment while sitting stationary. Even seated the learner was still able to move their head and/or hands to change their view or otherwise interact. Regardless of choice, the checklist and interactive elements remained the same, the movement and degree of participation is entirely user guided and the learner was expected to sequence through the entirety of the checklist and perform the given task items to completion.

Practice - Conventional Method exercise

After completing the VR Experience, the individual participant had the opportunity to take a short break before moving into the workshop area in the training hangar to participate in the Conventional Method exercise.

The Conventional Method exercise took place on a physical engine mockup, described as the part task trainer (PTT). Because this intervention represents the typical training experience for the study's participants there was no warmup exercise like there had been for the VR experience, there was however a preparation step in which the learner ensured they had the proper tools available for the conventional method training task. These tools consisted of a set of ignition leads, a metric set of various sized sockets, a ratchet, a set of various sized metric wrenches, as well as a multimeter device. These tools were utilized to disassemble, test, and reassemble the practical task trainer's igniter box assembly per the designated task card. The participant was sequenced through the entirety of the task card checklist and had to complete the given activity prior to moving on to the final stage of the study

Perform - Performance Evaluation (Transfer Task)

Upon the sequential completion of the two-practice training exercises the participant moved on to the performance evaluation portion of the study. This was accomplished via an individual task performance evaluation, as I was evaluating the effectiveness of two differing training interventions and not the summative knowledge of the whole training experience or course.

This portion of the study was facilitated via a near real to life aircraft mockup, known as the Closed Trainer. In the Closed Trainer, the engine is mounted in a manner representative of a live aircraft, is fully cowled (closed with paneling), and rigged to be fully operational. These three characteristics make the closed trainer a wholly different experience to both the PTT as well as the VR task trainer.

When the participant was ready to begin, they walked to a different training hangar where the Closed Trainer was set up. As this portion of the study was centered around transfer of skill, each of the two previously trained tasks were then performed on the Closed Trainer. The order in which these tasks were performed was randomized to account for counterbalancing. Counterbalancing is an added level of scrutiny for this research design to ensure learning or carry over effect would not apply, despite the different relative subject matter of the tasks at hand.

As the participant went through the two tasks, the instructor observed and evaluated the participant based on a predetermined criterion appropriate to this instructional context. The criterion used included variables which measured the accuracy of the participant performance, the time in which performance took place, safety considerations for the specific task elements, and the number of times the participant required assistance. These variables along with the actual instructor assessment form are included in Appendix I. When the participant had completed all of the tasks on the Closed Trainer, they were then asked to complete the post training questionnaire prior to leaving for the day.

Post Training Questionnaire and Open-Ended Interview

Finally, at the conclusion of the transfer tasks the participants were asked to complete a 13-item questionnaire followed up by a short open-ended interview to help evaluate potential mitigating factors which may have affected the training interventions’ effectiveness.

The questionnaire was effectively split into three subsections, with each section featuring questions aimed at a potential mitigating factor. The first section centered on the technological element of the VR experience asking questions regarding motion sickness and head-set perceived ease of use. The second section focused on the participants' perceptions of each of the study's training interventions from an instructional perspective. In this series of questions participants were asked to describe their perceived preparedness heading into the transfer task. Finally, the last series of questions centered on the participant's interest, expectations, and preferences. Participants were asked which interventions met their expectations, what training interventions they would be interested in using again, and how they would rank their preference for future training interventions. These items were answered on a 5-point Likert scale.

After the completion of the questionnaire, the participants were then asked a series of open-ended interview questions aimed at gathering a greater understanding of the experiences participants both brought to the study as well as the experiences they took from the study. The open-ended interview protocol was intended to provide additional context to the participants' performance scores and questionnaire responses. While the specific number and content of the questions were somewhat varied between participants, in general the questions continued along the themes found within both the Pre-Questionnaire and the Post-Questionnaire. In both circumstances I was interested in discovering the presence of previously discussed mitigating factors which have been found to affect transfer. As such, additional context was sought to broaden the understanding of; prior experience in mechanical predisposition, computer game and VR use; preparedness felt heading into the transfer task; and the preferences and expectations of future training experiences.

Captured Data

To answer the research questions put forth, I collected the performance scores (PS) for each of the near transfer tasks which took place during the performance evaluations. The PS is a single numerical value with a maximum score of 50, which represents the overall performance of the specific task. PS is made up of five variables evaluated twice during each task’s two segments (i.e. remove and replace). These variables included: task card compliance, PPE & safety, part & equipment handling, tool usage, and faculty intervention. Each variable was placed on a 5-point scale, with the value five (5) representing that individual task action was completed satisfactorily, with no errors and the value one (1) representing unacceptable performance with an unsafe error. PS is the aggregated score of each of these variables, with a minimum PS standard being 35.

To provide context for mitigating factors I also collected the multiple-choice knowledge check answers from the eLearning modules, survey responses from the background questionnaire, survey responses from the post training questionnaire, and data from the post training open-ended semi-structured interview.

Table 1

Methodology Sources and Analysis

Research Question	Data Source	How Collected	Method of Analysis
RQ 1 - How do aircraft technicians perform on near transfer tasks after each of the study's DI experiences?	Participants	Grading Sheet	Within Group Repeated Methods Analysis (rANOVA)
RQ 2 – What perceptions, preferences, and expectations do participants bring into and take away from the study's instructional experiences?	Participants	1. Pre & Post Questionnaires 2. Participant Protocol	1. Comparative Analysis 2. In Vivo and Descriptive coding

CHAPTER V – RESULTS

Introduction

To address the two research questions put forth within this study, I first performed a one way within-subject repeated measure analysis of variance (rANOVA) utilizing a framework and procedure put forth by Verma (2016). Each participant was measured along the same dependent variable (PS) within each treatment of the independent variable (DI training experience).

Secondly, to address the second research question I leveraged a combination of the pre and post questionnaires along with the semi structured interview protocol to discover emergent themes within the group. These findings were reviewed and verified by peers familiar with the research context and knowledgeable of the statistical methodology and analysis.

RQ1: How do aircraft technicians perform on near transfer tasks after each of the study's DI experiences?

As evidenced by the data, participants performed above acceptable PS expectations (35) regardless of differences in training intervention. The results of the group mean comparison indicated a statistically significant decrease in performance score observed during the Oil Filter performance evaluation as compared to the performance scores achieved during the Inspection Lead performance evaluation. On the basis of the sampled data, it appears the training intervention type used did affect the transfer, but not to a degree that participants could not complete transfer tasks above acceptable standards. The following section surrounding the use of the within-subject repeated methods analysis provides the protocols and data sets which led to these results.

Within-Subject Repeated Methods Analysis (rANOVA)

As previously discussed, in repeated measures experimental design there are no control or intervened groups. The participants themselves are the control because the model assesses how the students respond to each of the treatments. The result is that only the variability within-subjects is included in the error term making the error term smaller and the analysis inherently more powerful (Guimarães & Lima, 2021). Additionally, repeated measures design was more convenient for the context of this specific instructional setting because it requires fewer numbers of subjects and less overall time to conduct an experiment (Verma, 2016).

The analysis of this repeated measure's design was accomplished through the means of a one-way repeated measure analysis of variance (ANOVA). Repeated measure ANOVA is often written as rANOVA (Verma, 2016), however the basic principles utilized within the analysis are the same as the more common between subject's experimental design and ANOVA with a few notable exceptions described below.

Assumptions for rANOVA

As is the case with all statistical analysis there are several assumptions which must be satisfied to fulfill the design's implicit requirements. Failure to do so would result in an inflated level of significance and a reduction in the overall power of the test. These assumptions are:

1. The independent variable must be categorical, either nominal or ordinal, while the dependent variable must be metric, either interval or ratio.
2. Within repeated measure research designs no outliers should exist.
3. Scores of the dependent variable between the two or more related groups should approximately be normally distributed.

4. Sphericity must be satisfied, as in no sphericity should exist within the data. Sphericity assumes that the variances of the differences between all combinations of related groups must be equal.

Within this study's context all assumptions have been statistically satisfied with pertinent information and formulae represented in later sections within this chapter for review.

Steps in rANOVA Analysis

The analysis of variance for this this repeated measure study followed the following steps

1. Hypothesis construction
2. Layout of the design
3. One-way repeated measures ANOVA model
4. Computation in one-way repeated measures ANOVA
5. Testing sphericity assumption
6. Testing significance of treatment effect

Hypothesis Construction

In this study my aim was to investigate the effectiveness of the two training interventions. Effectiveness was measured via performance score (PS) during the study's transfer task. The study included the participation of 17 subjects. Controls in the experiment included identical access to tools, checklists and venue locations. The subject's PSs were evaluated after the three Practice task training sessions via a performance evaluation; the scores obtained were recorded and are shown in the Table 2.

To address and ensure there could be no carryover effect or learning effect from each of the practice tasks, counterbalancing was done during the evaluation of the treatments so as to minimize the effect of any systematic variance in the study. To analyze the data a one-way repeated measures ANOVA (rANOVA) was applied to find as to which type of practice training intervention enhances the performance score during the transfer task. With the chief assumption being, the higher the performance score, the more effective practice intervention was. The following hypothesis testing was accomplished at .05 level of significance.

The following null hypothesis is required to be tested against alternative hypotheses that at least one of the groups means differ.

$$H0 : \mu \text{PCBased} = \mu \text{VRBased} = \mu \text{PTTBased}$$

In a repeated measures design, variability due to subject is isolated from the treatment and error terms, this results in an overall reduction in the measure of error sum of squares. This aids in the efficiency of the design when compared to that of independent measures designs. As such the total sum of squares (TSS) is split into SS between groups (treatment) and SS within groups. Additionally, SS within groups is further divided into SS due to subjects and SS due to error. As such, in a one-way ANOVA with repeated measures, the model becomes:

Total SS = SSTreatment + SSWithin Treatment = SSTreatment + SSSubject + SSError

Total SS = Variation of all the scores around combined mean value.

SSBetween = Variation of treatment group means around the combined mean

SSSubject = Variation of within-subjects scores around its mean

SSError = Variation of within treatment groups excluding individual variations

Layout of the design

As previously covered within the Procedures section the study's design situates the learner into two tasks for evaluation. A challenge experienced within the design of this experimental study exists in guidance that the minimum number of variables for a repeated measure design be three. Therefore, a third variable listed as Boroscope (PC) in subsequent data representation was added to the study's procedure but was not included within the scope of this study's findings.

Additionally, as this is a repeated measures design where all the 17 subjects have been tested, it was necessary to use the aforementioned concept of counterbalancing. This was accomplished within the transfer task described as the Performance Evaluation, in that the order of evaluation task was sequenced differently for each participant randomly. The design shown in Table 2 explains how the treatment conditions were sequences.

Table 2

*Collected Performance Scores**

Subject	Oil (VR)	Boroscope (PC)	Leads (PTT)
307	46	50	49
312	47	50	49
303	41	50	50
318	35	42	41
305	49	50	50
317	41	38	50
301	36	50	48
302	32	42	39
315	45	50	50
320	38	42	39
309	46	48	49
308	40	48	45
316	44	46	48
311	38	50	46
321	44	50	49
319	48	50	50
314	45	46	49

* Maximum Score = 50

Table 3

Transfer Task Sequencing

Subject	Oil (VR)	Boroscope (PC)	Leads (PTT)
307	1	2	3
312	2	3	1
303	3	1	2
318	1	3	2
305	3	2	1
317	2	1	3
301	1	2	3
302	2	3	1
315	3	1	2
320	1	3	2
309	3	2	1
308	2	1	3
316	1	2	3
311	2	3	1
321	3	1	2
319	1	3	2
314	3	2	1

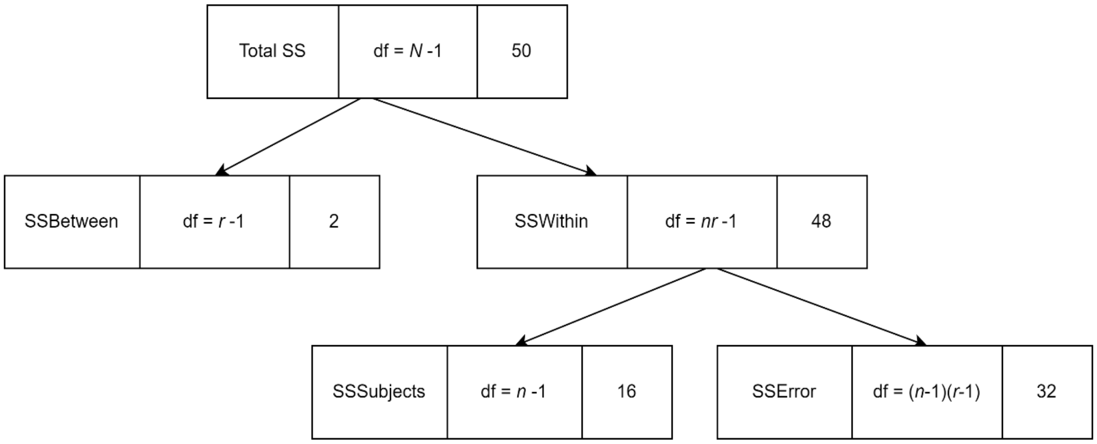
One-way repeated measures ANOVA model

Dissimilar to one-way ANOVA use for independent measures, with repeated measures design the subjects serve as their own control. Therefore, part of the experimental variability is explained by the subjects themselves. This causes error variance to be reduced resulting in an increased statistical F value. As such even slight effects found in the criterion variable due to the change in the independent variable are better detected (Verma, 2016). Within this design, this is represented by splitting the total sum of squares into different components along with their degrees of freedom.

As displayed in Figure 15, the sum of squares within groups has been divided further into both sum of squares due to subjects and sum of squares due to experimental error. In this design error is represented by SSError rather than SSWithin as is the case within independent measures design.

Figure 15

Mapped Depiction of Repeated Measures ANOVA model



Within this study the total degrees of freedom, N − 1(= 50), has been partitioned into r − 1(= 2) df due to variation in treatment groups, whereas N − r (= 48) df is as result of variation within treatment groups. Since SSWithin treatment is further divided into SSsubjects (due to subjects) and SSerror (due to error), the degrees of freedom for SSWithin treatment, nr − r (= 48) is ultimately split again into n − 1(= 16) df due to subjects and (n − 1) (r − 1) [= 32] df due to error.

Computation in one-way repeated measures ANOVA

The computation for the one-way repeated measure analysis was accomplished utilizing IBM's SPSS version 26 Build 1.0.0.1275. The following steps represent both the computational output of this analysis as well as the explanation behind these findings.

First, Table 4 shows the descriptive statistics found within the study. In the aggregate, it is evident that between the two variables that the Leads inspection task has the higher of the two mean scores and a lower measurement of standard deviation. Of note however is that the average PS for participants in each training intervention exceeds the acceptable PS of 35, with only 1 participant scoring below the threshold on the Oil Filter task.

Table 4

Descriptive Statistics

	Mean	Std. Deviation	N
Oil Filter (VR)	42.06	4.943	17
Boroscope (PC)	47.18	3.877	17
Leads Inspection (PTT)	47.12	3.839	17

Testing normalcy assumption

Table 5 shows the Kolmogorov–Smirnov and Shapiro-Wilk test statistics, tests used to determine normality of the captured data set. When the tests are not significant, normality exists. For this study due to the sample size, we utilized the Shapiro–Wilk test as it is more suitable for small samples ($N \leq 50$)(Verma, 2016). Thus, a p-value within these tests of more than 0.05 is considered to be normal. Looking to the values of these tests in Table 5, it can be concluded that the data obtained for Boroscope (PC) and Leads Inspection (PTT) is nonnormal ($p < 0.05$), whereas normality exists for the data Oil Filter (VR) ($p = 0.432$). Below, three Q-Q Plots are provided for a graphical representation of each of the three variables. Each dot depicted on the graphs represents a specific score relative to the normal distribution, note how the PC and PTT plots show fewer values due to participants sharing identical performance score values.

Table 5

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Oil Filter (VR)	.182	17	.137	.948	17	.432
Boroscope (PC)	.296	17	<.001	.755	17	<.001
Leads Inspection (PTT)	.297	17	<.001	.732	17	<.001

a. Lilliefors Significance Correction

Figure 16

Normal Q-Q Plot of Oil Filter (VR) Performance Scores

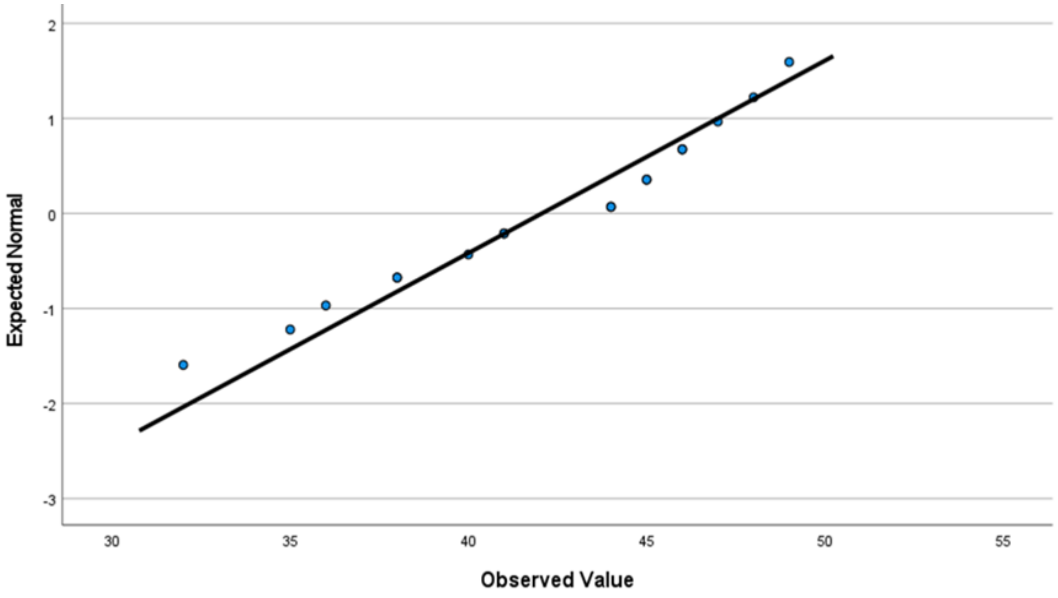


Figure 17

Normal Q-Q Plot of Leads Inspection (PTT) Performance Scores

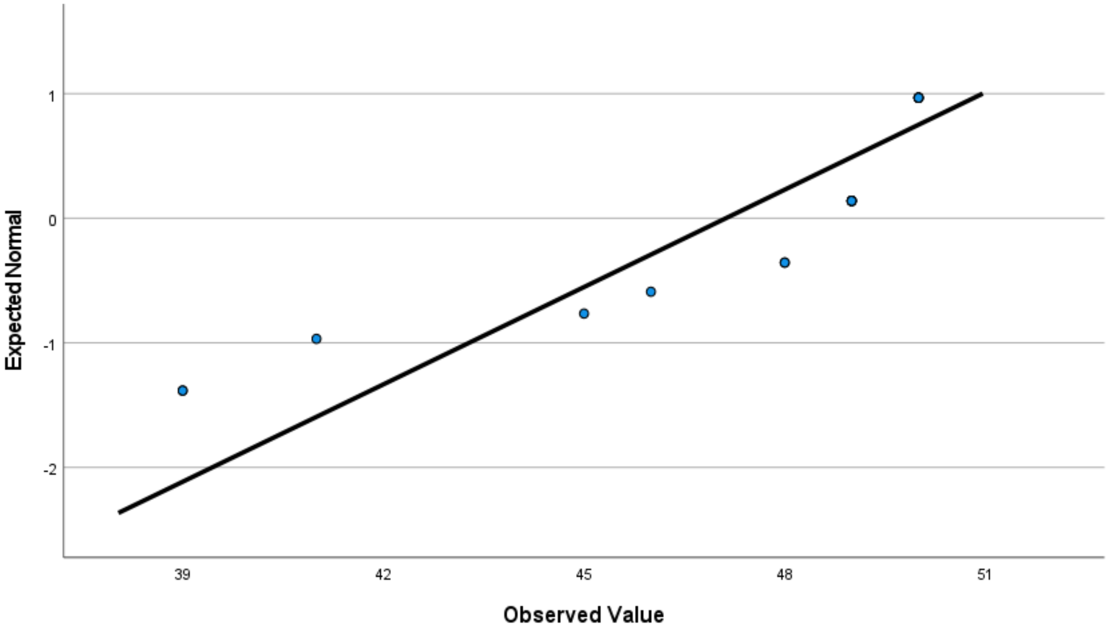
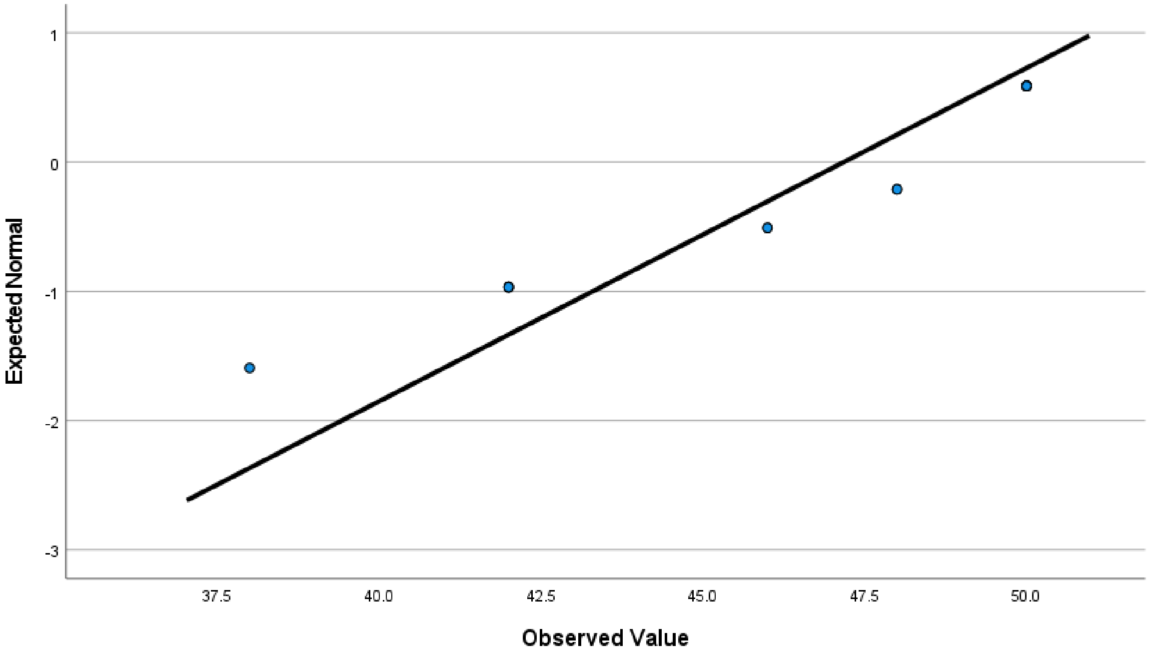


Figure 18

Normal Q-Q Plot of Boroscope (PC) Performance Scores



Testing sphericity assumption

The sphericity assumption is one of the main assumptions made in repeated measures design. Utilizing the sphericity assumption is how treatment and error variances can be compared by computing the F value. That is not to say there is not a means to correct for a sphericity assumption violation. If such a violation is represented within the initial analysis, then a correction in the dataset's degrees of freedom is made while testing the significance of F value.

Table 6 shows the Mauchly's test for sphericity as performed within SPSS. As evident through the test for sphericity, the test is not significant because the p value associated with the $\chi 2$ is 0.246 which is greater than 0.05. Thus, in this case the significance of F value will be tested by assuming sphericity and without doing any correction in the degrees of freedom of treatment and error terms.

Table 6

*Mauchly's Test of Sphericity **

Measure: Performance_Score

Within-subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon **		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intervention_Type	0.83	2.803	2	0.246	0.854	0.946	0.5

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
* Design: Intercept
Within-subjects Design: Intervention_Type
** May be used to adjust the degrees of freedom for the averaged tests of significance.
Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Testing significance of treatment effect

In terms of the significance of the treatment effect, training intervention type, the F value is significant due to the associated p value of F is <0.001 which is less than 0.05 as shown in Table 7. The partial Eta Square of 0.565, a moderate value, shows that training intervention was meaningful to performance score during the Performance Evaluation.

Table 7

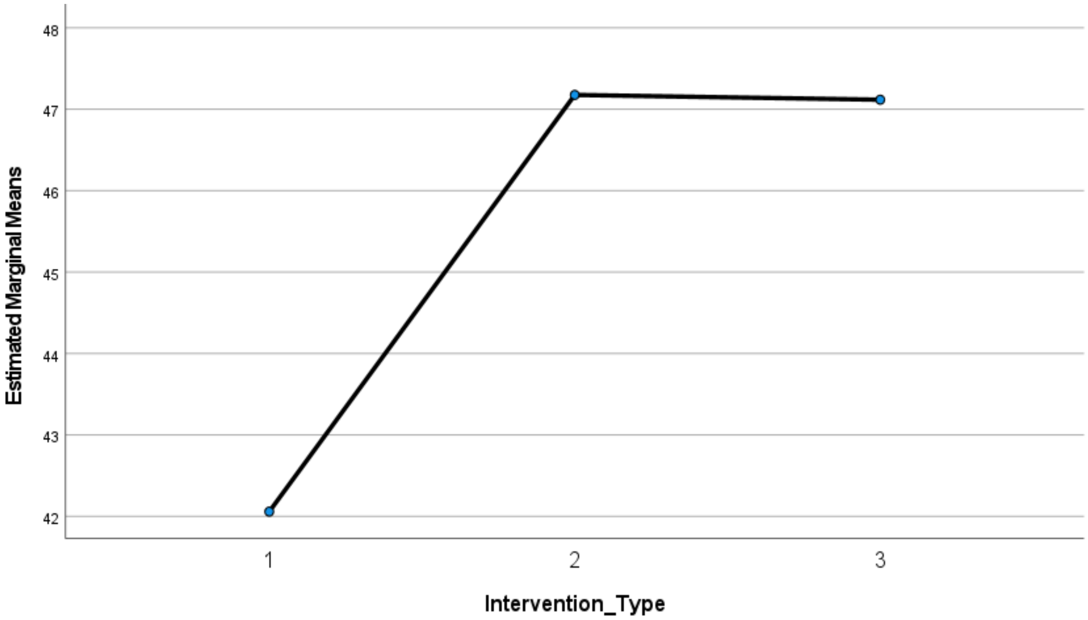
Tests of Within-Subjects Effects

Measure: Performance_Score

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intervention_Type	Sphericity Assumed	293.451	2	146.725	20.786	<.001	0.565
	Greenhouse-Geisser	293.451	1.709	171.73	20.786	<.001	0.565
	Huynh-Feldt	293.451	1.893	155.041	20.786	<.001	0.565
	Lower-bound	293.451	1	293.451	20.786	<.001	0.565
Error (Intervention	Sphericity Assumed	225.882	32	7.059			
	Greenhouse-Geisser	225.882	27.341	8.262			
	Huynh-Feldt	225.882	30.284	7.459			
	Lower-bound	225.882	16	14.118			

Figure 19

Estimated Marginal Means of Performance Score



Pairwise Comparison of Marginal Means

Post hoc tests are not used within repeated measure designs, therefore no option for such tests is available within SPSS. Regardless, as the F value has been found to be significant, paired t tests are applied to compare each pair of the group means. This action, the multiple comparisons of means, causes an error rate 0.05 across the treatment effects. To compensate for this error, a correction is used known as the Bonferroni correction. The Bonferroni correction adjusts p value for testing the significance of individual treatment F statistics represented in Table 8.

Table 8

Pairwise Comparison

Measure: Performance_Score

(I) Intervention_Type	(J) Intervention_Type	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for	
					Lower Bound	Upper Bound
1	2	-5.118*	1.074	<.001	-7.989	-2.247
	3	-5.059*	0.755	<.001	-7.076	-3.041
2	1	5.118*	1.074	<.001	2.247	7.989
	3	0.059	0.876	1	-2.284	2.402
3	1	5.059*	0.755	<.001	3.041	7.076
	2	-0.059	0.876	1	-2.402	2.284

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
**. Adjustment for multiple comparisons: Bonferroni.

As such, the significance of difference between group means has been tested at the usual 0.05 level because the Bonferroni correction enhanced the p value accordingly. From Table 8 that the difference between the group means of intervention type 1 (OilFilter VR) and both treatment 2 (Borescope PC) and treatment 3 (Leads Inspection PTT) are significant because the significance value associated with these two t values are each 0.000 which are less than 0.05. However, no significant difference is found between the treatment 2 (Borescope PC) and treatment 3 (Leads Inspection PTT).

RQ 2 – What perceptions, preferences, and expectations do participants bring into and take away from the study's instructional experiences?

While the findings found within the quantitative section of this analysis are significant in their own regard there were several elements discovered held within the lived experiences of the participants which helped shed a better light onto the study's results. As such, the study put forth a series of questionnaires and an interview protocol featuring open-ended questions. The findings within this section expressed through discovered themes, help provide greater context to both the learners who participated within this study as well as the feedback to the instructional intervention itself.

Questionnaires and Interviews

While the findings found within the quantitative section of this analysis are significant in their own regard there are undoubtedly elements held within the lived experiences of the participants which help shed a better light onto the study's results. As such, the study put forth a series of questionnaires and an interview protocol featuring open-ended questions. The findings within this section help provide greater context to both the learners who participated within this study as well as the feedback to the instructional intervention itself.

Pre-Questionnaire

As described within the Procedure section, after the participants had gone through the initial Present portion of the study's instructional design a 10-question background questionnaire was administered via Google Forms. The questionnaire aimed to assess the participants' predisposition to immersive media devices, gaming platforms (interest, previous use, frequency of use), mechanical predisposition as well as basic demographic information. Demographic data placed all participants in a range of ages from 18 to 29, and the gender of the participants was split with five of the seventeen participants being female. As prescribed by the study's inclusion criteria all participants were enrolled within the universities Aviation Maintenance Science program and had yet to take Turbine Engines, a powerplant course which would have given participant experience in the study's chosen tasks.

Within the questionnaire, several questions were aimed at determining the familiarity and comfort with gaming platforms and systems. When asked how often do participants play on computer-based video games with either mouse and keyboard or gaming controller 10 or 17 particpants' indicated play at least once a month with 6 of the 10 stating they played games daily. Of the participants who indicated little to no game play in their repsonses 3 of the 7 participants indicated they never played computer-based video games. Dovetailing into this dataset, when participants were asked whether or not they owned a video game console, 11 of the 17 participants indicated they did not. All 6 participants who indicated daily play of computer-based video games additionally indicated they owned a gaming console. To complete the initial set of questions surrounding the practical familiarity with gaming consoles and computer-based video game play, I asked participants how familiar they were with the use of modern video game controllers. Use of said controller was a required element of the study's virtual reality option and thus knowing how familiar with controller used experiences was seens as a critical element in the design of the instructional task. Of the 17 participants, 13 of the participants agreed or strongly agreed that they were familiar with gaming controllers. Those not agreeing with familiarity were split between neutrality, 1, disagrement 1, and strong disagreement 2.

Figure 20

How often do you play on computer-based video games with either mouse and keyboard or gaming controller?

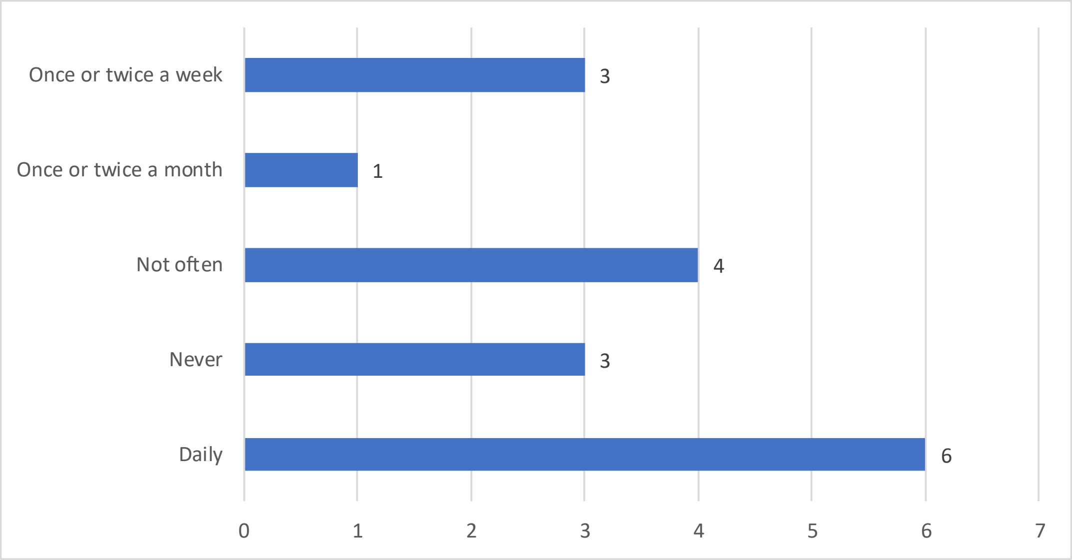
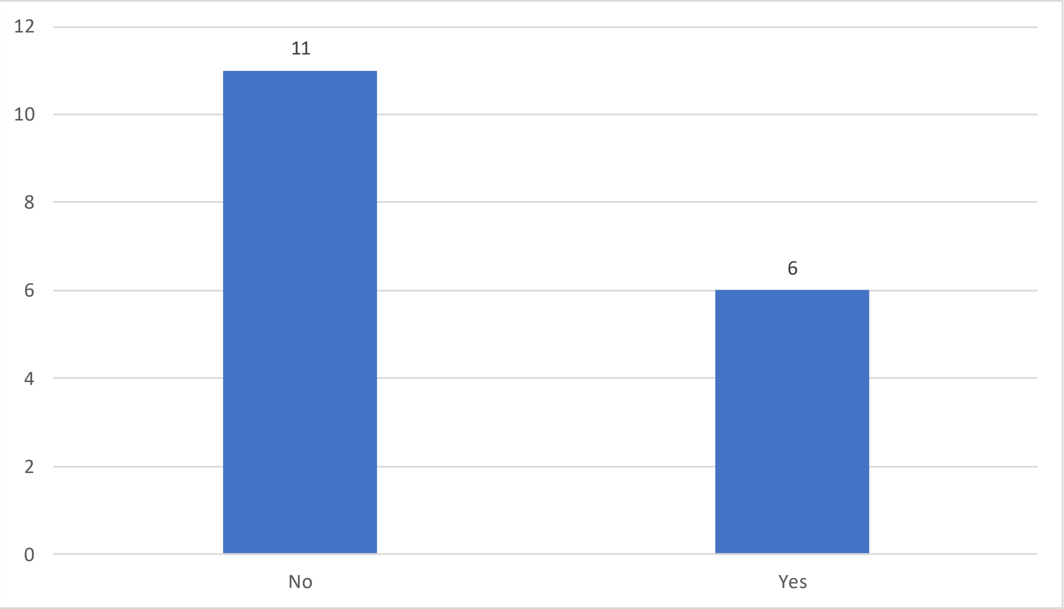


Figure 21

Do you currently own a video game console?



Up unto this point the questions asked had been generically surrounding the use of computer-based video games and their respective elements. The next segment of questions focused on the use of virtual reality itself, with the differentiation now that virtual reality could include non-game-based experiences. The first two of these questions represented a repetition of the initial two questions, first asking how often participants utilized virtual reality and whether or not they owned a virtual reality console. Not surprisingly both of these measures showed that both regular use and ownership of virtual reality products was much lower than general computer-based video games. When asked how often participants used virtual reality experience or games, 13 of the 17 participants stated they had either never used virtual reality (3) or that they used it not often (10). There remained only one participant who indicated they were using VR on a weekly basis.

Figure 22

I am familiar with using a gaming controllers (example: X-Box, Playstation, or the like)

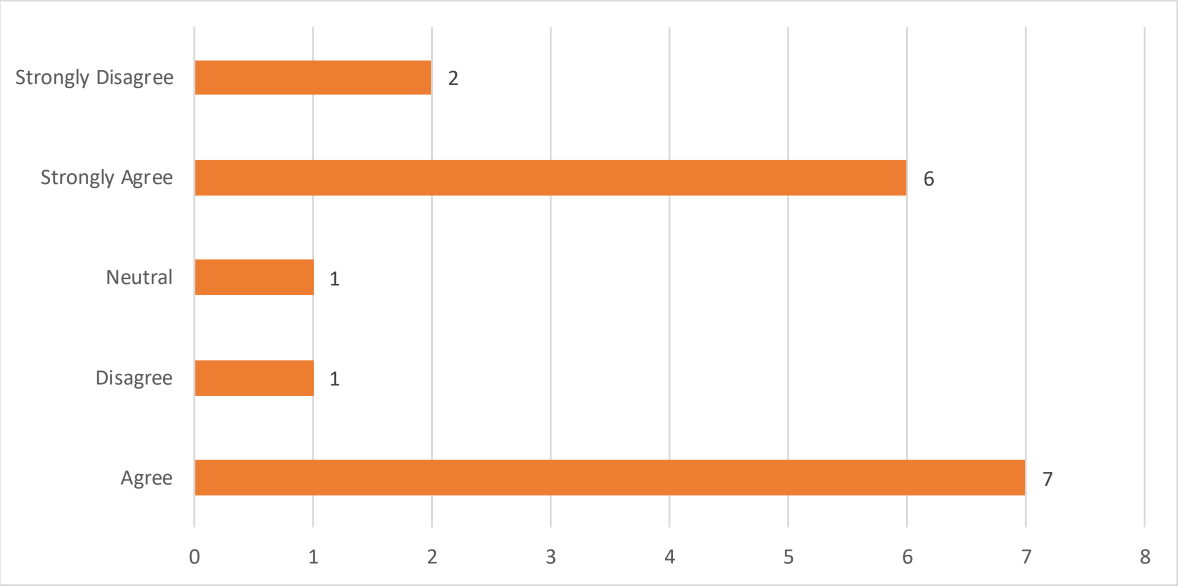
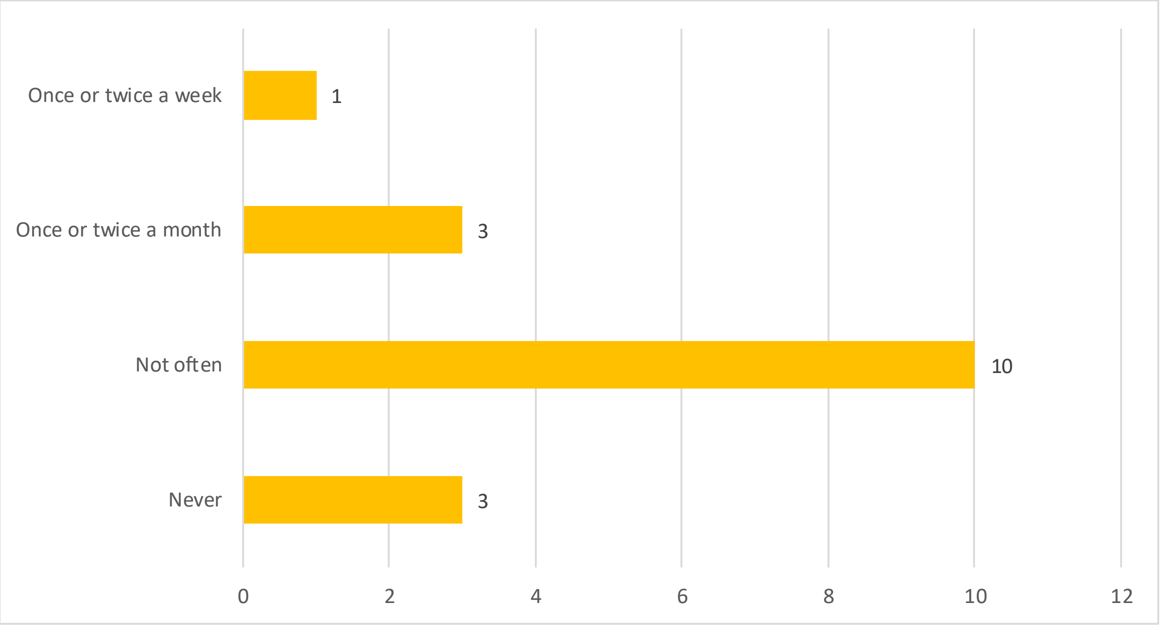


Figure 23

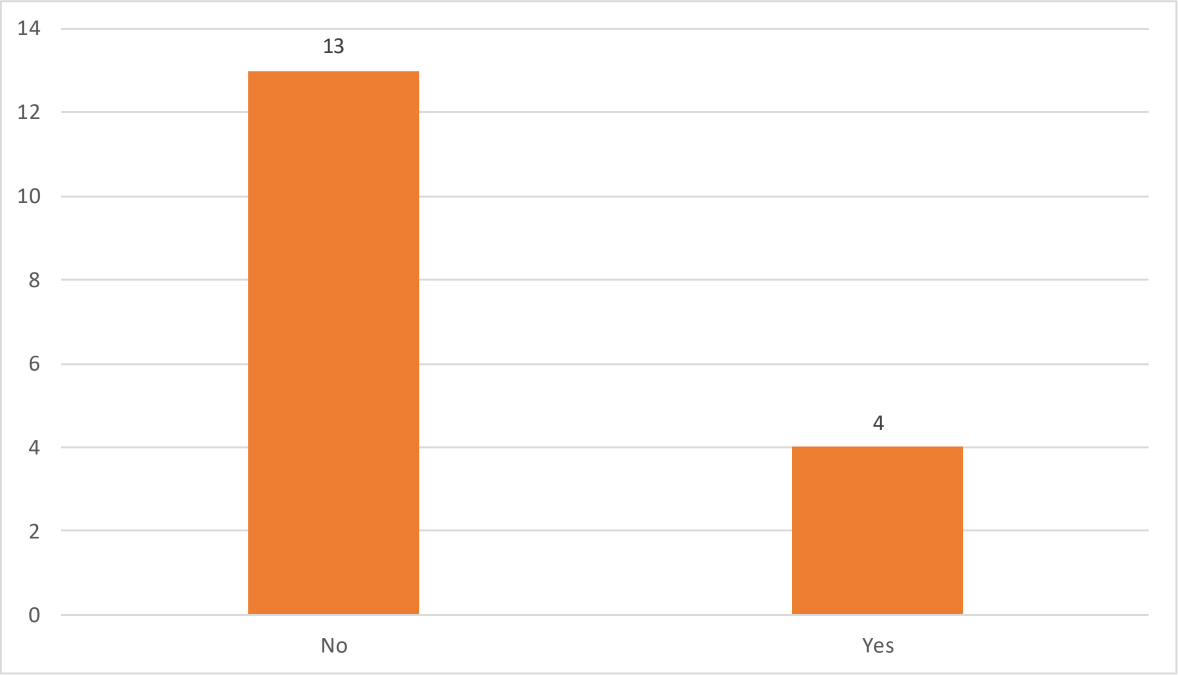
How often do you participate in virtual reality headset experiences or games?



As expected, these lower numbers of participatory use also seemed to coincide with lower levels of VR console ownership, with 4 of 17 participants indicating they owned a VR console (headset).

Figure 24

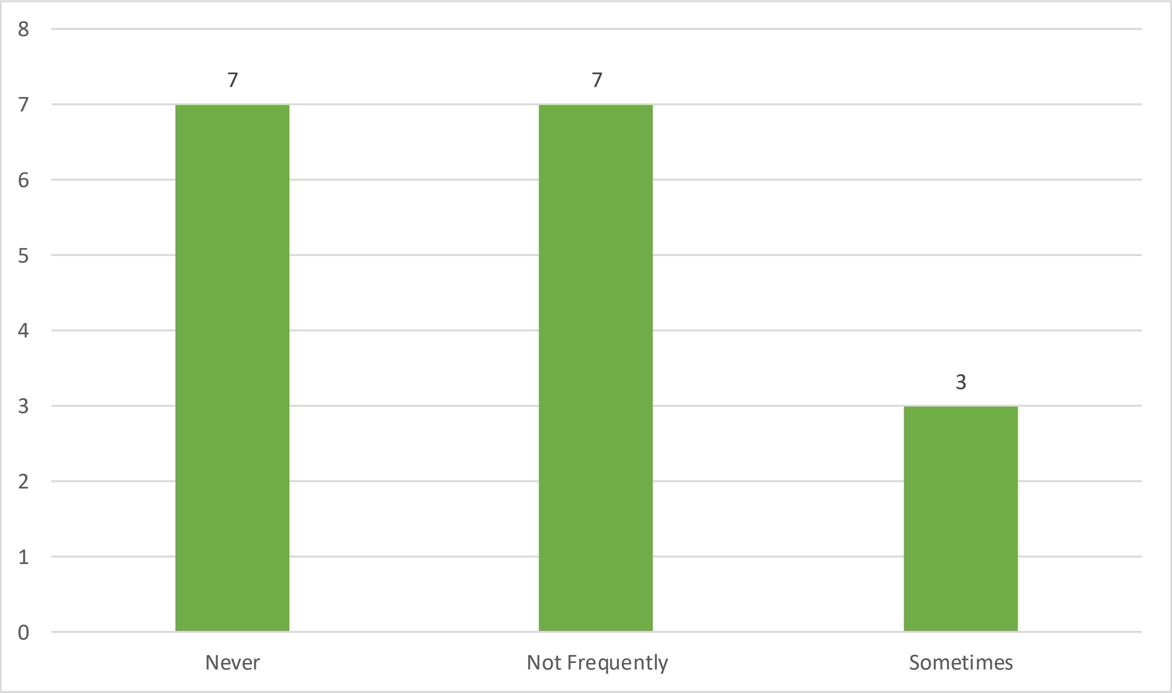
Do you own a VR headset?



The final VR question centered around motion sickness, a characteristic often brought up in the conversation surrounding virtual reality both within academia and professional practice. The question served two functions; one being a preparatory allowance for the researcher team to prepare for any who self-identified as being prone to motion sickness, the other to establish a baseline for how participants' predisposition to motion sickness ultimately compared to the study's virtual reality experience. 14 of 17 participants stated they either never or not frequently get motion sickness, with three participants indicating that they were sometimes prone to motion sickness. No participants selected the other two available options, those being frequently and almost always.

Figure 25

I am prone to motion sickness



The final two questions included within the prequestionnaire, focused on mechanical predisposition. While all participants included within the study brought with them some level of mechanical experience from the introductory courses included within the Aviation Maintenance Science (AMS) curriculum to which they were enrolled, we were particularly interested in how regularly mechanical tasks were being performed within the participants lives and to what types of experiences these activities constituted.

When asked how often respondents participated in maintenance type activities, most of them indicated maintenance type activities were a regular part of their daily life with 15 of the 17 answering at the daily, once or twice a week, and once or twice a month level with each level receiving five responses. The other two individuals split the remaining options at one a piece, that being that they had never or not often participated in maintenance type activities.

Delving further into mechanical predisposition is the final question which aims to further clarify the specific maintenance type activities they were routinely participating in. For this question participants were given a series of options they could select from, with the ability to select as many options as possible which applied including the option to select others and provide free form text. Almost half of the participants indicated that they had had previous experience working on automobiles and motorcycles (8), with working on robotics and woodworking coming in closely behind at 6 and 5 respectively. Four participants had indicated they had specific previous aircraft experience, three of which specific to the military and one being a non- certificated repairman on a passenger carrier aircraft.

Figure 26

Prior to enrolling in AMS program how often did you participate in maintenance type activities (tinkering, fixing, repairing)?

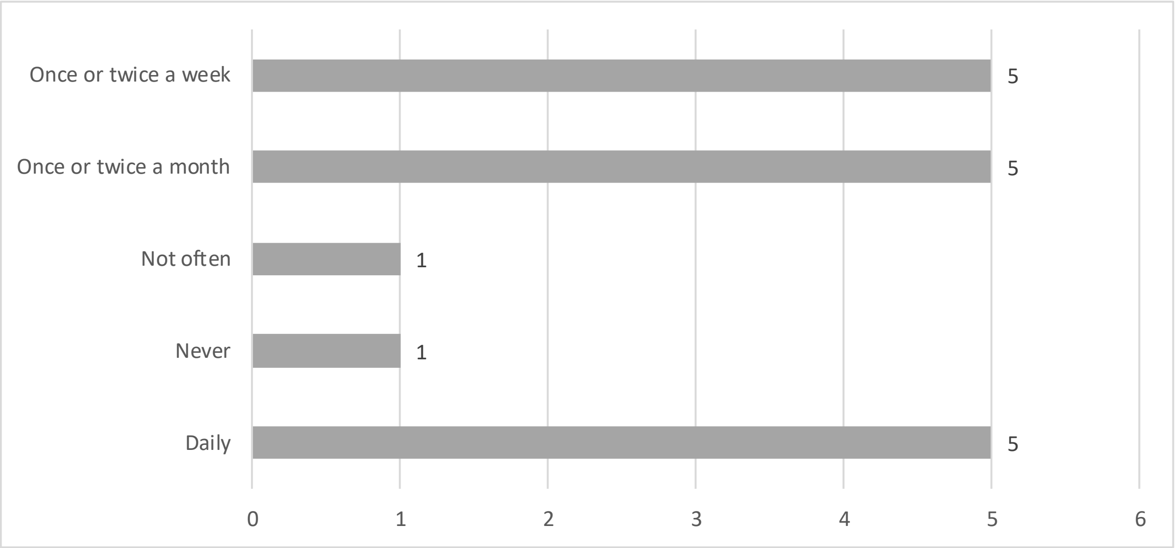


Figure 27

I have experience in the following activities (select all that apply)

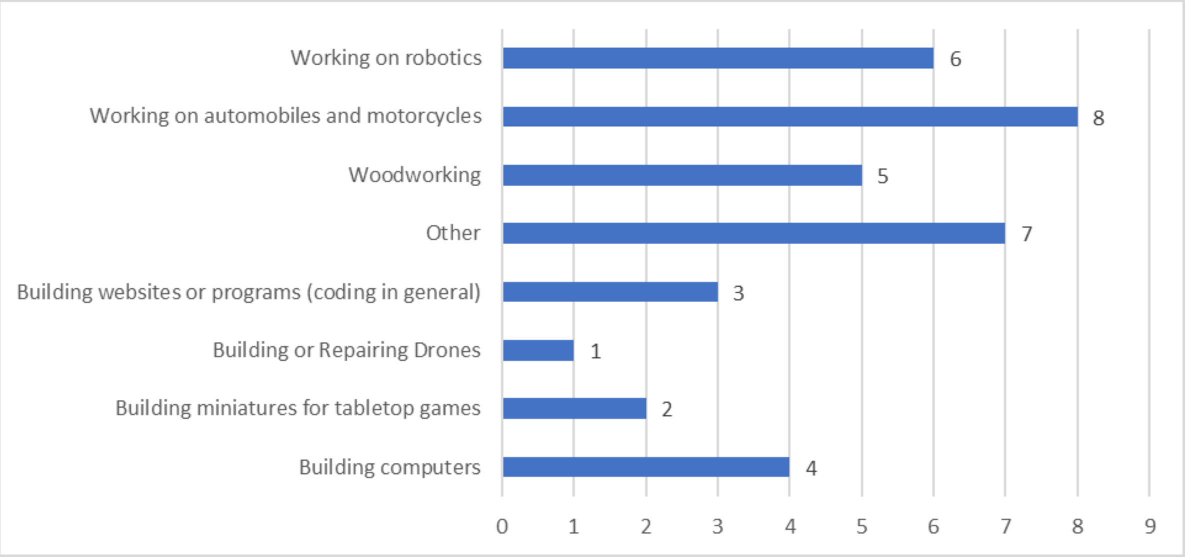


Table 9

Activities included in 'Other' categorization

Other Category Activitiy
Avionics in the military
Graphic design
Built experimental aircraft
Aircraft maintenance on F-35s
Working on ATR 42-600 and 72-600 aircrafts
Working on UH-60 Helicopters
Explosives work (non-electric, electric, improvised, firing systems)

Post Questionnaire

After the completion of the performance evaluation each participant was then asked to respond to a 13-question survey which focused on the user experience of the VR training intervention, the perceived preparedness heading into each of the transfer tasks, and then ultimately the participants' interest in using each training intervention again. For this questionnaire, a 5-point Likert scale was applied to 12 of the 13 questions, with the final question being a ranking of intervention preference. The five-point Likert scale selection was made via Google Forms, selected options were displayed 1 through 5 with 1 being represented as 'Strongly Disagree' and 5 being 'Strongly Agree' at the scale's terminuses.

The first set of questions acted as follow up questions to the prequestionnaire specifically surrounding the user experience with virtual reality. First, when asked if the headset driven VR experience gave the participant a level of motion sickness or general discomfort 14 of the 17 respondents gave the answer of strongly disagree (1) with the remaining 3 individuals each scoring the question as a 2, indicating disagreement. Following this question, the participants were asked to rate the VR training experience's ease of use and control intuitiveness, mirroring the pre-questionnaire's item surrounding game controller familiarity. In this case, there was a more varied response, though overall continued to be quite positive. Out of the 17 respondents 15 indicated high levels of intuitiveness and ease of use with 6 strongly agreeing. The remaining two participants split between a score of 3 representing neutrality and a score of 1 representing disagreement with the questions' statement. Finally, when asked as to whether participants felt VR met the training expectations, we again saw 15 of the 17 respond positively with 6 participants strongly agreeing. Again, the remaining two participants split between a score of 3 representing neutrality and a score of 1 representing disagreement with the questions' statement. In this finding we found participant answers between the last two questions were identically placed.

Figure 28

The headset driven VR Experience game me a level of motion sickness or general discomfort

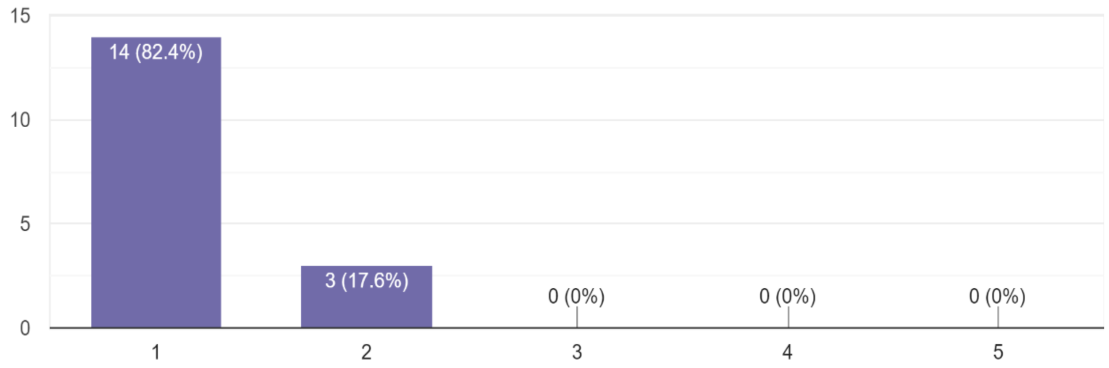


Figure 29

The headset driven VR Oil Filter activity was easy to use and controls were intuitive

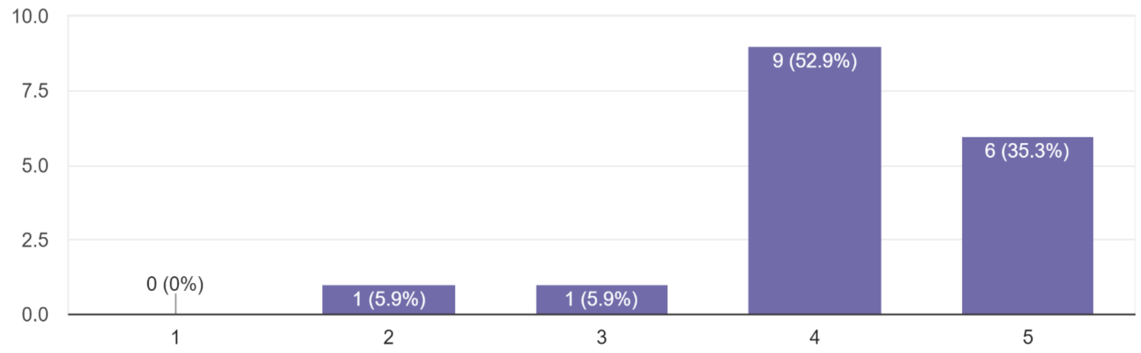
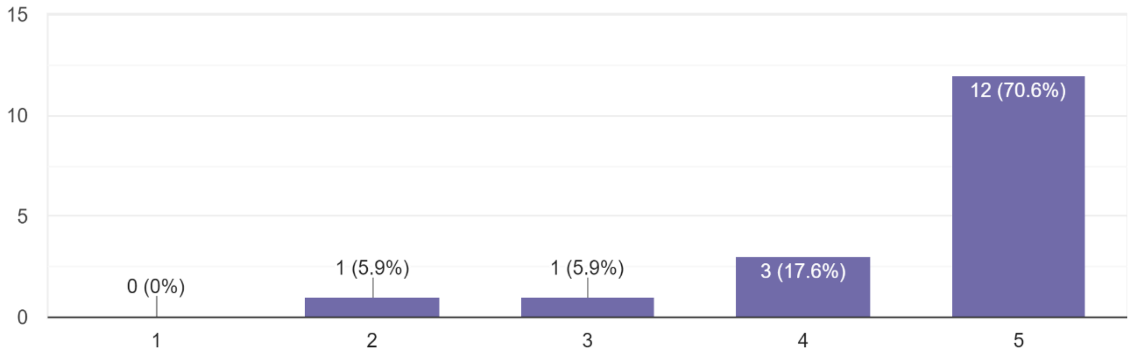


Figure 30

The VR based experience meeting training expectations



Next the participants were asked about their perceived preparedness heading into the performance evaluation also known as the transfer task. For the Oil Filter Task all participants either agreed or strongly agreed that they felt prepared for the task, with 8 participants scoring at the strongly agreed level. For the Leads Inspection task, the responses while slightly more varied still came through with overall agreement. Out of the 17 participants, 14 responded that they strongly agreed with the question's statement, with the remaining 3 participants splitting between agreement (2) and neutrality (1).

Figure 31

I felt prepared to perform the ignition lead task

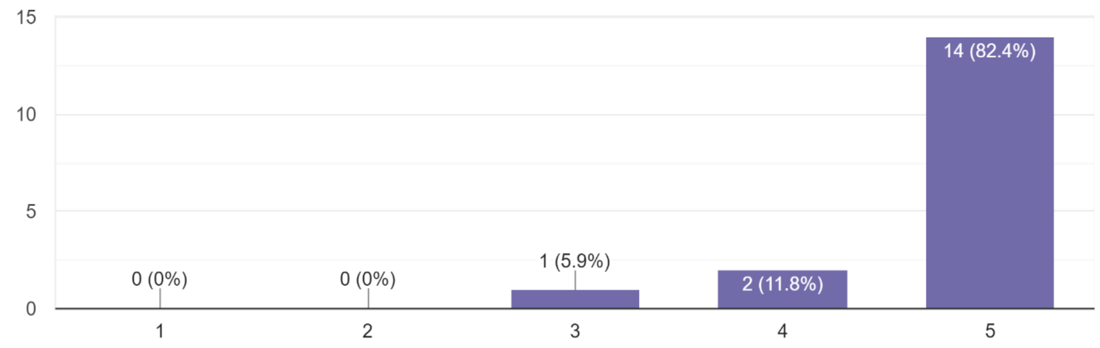
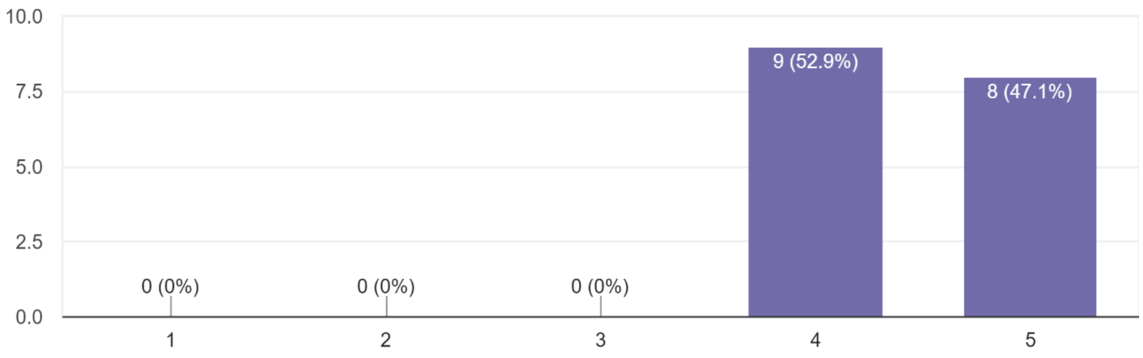


Figure 32

I felt prepared to perform Oil Filter Task



"

Finally, the respondents were asked about their relative interest in participating again with the study’s various intervention types and their preference for future trainings. Each intervention type saw high levels of interest for future use with the Part Task Trainer being the highest among the two receiving 15 of 17 ‘Strongly Agree’ responses.

Figure 33

I am interested in using the Part Task Training experience again

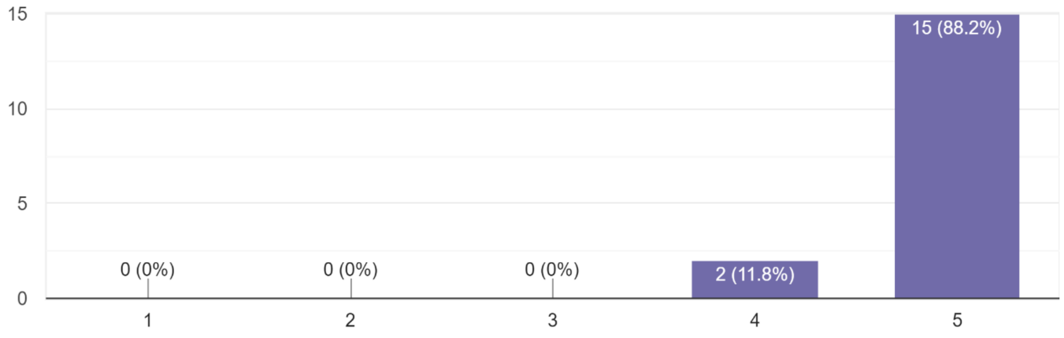
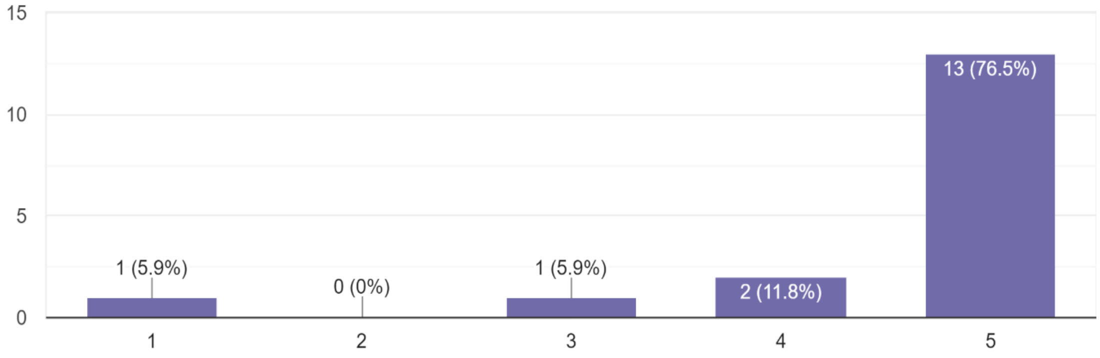


Figure 34

I am interested in training using the headset VR experience again

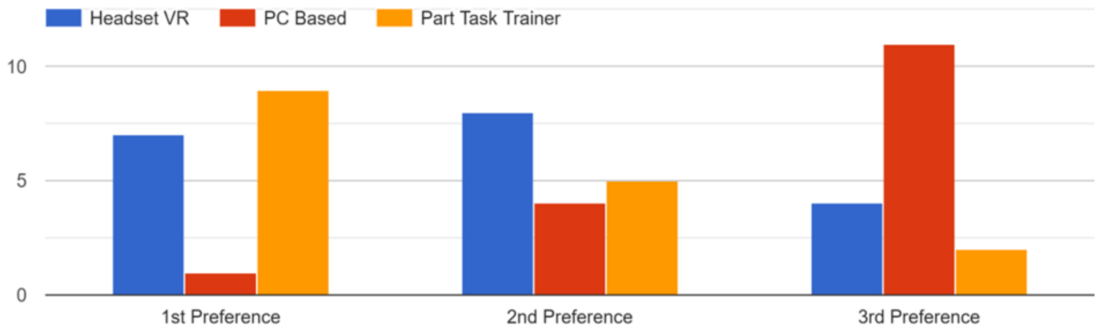


The VR experience also saw a high level of interest for future training scenarios however there were participants who felt both neutral (1) and strongly negative (1) toward their future interest in the intervention.

These findings are then further corroborated with the final question of the questionnaire when participants were asked to rank their preference of intervention for future training experiences, in which Part Task Trainer received the most first preference votes, followed by Headset VR and finally PC Based which was otherwise not included within this study.

Figure 35

Rank of future training experience preference



Open-Ended Interview Responses

The open-ended interview represents the final element of data collection within this study and was fittingly acquired as the last element of the research design. The interviews themself were conversational in nature and took the form of a reflection on the study as a whole. Eight questions were asked of each participant. Several of these questions mirrored questions set forth in the two questionnaire activities to help give further context to respondent answers and clarify answer nuances. Other questions were more exploratory, looking deeper into how participants felt about the study’s training experiences and their thoughts about the future of aviation maintenance training experiences.

The first questions asked whether participants had always liked working with their hands, tinkered with things, or enjoyed fixing things and whether or not they had any jobs or had done any projects which they felt related to their maintenance skill set. This question is contextually related to the pre-questionnaire’s final two questions surrounding mechanical predisposition.

Within the responses to these questions there appeared a clearer picture to the schema which made up the participants’ backgrounds in mechanics in general. Many of the participants (12 of 17) indicated that fixing and tinkering with things had been essentially a lifelong pursuit with respondents using words and phrases like, “I’ve been doing it [fixing things] as far as I can remember”, “since I was a kid”, “lifelong path.” These statements appeared to indicate that mechanical thinking and hands-on maintenance work exist as a passion established earlier in the life of respondents prior to their time in school. From the second question within this pairing there are hints to suggest that this ‘passion’ stems from the home environment with many participants (9 of 17) mentioning some element of their upbringing such as, “working on a car with my father,” or “they had this program at the library when I was a kid.” An unexpected finding within this set of questions was the number of people who had highly technical backgrounds in the military had, 5 of the 17 participants when asked the second question spoke of their military experience within aviation. This was an unexpected finding for the study as the selection criteria for inclusion of the study was based around the participants placement within the university’s AMS program. This will be discussed further within the following chapter as a limitation of the study’s design.

The following three questions of the interview protocol also centered around adding context to the pre-questionnaire this time surrounding the concept of video game predisposition. Participants were asked to clarify whether they would consider themselves to be a gamer, what types of games they identified as being their favorite, and if they had used virtual reality before expanding the question to include experiences outside of gaming.

This first of this block of questions was helpful in that the questionnaire focused on whether or not participants were playing games often, and if they owned a video game console. These are matters of a certain level of objectivity to the participant, whereas asking if someone is a gamer is more about personal identity. Less than half the respondents identified as being a gamer (7 of 17) showing an interesting point about the participants' perception of gaming and perhaps what constitutes a gamer, as from the quantitative data more than half report regular video game play (10 of 17). It is possible this has something to do with the types of games the participants are regularly playing. When asked what type of games people are playing the answers fell into three camps; solo adventure type games like "Skyrim", "Zelda", and "Hollow Night", first person shooter games (FPS) like "Call of Duty", and team games mostly centered around the social element of play. Several participants specifically connected the FPS game type and the social element of game play, but this combination was not uniform throughout the group, and others who mentioned social play did not specifically mention game titles.

As with the previous questions, the next questions sought to add further context but this time focusing on elements from the post questionnaire. First, participants were queried on how prepared they felt heading into the evaluation event. Overall, most participants mentioned some level of confidence heading into the evaluation event, participants used phrases like, "I could remember everything I was supposed to do," and "I felt pretty confident going into the actual hands-on stuff," and "pretty well prepared." Of specific interest however to this study's overall design and analysis was just how often the video presentations (Present phase of DI) came up in conversation. A majority of participants (13 of 17) mentioned the videos when answering this question. Statements included things like, "…the online training videos were really similar to that [the task], and then I also had like the VR based experience. So, once I was actually doing it, I actually knew what I was doing," and "I don't think I'd work figured it out if I didn't have a video watch," and "I didn't pay attention as well as I should have for a couple of the videos."

The final two questions added changes to the wording of the post questionnaire element to emphasize the question's focus onto the individuality of the participant. In these questions, I asked participants to reflect on their individual experiences throughout the study and comment on their preferences. The first of this final set of questions sought out the participants' opinions on virtual reality now that they had gone through this specific VR experience. Overall, the opinions of the participants seemed mixed on just how useful the virtual reality really was for them in terms of learning new material. The majority of participants (15 of 17) discussed how the virtual reality was, "a good way to get experience," or "gives you the general idea," giving general statements about the technology itself but paired with this was a nearly universal sub context said in both words and viewable attitudes that it was "…pretty good, like if you if you don't have access to like the actual equipment, you can familiarize yourself with like VR."

` Finally, aligning with the post questionnaire's final question, I asked the participant to comment on what they felt would be an ideal training experience in the future. Each time, I used one to two minutes to describe a short scenario to the participant where the participant one day would be working within the profession and would be sent to training. The scenario question then asked participants to describe what they would like to see training look like. Participants largely stuck with the selections they had made in the final question of the post training questionnaire which saw hands-on training be selected as the most preferred future training choice. However, beyond this continued finding, a new finding centered around the video presentation and sequencing of training events. Twelve of the seventeen participants indicated that video presentations, like the ones used in the Present phase are highly expected. Many participants even commented on how the way videos were made aided in future task comprehension saying things like “I think the videos in the online course were good because it had someone walk you through it and it was a person as opposed to a robot,” and “There's like a threshold of people that can watch somebody do something, but I think the videos y’all made were good, like YouTube.”

Coding and Outcomes

I did not enter the analysis of the open-ended interview protocol with an a priori list of codes to evaluate from. Due in part to the relatively unexplored context of this study’s inquiry I felt it most appropriate to allow codes to emerge during the various phases of analysis. My overall approach to coding the interview response was derived from the two cycle processes outlined by Miles, Huberman, and Saldana (2020). Miles et al. posit that codes are primarily used to discover, derive, and group segments of information relevant to a researcher’s path of inquiry. These groupings then set the stage for further forms of analysis. As such, I used a two cycle or two-phase coding process representing a combination of In Vivo and Descriptive coding to then derive patterns and determine overall themes.

First, In Vivo coding was specifically employed so as to leverage the language and terminology the participant themselves used during our conversations. During the interview process I would occasionally write in my field notes times when specific words or phrases were used to express specific meaning relative to the interview question and the study's context. I then would later compare these words to the interview transcript documents of both the speaking participant and the others to see if these words were repeated by other or if other specific words appeared related to be the same contextual meaning. I did this process manually as described without the use of any analytics software (i.e. NVivo). An example of this can be seen amidst the various terms participants used to describe their previous mechanical experience. These words included things surrounding each participant's upbringing and how they came to be interested in mechanical work. These word's often included mention of their parents, grand-parents, mentors, friends as well as words associated with mechanical activity occurring around the home, words like garage, shop, shed, tractor, project, etc. At the end of the first phase of coding I had 34 In Vivo based codes which like the examples previously described amounted to specific highlighted words from the participant's responses.

Not surprisingly however, when reading through the entirety of interview responses I recognized language used, tone, and incidental items like humor tended to cause respondent answers to diverge from specific words' plain meaning. As such, I employed a descriptive coding protocol to include not simply just the words spoken within the interview responses but also the sub contexts and illustrative meanings found behind the participants words. An example of this was the conditional language used surrounding VR. Many participants mention how the VR intervention was "pretty good" or "great" but then would often provide a conditional statement afterwards, thus lessoning the weight of the specific word choice. These types of language provided subtext beyond the plain word's spoken which better revealed participants' overall opinion on the VR experience. This phase of coding found a coalescence of the In-Vivo codes into new descriptive codes. For example, 7 of the In-Vivo codes associated with previous experiences in maintenance coalesced into the singular descriptive code labeled “life-long.” Additionally, 2 new codes had been found which had not been readily evident in the In Vivo stage. At the end of the second phase of coding, 12 Descriptive codes were identified.

After this process, I utilized Microsoft Excel to place the transcript information into a singular column. In the adjacent column I placed a drop-down menu to which I could select from the various codes I had identified. In the next subsequent column, I added items I made note of during the interview process via my handwritten field notes. I then compared these three columns collectively, writing a sentence or two that described the responses and my interpretation to the specific answers into a fourth column of the same spreadsheet. This process represents what Miles et al. (2020) define as the second cycle of the coding process. What emerged from this activity was a further coalescence of codes into four clearly defined themes. These themes included: passion for fixing, confidence in evaluation, VR as preparation but not learning, and the importance of video.

Themes

In examining the findings of the study through the lens of the second research question we discover a number of emergent themes which prove critical to the findings of this study.

A passion for fixing

In both the questionnaire and the semi structured interview, when asked how often respondents participated in maintenance type activities, the vast majority of them indicated maintenance type activities were a regular part of their daily life and oftentimes described it as being with them from an early age. When peering into the participants’ performance scores it would appear that those who indicated maintenance task doing as a lifelong activity, or a passion scored higher than the few who mentioned having very little to no previous maintenance task experience prior to enrollment in the program. This is likely to be expected as undoubtedly the schemas for participants who have been exposed to maintenance tasks will include nuance and behavioral attributes that new participants have not previously devised.

Confidence in evaluation

Regardless of background however, the study found 100% of participants' scoring within acceptable criteria for the performance evaluation tasks. And when queried about the evaluation task, all participants indicated high levels of confidence heading into the evaluation task regardless of practice intervention type or other predisposition. Of specific interest to the findings within this study however is just what made participants feel so comfortable heading into the evaluation, more than half the participants specifically used the words "very prepared" to describe their feelings about the evaluation task. A note of interest in this finding was just how little the experimental training interventions (the practice phase tasks) came up when asked about why participants felt prepared. Far more times than not, participants mentioned the training videos used within the present phase of the training experience with several participants making comments about how the video paired with the checklists for each task were the most useful elements in preparing for the transfer task. Additionally, participants who indicated any trepidation about one of the specific elements of the evaluation task universally mentioned that they had wished they paid more attention to the training videos, or it would have been good to have the training video available to them during the evaluation task.

VR as preparation but not learning

The previous finding pairs interestingly with the subtext found within conversations surrounding VR. While many participants mentioned how great the VR experience was, they often abstracted the usefulness of the experience beyond their personal preferences, saying things like “it would be great to have access,” or “certainly would help get access to the training equipment [engines],” or “I’m sure this could help a lot of people.” Each of these statements, and others, highlight what I perceive as a trepidation to accept VR experiences as actual training. It would appear that the students themselves see VR as somewhat of a novelty still, and not actually where people learn things. One might then conclude that it is not the practice phase that participants’ perceive as the place learning is achieved, but rather the present phase within the direct instruction framework. But the findings suggest otherwise. Participants routinely indicated they would prefer hands-on practice as training, mentioning it often as the thing they would expect and prefer heading into future training events. What this potentially means for virtual reality as a training intervention within this subject’s specific context is covered in a later chapter.

The importance of video

The most surprising finding within this study’s inquiry is just how critical video was perceived as an area of importance for the participants. The mention of video spanned across the semi-structured interview questions and was often the topic of self-guided statements indicating just how large an impact the video-based presentation phase was to the overall instructional design of the study’s interventions. Participants made direct comments about the video content sequencing, visual design elements, the use of the real-world tools, the narration, the video duration and even the ability to start, stop, and rewind the video easily. When asked what participants expect the future of training to look like, very few of them spoke of PC-Based gaming experiences or virtual reality, but most mentioned the use of video to discuss and prepare for hands-on maintenance work.

CHAPTER VI – DISCUSSION

In this chapter we discuss the results of the study and their potential implication to the greater world of aviation technician training and instructional design. To frame this discussion, we return to the study's multifaceted purpose by providing an overview of how this study and its instruments directly address the gaps found both within the aviation training industry as well as research in the field of instructional design. We then discuss the possible implications of this research to the greater field of instructional design with specific emphasis places on this study's experimental methodology. Which is then followed by a review of the study's various limitations. Finally, in this study's concluding arguments we cover the primary contribution of this study, along with suggestions for future research.

Overview of Findings

Addressing the Technician Shortage

The industry trade group ATEC, in their 2021 pipeline report posed a challenge to the industry at large (Aviation Technician Education Council, 2021). How do we train thousands of technicians over the next twenty years faster than we ever have at a lower cost and with less access to physical aircraft and components? This question is ultimately what nearly any instructional designer within the aviation industry is asked to currently solve. Interestingly, this very same question was asked a number of years ago but within the context of pilot training serving as the impetus for several seminal works. These works helped issue in the modern age of pilot training, which features more scenario based training, more flight simulation, and less flying actual airplanes (Combs, 2019; Hays et al., 1992; Homan & Williams, 1997). The same fervor which had once been seen within the literature surrounding pilot training for many reasons did not transfer to the training of maintenance technicians. The most common reasons cited within the industry for this disparity are the economics of the technician training footprint (Hammer, 2019), the state of available training technologies (Dyen, 2017), and until recently a broad surplus of qualified and available talent (Alba, 2020). As previously discussed within Chapter 1 of this work, these variables have changed in recent years and the industry now looks to researchers to answer a simple question. Can you do aircraft maintenance training without the aircraft?

The results of this study indicate the answer to this question to be in the affirmative. In this study we were able to see nearly all participants perform above industry established acceptable performance standards on real-world aircraft transfer tasks without the aid of a real-world aircraft or physical practical task training device during the performance evaluation task measured via near transfer. But tied with the confirmation of capability to do such activities there exist some very notable caveats which undoubtedly affect the ability to implement fully virtualized training within aircraft technician training contexts. Elements which must be duly accounted for should anyone consider implementing elements of this study's design in a practical case. For one, it would appear that participant background and comfort with mechanical tasks, in this study known as mechanical aptitude, is highly critical in a participant's overall success regardless of training intervention type. As in, performance score while not completely correlative to mechanical predisposition does seem to be highly connected and a leading indicator in expected success of participants during evaluation tasks within this study. This puts forth a number of challenges to the overall industry and to the role of education itself in exposing students to this line of technical work.

Next, while it is possible to do training without the engine, this does not indicate it is as effective. In fact, the study very clearly shows the DI experience featuring VR is less effective in terms of training transfer during the evaluation task. Despite the lesser effectiveness of the DI experience including the VR practice task comparative to the study’s counterpart, it should be noted that the performance scores of the Oil Filter task (the DI experience including VR) were still well above the acceptable thresholds in the transfer tasks. This, in some ways, was to be expected as real-world hands-on activities are still considered by many to be the gold standard for technical training (Li et al., 2009; Marsick, 1990; Watkins et al., 2013). The fact that the transfer task scores for the virtual reality tasks are as close to the real-world hands-on scores shed light on two potential findings. One is that the VR training tools of today, as used within this study, may be advanced enough to sufficiently represent real world training task experiences. The second would be that VR training tools can be successfully implemented when set within holistic instructional approaches, as has been done in this study’s use of Direct Instruction.

Ultimately, in answering whether or not we can do engine training without the engine this study has discovered evidence to strongly suggest the ability to perform this type of training is less reliant on the technological choices of the various training interventions as posited by Rupasinghe et al., (2011) but more so in more so in the design of the overall instructional experience effectively confirming the long standing view of Clark and his counterparts within the great media debate (Clark, 1983; R. Kozma, 2000; R. B. Kozma, 1994).

The use of Direct Instruction

Central to this study’s purpose was the evaluation of two parallel instructional experiences set within the same instructional framework. The results of this evaluation were statistically significant, in that all participants performed above industry established performance standards on the real-world aircraft regardless of the differences set within each intervention’s Practice phase. This in and of itself is considerable finding, which appears to corroborate the views of previous researchers like Gagné and Gunter who each identified DI as an ideal instructional approach for work surrounding motor skills (Gagné, 1985) and vocational contexts (Gunter et al., 1990).

Furthermore, when we include the participant responses via the questionnaire and semi-structured interviews, we gain insights that move beyond just the intervention's Practice phases to rather include the whole of the two instructional experiences. Most prominent in this regard, are the participant responses surrounding level of preparedness heading into the evaluation task and instructional preference for future training interventions. In each of these domains, participants routinely emphasized the video elements used during the Present phase of the DI framework. Participants regularly commented on the helpfulness of the video interventions, and consistently mentioned how they expect future training experiences to include as much or more video presentation. This finding is juxtaposed with the very few individuals who specifically mentioned the use of VR as an expectation of future training experiences.

Secondarily, participants showed continued interest and preference to the non-virtual hands-on training experiences represented in the study's Practice and Perform phases. Within the survey and open-ended question responses participants regularly expressed how hands-on training (non-virtual) will be central to their expectations for future training. Interestingly, participants routinely included the self-guided activity performed on the Closed Trainer, the study's evaluation task, as an element of the instructional experience in their discussions. This indicates to some degree that participants saw even the evaluation element of the instructional design as a learning opportunity, which seems to corroborate previous research from Magliaro et al. (2005) and Rolf and Slocum (2021) who each described the value of the DI framework for encouraging real world transfer and mastery learning. It stands to reason that sequencing the instructional experience to have a culminating activity, featuring independent learner interaction, on the near to real life equipment was not only instructionally sound but also seen as desirable to the learning participants.

In review, the interventions designed for this study's purpose included the systematic development of self-paced, student-oriented objectives within both the present and practice phases of the experience and the use of self-guided mastery learning accomplished through the interventions' Perform phases; all of which exist as hallmarks of the DI framework (Magliaro et al., 2005; Rolf & Slocum, 2021). As such, when we consider the results of the study using this explicit design, we find empirical data which indicates DI to be a viable instructional framework for the aviation technician training context.

Near Transfer via Within Subject Repeated Measure Design

While these findings are notable within their own regard, it is quite possible that those within the field would see the claims made within this work as a new version of the often-maligned media comparison study outlined within Clark's (1983) seminal work. Paradoxically, it is my belief that this study instead provides scientific evidence *confirming* Clark's claims that media itself is not the thing to which to compare instructional experiences.

Within Clark's work, which has been added to and clarified several times throughout the years (Clark, 1986, 1990, 2009), a clear theme abounds. It is that media itself matters very little, but the design of instructional messaging, sequencing, contexts, and assessment parameters are paramount. Within Clark's original work (1983) and central to Kozma's rebuttal (1994) is a finding that perhaps the greatest reason for the inability to truly compare forms of media, and therefore many instructional experiences, is the lack of proper experimental controls and overall research designs. At the onset of this study's work, it was a principal goal of mine to address this very issue with the implementation of a novel research design.

In short, this study set out to evaluate the effectiveness of two parallel training interventions. And while it may be natural to compare the results of the quantitative analysis between the two interventions so as to determine which intervention was "more" effective this would be a logical fallacy. To Clark's initial and subsequent points these two instructional experiences are inherently unique to the user's experience (Clark, 1983, 1985). As such, rather than comparing the two instructional experiences to each other, this study has evaluated how each of the instructional experiences relate to individual participant performance relative to the established standards set within the industry. This was accomplished by quantifying the level of near transfer into a real-world task. Attempting to quantify near transfer addresses several long-standing calls from across the literature (Broad, 1992; Schoeb et al., 2021). As discussed throughout this work, the specific research methodology used to evaluate near transfer was a within-subject repeated measure design. Having now performed the study there are several elements that warrant further discussion regarding the use of the experimental methodology.

Firstly, there are a number of factors which must be considered when designing a within-subject repeated measures design which otherwise would not be considered in a typical between subject design. One such factor is that the independent variable used within the study must be categorical, either nominal or ordinal, and the dependent variable must be metric, either interval or ratio (Verma, 2016). This is of particular importance when a researcher begins to consider how items will be scored within the experimental design as non-categorical values will not provide appropriate values for analysis (Guimarães & Lima, 2021). Secondly, the sequencing of experimental events themselves is a sensitive area within repeated measure experimental designs.

As in, since every participant is going through each independent variable the timing and sequencing of these variables may be causing itself an independent effect. This is most commonly referred to as carryover effect or order effect, which refers to the improvement or decline in performance during the duration of the various performance evaluations (Shin & Park, 2019; Verma, 2016). Elements within this effect could also include learning effects or even simply general fatigue. To address and ensure there could be no carryover effect or learning effect from each of the practice tasks, counterbalancing was required during the evaluation of the treatments so as to minimize the effect of any systematic variance in the study (Dang et al., 2020; Sommerauer & Müller, 2014). Counterbalancing involves sequencing the evaluation elements of the study to account for carryover effect. Within the context of this study, counterbalancing was relatively easy to accomplish during the evaluation task however it may have been even better implemented if the sequencing of the practice training elements were also randomized. This possible improvement would have required participant additional time and introduced logistic challenges which were deemed unacceptable. Additionally, as the evaluation task was the only element with actual performance data being captured it represented the only place where counterbalancing was explicitly required.

Within the context of this study carryover effect was additionally minimized through the task selections themselves. When I was designing this study, I specifically sought-after tasks which would minimize learning or carryover effect. This was practically accomplished by reviewing the types of tools, actions, and even system locations for the two tasks used within this study and ensuring the tasks shared very little commonality in their respective actions without adding undue challenge to the tasks themselves. This was a challenging process and involved a significant amount of effort between myself and the instructional staff who assisted with the subject matter expert necessities for this study. In the end, the tasks selected were done so because they represented tasks which shared a common rubric, successful performance was well documented within existing curriculum, and ultimately the FAA authorized instructors deemed the tasks equally challenging.

An additional factor to address with the use of repeated measure design is the relative rarity of it within the research community. This in and of itself posed challenges in first the development of the study and ultimately, its analysis. While there do exist many examples of within-subject repeated measure experimental designs within the literature, the majority of them center around the use of differing levels of time as the independent variable, as this research design is especially useful in time-series experimental practices. This poses challenges for the researcher in performing analysis as there are few examples to build from.

Finally, within the literature there are certain characteristics which are listed as pros and cons of this form of experimental design. One pro is that a smaller total number of participants are necessary to achieve valid and significant experimental results, to which this study corroborates. A con which is regularly described within the literature is that studies of this type often require a large amount of time and are inherently difficult to practically carry out. I believe that this con is potentially well founded when discussing time-series studies as described above, for there are a number of research design factors which must be additionally accounted for in those types of studies. As for this specific study, it was an initial challenge for myself to convey the importance of including all the various tasks within the study's design to the instructional staff in coordinating the first steps of the study. Ultimately, the time it took to perform the actual study represented approximately 4 total hours of participant time generally spread over 2 days. While this did represent a significant time investment for myself and the participants themselves, it was not a challenge to acquire participants, nor allocate enough time within the confines of an academic calendar to perform the study itself.

Overall, the results of this study confirm that within-subject repeated measure design (Creswell & Creswell, 2017; Verma, 2016) can be used to evaluate the efficacy of individual interventions for a group of individual learners. This is an available, repeatable, experimental design set within an instructional design context that avoids comparing the efficacy between two disparate learner groups, squarely addressing many of the concerns put forth by Clark and others (Clark, 1983; Clark & Feldon, 2014; R. B. Kozma, 1994).

As such, I find the results of this work to be largely confirmatory of Clark's initial concepts on the study of media. Yes, while the findings between the performance scores for the study's two parallel tasks are statistically significant, when looked at through the practical lens of the industry's established performance criteria both interventions performed exceptionally. I find this to be a more logical method of considering differing training interventions within a research setting, in that training interventions themselves rarely can be considered as a singular variable for comparison. Additionally, these results provide evidence to suggest new or novel training interventions, like the VR training experience utilized within this work, may be highly effective when placed within a holistic instructional design framework rather being considered as a singular media element.

VR and a Note on Immersion

As this study included a VR element within its instructional design, it seemed natural to leverage the results of the study's primary goal to also possibly address the field's considerable interest in finding better ways to include VR within instructional experiences and evaluate their effectiveness (Bower & Jong, 2020; Pletz & Zinn, 2020).

As was previously discussed, this study utilized a purpose-built VR experience to deliver the Practice phase of the Oil Filter maintenance task. Overall, the VR experience appeared to meet the expectations of both the instructional experiences as well as the research protocol. With this understanding in mind there are several design considerations and practical lessons learned within the development of the VR experience itself as well as the implementation of the experience within a research setting that may be of interest to those who are considering designing and using VR for research or practical purposes.

First, it is important to note that the VR experience described and utilized within this study is completely custom built for this study’s purposes. The environment itself, the models used, the interactions and mechanics, and the data structuring was all built by a small group of professional developers over the span of four months. A significant amount of this time was used to prepare the base engine model for virtual reality, as the initial model provided by the engine manufacturer for this study’s purposes was far too large (number of polygons) to be practically utilized within the VR headset. The team was made up of this study’s researcher (myself), a Unity game engine developer, and two technical artists. To develop this module the team initially storyboarded the entire experience utilizing the checklist provided for the tasks, hand drawn story-boards, narrative descriptions of each step, source photography of the actual engine model, and a developed matrix of key bindings and game-based action prompts. The VR development effort was reviewed on a weekly basis by the project team and reviewed twice over the span of the final two months by the subject matter experts at the university where this study took place. All of this is mentioned to make clear that VR is by no means a small amount of effort for even a highly specialized team, and all this effort went into building a task that on average took study participants less than 15 minutes to complete.

Naturally, there is a question as to whether it is practical to build VR experiences for specific use cases, such as was done in this study. As one might expect, the answer to this question is relative and subjective. There are pros and cons to both options for a given set of learners, in any given context, and there are several highly regarded works out in the field which tackle many of these considerations today. Considerations like; learner access and makeup (Alfalah, 2018), instructor availability, cost-benefit ratio, training budget allowances, and many others (Sattar et al., 2020). With VR however there are some unique considerations that merit discussion.

For one, with the case of nearly any industrial field there is the chance for bodily injury when participating in hand-on training tasks (Bun et al., 2017; Lamb et al., 2018). The risk of bodily injury is a two-fold challenge for any instructional designer. One is the very real consideration that someone could hurt themselves. This concern is usually addressed with an exceptional amount of caution placed into the hands-on training experience, which is warranted but increases the amount of time required to perform the training experience (Caporusso et al., 2019; Grabowski, 2019). Secondly, the known risk element is undoubtedly explained to the learners themselves. While knowing something possibly harmful can happen during a training exercise is pertinent information, it also brings forth a level of fear or apprehension to the training experience (Han, 2021). Fear is generally an emotion that instructional designers are attempting to avoid when teaching new material (Cannava et al., 2018). In these circumstances, VR experiences may serve well to cover introductory exercises or complete tasks in a threat free environment prior to more advanced task training exercises.

Secondly, VR may also be an ideal tool to utilize when other training options include access to other time sensitive or expensive training interventions (González-Zamar & Abad-

Segura, 2020; Smith et al., 2018). Access to an aircraft engine of this type would be challenging for the general public because either availability is reserved for established collegiate program, or engine access is reserved for physically powering aircraft. When one considers the logistical challenges acquiring an aircraft to do training, along with the risk associated with training and potentially damaging a live aircraft, the access and cost benefits begin to shine more clearly for VR interventions.

Finally, it should be noted that although VR appears to be a viable tool for this and potentially other technical training applications, there exist other forms of immersive media which may be equally or even more appropriate for specific instructional contexts. For instance, within the study's Method section I discussed the need to have an additional variable so as to perform a repeated measure design. This variable was a PC-Based immersive experience which mirrored the controls and functionality of a first-person game experience. In this experience participants performed a borescope inspection, and like the other tasks already discussed ultimately performed this task as part of the evaluation element of this study giving the research team a third variable. Unexpectedly the average performance scores for the Boroscope evaluation tasks were higher than not only the VR experience, but also the Part Task Trainer experience though not by a statistically significant amount. These two experiences, the VR and PC-Based experience, would generally be considered differing levels of immersive media, with levels of immersion being a topic of some discussion within the extent literature concerning immersive media (Milgram & Kishino, 1994; Skarbez et al., 2021). While the focus of this study does not include the scope to make claims about the viability of differing objective levels of immersive experience as put forth by Mayer (2021), it is my belief that it may be possible to define differing objective levels of immersion and optimize these objective levels for specific instructional opportunities. These objective elements could potentially take the form of a matrix, a framework, or a taxonomy utilized by instructional designers to determine the optimal amount of immersion necessary to deliver specific instructional tasks potentially helping with the aforementioned challenges associated with development costs and timelines. Further inquiry and experimentation are required to make these claims, and it should be noted that these objective levels would not necessarily correlate to specific learning gains because naturally any form of immersive media must be properly situated first within an appropriate instructional context and design.

Mitigating Factors

The last element of specific inquiry within this study set out to understand how technicians perceive this study's instructional methodology and training interventions. As Part 147 programs represent a relatively unexplored context within the field of instructional design, this study sought out to investigate the perception of new training methodologies and how those perceptions represented mitigating factors to training transfer and technological acceptance.

Within this investigation four emergent themes were found and discussed, those themes being: a passion for fixing, confidence in evaluation, VR preparation but not as learning, and the importance of video. These emergent themes each appear to corroborate previous research surrounding the effects of participant perception and preference relative to training transfer. For example, within the study respondents continued to express preferences for the hand-on training intervention as the primary expectation for future experiences, while also indicating routinely that they felt the part task trainer left them the most prepared heading into the evaluation task. These findings, when combined with the responses surrounding their previous mechanical experience shed light on how previous life and learning experience continue to be a leading factor in the preference and perception of instructional experiences (Hite et al., 2019; Sakkal & Martin, 2019).

Additionally, the findings discovered through the study's two questionnaires and the open ended interview protocol surrounding game console use & ownership, frequency of video game play, and familiarity with VR experiences each relate to previous work within the literature (Alexiou & Schippers, 2018). That a majority of students reported regular game playing, familiarity with VR experiences, and a high level of prepardness after the VR Practice task appears to corroborate findings that perceived self-efficacy in technological learning tool act as a precursor to a participants' rate of motivation and ability to transfer learned skills into work environments (Arasanmi & Ojo, 2021).

As for the found themes themselves, the theme passion for fixing appears to relate quite closely with Day et al.'s (2012) work regarding transfer; corroborating that prior experience within the relevant subject matter continues to be amongst the greatest predictors of learner success in transferring learned skills into real-world environments. While insightful, the instructional designer and the industry at large has little it can do to establish a lifelong passion for specific instructional content and thus continues to be a significant mitigating factor in the evaluation of training effectiveness.

Fortunately, the second theme, confidence in evaluation, directly relates to the work instructional designers can do to help ensure learner confidence and training transfer. As described within the study's results, when participants were queried about the evaluation task, all participants indicated high levels of confidence regardless of intervention type or other mitigating factor. This represents a significant finding, as participants universally responded that their perception regardless of the study's differing intervention, was that they were prepared to succeed in the evaluation task. This potentially indicates that learners were positively responding to each task's collective instructional experience, further corroborating this study's findings regarding the viability of DI as an instructional approach within this setting.

As a note of additional interest, the Practice phase elements, which represented the most variance between the two training interventions came up very little when participants were asked about why they felt prepared. Of the study's 17 participants, 13 of them mentioned the training elements used specifically within the Present phase of the training experience, highlighting the theme surrounding the importance of video. This couples with one of the themes identified within the study's results; VR as preparation but not learning. As previously discussed, many participants mentioned positive attitudes toward the VR experience but not necessarily interest in its continued use. This finding indicates that students may continue to see VR as somewhat of a novelty within educational contexts, and not necessarily a medium for learning. In some ways, this corroborates findings previously put forth by Mayer (2021) and somewhat challenges the viewpoint of findings discovered within Pletz & Zinn (2020).

In Mayer's discussion surrounding what he defines as the Immersion Principle, he states that "people do not necessarily learn better in 3D immersive virtual reality than with a corresponding 2D desktop presentation. (Mayer, 2021, p. 357)." His conceptual rationale is based off the positive motivational elements, primarily associated with experiential enjoyment and presence, being balanced against the extraneous elements set within the immersive world not positively contributing to the instructional requirements (i.e extraneous cognitive load). In the experimental studies Mayer puts forth as the empirical evidence behind his immersive principle, he specifically mentions how the feeling of presence within an immersive experience provides the ”wow” (Mayer, 2021, p. 361) factor and little more. This finding aligns with previous studies surrounding VR in educational contexts and the presence of the so called novelty effect (All et al., 2016; Chen et al., 2021; Lanier et al., 2019) in that in each of these circumstances VR is seen as little more than a motivational tool which gets participants engaged with the subject matter but does little to actually help the learner comprehend the instructional material, similar to how this study's participants saw the VR trainer.

This is at odds with the approach Pletz and Zinn (2020) took in their inquiry of virtual reality, which was part of my reasoning for featuring their work so heavily within this study. Pletz and Zinn's study was set within a vocational environment where the idea of presence was more firmly rooted in fidelity of both the simulated virtual space and equipment used represent the ultimate workshop reality.

Perhaps where Pletz and Zinn's findings most greatly differ is in the interpretation of how presence is conceptualized and motivation is perceived. Mayer sees presence as a means to motivate learners to engage with the subject matter in a positive manner, where as Pletz and Zinn do not actually use the term presence in favor of various forms of situated or situational. Both these terms effectively refer to a person being partially or fully immersed within the instructional experience via VR, but from Mayer's take on immersion is simply to get the learner into the experience, whereas Pletz and Zinn indicate it is about embodiment of the expected behavior. Thus, in both cases Mayer and Pletz and Zinn we find the research participants indicating high levels of motivation to participate with the VR training tool, but the resultant viewpoints differ in terms of both the perceived usefulness of the experience by the learner and the various studies quantitative results. Simply put, Mayer's results seem to indicate that VR is a 'nice to have' motivational tool, which echoes one of this study's prevailing themes. While at the same time, Pletz and Zinn see VR as a means to aid in the development of situated cognition in vocational tasks, which not coincidentally is also corroborated with this study's findings.

What both Mayer and Pletz and Zinn seem to overlook within their research studies was the effect the surrounding instructional elements played in the ultimate evaluation of VR. In Mayer's studies which each feature an immersive game-based learning experience (Makransky, Borre-Gude, et al., 2019; Parong & Mayer, 2018) there is routine use of narration, video elements, paper based worksheets and oral question prompts. In Pletz and Zinn, they described verbal discussion of terms followed by a live demonstration of the target behavior to be covered within the VR training intervention. Throughout these studies, specific interest is placed upon the inquiry of VR, yet there is little discussion surrounding the totality of the instructional experience.

I feel this poses a unique challenge for instructional designers and researchers, in that, without considering the holistic viewpoint of the entire instructional experience it becomes challenging to truly articulate when a specific element found within a training intervention is effective in meeting its specific instructional purpose. For instance, participants within this study did not indicate they expect to see VR in future training scenarios, nor did they indicate VR as their primary preference, but I myself didn't ask the same questions about the use of the eLearning-based videos which were equally represented within the study's Present phase. To some degree, by basing my experimental inquiry off of Pletz and Zinn's methodology I too placed an unbalanced level of focus on the PTT and VR Practice Phase. It wasn't until the participant's own words were analyzed did I even realize one of the major prevailing contributions of the overall work.

Perhaps, further complicating the matter is that instructionally the VR experience appears to have sufficiently met the instructional requirements for the Practice phase of the DI framework and directly address calls from the industry to find less expensive more accessible instructional interventions (Alba, 2020; Hammer, 2019). Thus, from this perspective I could make the claim that VR when placed within a DI framework has been shown to effective within this specific vocational context despite it not being the stated preference of the target group of participants.

Ultimately, it would appear the perception and acceptance of VR as a training tool continues to be a matter of debate and one that warrants additional inquiry within the field of instructional design.

Primary Contributions of this Study

In this work we were able to see each of the study's participants perform above industry established performance standards on real-world aircraft without the aid of a real-world aircraft or physical practical task training device, directly addressing the study's purpose and various calls throughout the industry (Hammer, 2019; Hannon, 2007; *National Training Aircraft Symposium Conference Topics*, 2022). This finding is, to the best of my knowledge, the first of its kind within this specific instruction context and may provide some means for the aviation training industry to leverage certain elements of this study's design to address the existing training challenges found throughout the field of aviation maintenance.

Additionally, this finding is especially relevant for instructional designers tasked with addressing the challenges the industry faces today, in that, the DI framework proved to be effective in each of the study's interventions. That each of interventions proved effective in transferring skills certainly suggests that the tooling and resource limitations cited by those within industry (Hannon, 2007) may be mitigated with more conscientious approaches to instructional design, like DI. This finding specifically assists instructional design researchers by providing an example of a DI instructional approach applied to a vocational context and set within an experimental design.

The experimental design and its methodology for evaluating training effectiveness via near transfer each offer their own significant contribution to the field. For one, the use of within-subject repeated measure design within instructional contexts is currently extremely limited yet represents a methodology which may address long standing critiques of experimental designs within the field of education at large (Clark, 1983, 2001; R. B. Kozma, 1994). Secondarily to this point is the method in which near transfer was quantified and evaluated within the study. Each of these elements directly address calls made by the field (Beckman, 2000; Parong & Mayer, 2021; Pletz & Zinn, 2020) and provide a potential framework for future researchers interested in empirical methods for evaluating training transfer and training effectiveness.

Furthermore, as this study includes a VR training element, this study contributes to the growing field of instructional design focused on the use of immersive media. This study contributed to this burgeoning subsection of the literature by clearly articulating the method in which the VR intervention was developed and designed to fit within an established instructional framework. Additionally, this study's experimental design and methodology has shown a potential method for researchers to evaluate the effectiveness of VR training interventions through quantitative experimental methods.

Lastly, this study provides a significant contribution to the relatively small body of research focused on Part 147 technician training schools. The discoveries found within this study's emergent themes and mitigating factors are of considerable interest to practitioners, regulators, and researchers working within the context looking to address learner perceptions. preferences, and expectations.

Limitations and Future Research Considerations

There exist several notable limitations to this study, some of which were accepted at the onset of the study's design, and others which were discovered during the study's experimental and analytical phases.

The first and foremost limitation to this study is the study's chosen context. Aviation maintenance is a relatively small field of interest within the scope of instructional design and education. This was one of the primary reasons I was interested in working within this context but doing so inherently included challenges associated with the relatively small number of previous works which have included the topic (Dyen, 2017; Hammer, 2019). To a degree, this study attempted to bridge into more studied contexts like technical, industrial, and vocational training which collectively make up an expansive body of scholarly work (Akkerman & Bakker, 2012; Bremer, 2008; Kilbrink et al., 2018; Pletz & Zinn, 2020; Sirakaya & Cakmak, 2018). However, aviation maintenance sits in a unique contextual space which makes elements of the profession and the study of it challenging to bridge into other technical fields. Primary among them is the vast regulatory makeup of the aviation industry, there exist very specific regulations surrounding training, personnel qualifications, aircraft and component certifications, and quality practice certifications (FAA, 2022b). Each of which make the study within this field inherently challenging. Additionally, the regulatory makeup of the industry is practically enforced at a regional and local level, by individuals who work for the Federal Aviation Administration in regional flight service district offices. This method of governance allows for a considerable amount of flexibility in regulatory interpretation which may stand to help or hinder development efforts within the field. All of this is to say, that perhaps the primary limitation of study is that it is quite possible that regardless of my best efforts, the training interventions used within this study would not actually represent an acceptable means of training according to an individual regulator. From my own experience within the industry this is an unavoidable risk when attempting to innovate within the field, and the study's design was crafted in a way that I felt was the most likely to represent a real-world training context for aviation mechanics.

The second foremost limitation of the study is also tied to the context of aviation maintenance but this time centering on the participants. As previously described the study had to use a purposeful sampling of a very specific group of students within a very specific aviation maintenance training program. This essentially forced the researcher to pull a relatively large group of participants from a small total pool of individuals within a small very specific population. One can see this manifest itself with some of the backgrounds which appeared in the study, of the 17 participants, 5 participants had previous professional experience within the field specific to military aircraft. These participants had undoubtedly higher relevant experience levels than their classmates but because they were enrolled in the same course plan as the other participants, which was the inclusion requirement of the study, they were effectively treated as new relatively inexperienced participants. The data from these 5 participants did not skew the data in a significant way and the trends found within the other participants carrier through even to these 5 individuals despite their relative experience. Ultimately the relatively small pool of participants likely makes for other types of selection practices to be largely impractical, thus limiting the potential reach of these findings to greater populations.

Next, the study's design utilized a within-subject measure design to evaluate two differing training interventions teaching two differing tasks. As already discussed, much emphasis was placed on the selection of these tasks with considerable effort being expended to ensure the differing tasks were of similar difficulty, would take about the same amount of time, and could be measured along the same rubric for grading. Regardless of these efforts it is possible that findings between these tasks relate less to the changes in practice intervention type, the experimental variables themselves, and more to the inherent differences in these tasks and the participants relative ability to perform them appropriately in the evaluation task. The design of this study took every precaution to diminish this limitation, yet it undoubtedly exists in practice.

Aside from improving the study by better accommodating for the aforementioned limitations there exist a number of items discovered during the study which may be of note for future research considerations. Primary of these is to take the design of this study and apply it to a broader more generally established vocational or technical field such as auto-repair or perhaps even heavy machinery certification. Both of these fields, among others, have a much larger potential population base and while still regulated, exist in a very different regulatory landscape. The core elements of discussion within this study are ultimately hands-on task training, it stands to reason a study designed in this way could easily be replicated or expanded upon in other hand-on task training environments.

For researchers considering researching VR specific experiences there exist several elements found within this study that could be considered for future research. First, there is a considerable amount of VR specific control inputs and technical specifications which may impact the usability of the equipment itself. This is a relatively unexplored topic within the instructional design discipline. For example, foveated rendering represents a software/hardware technical element included within certain VR head mounted displays. Foveated rendering simply explained is a way for the headset to track the participant's eye movement while wearing the headset and increasing the fidelity of the visual image at the place where the wearer is looking. In testing different headsets in preparation for this study, myself and the development team noticed that the ability to read the task checklists was nearly impossible without a headset which could do foveated rendering.

Aside from this very technical hardware/software consideration, there were a number of instructional design elements within VR experience which could also stand to see further inquiry within the context of scholarly work. The primary of these elements is the fidelity of bodily movements and how those movements relate to real-world actions. At the onset of the project, the development team building the VR experience leveraged common key bindings and practices found within the commercial game industry. This includes elements like game physics, object control, and physical presence within a VR space. During the literature review of this study and subsequent time since it's completion I have found essentially no scholarly work within the instructional design discipline which covers elements such as these, despite the fact that they represent some of the most key factors in a VR experience's design. Secondly, the fidelity of bodily movements and object interaction appears to be a specific challenge for VR experiences in that realism may or may not be an advantageous feature within VR experiences. For example, in the Oil Filter removal portion of the VR task the participants were required to use a puller tool. The participant may walk or teleport to the cart where the tool sits within the VR space. When the participant grabs the tool, there are three options to what the tool can do each of which is ultimately required for the successful removal of the oil filter. When I reviewed the first iteration of the tools used within VR, it was so realistic to the actual tool that it became almost impossible to use within the VR experience because the hand-based tolerances of the controller did not match up well with the virtual geometry and physics of the tool itself. Simply meaning, the developers had made the tool work essentially one for one with its real-world counterpart but the lack of fully dexterous hands within the VR experience due to the use of controllers made the virtual puller almost unusable. Similar challenges occurred with things like nuts, washers, and even ratcheting. In the end, the team made best estimate judgement calls for each of these interactions based off what ‘felt’ right, but there is undoubtedly a rich space for academic and practical inquiry on this topic alone.

The final place where there exists broad potential for academic inquiry is the design principles of a VR training experience itself. This could include everything from scaffolding needs, menu system designs, the use of audio, and accessibility concerns, among others. Upon building within VR, it quickly becomes evident that some of the bedrock elements used within instructional design, such as Mayer’s media principles, need to be reconsidered from the approach of wearing a VR headset. Additionally, in the broader context of instructional design where and how does a VR experience make the most sense? This study placed a VR experience during the Practice phase of a direct instruction framework driven instructional experience, but where could ideal placement be used within an experience utilizing Gagné’s nine events? Even further, there exists the possibility to consider how VR might be utilized to carry out the entirety of instructional experiences, how then might existing design models and taxonomies be applied in these circumstances? VR is a potentially rich, expansive, instructional tool, which in some ways provides the means for a fully controlled training environment, a hallmark of B.F. Skinner and other behaviorist’s ultimate goals within education, but there have also been several studies which have linked VR to more cognitivist practices (Radianti et al., 2020)with specific focus being placed on the theories of situated cognition (Pletz & Zinn, 2020; Schott & Marshall, 2018). All of this is to say, it is my belief that the affordances brought to a training experience by using

VR are far reaching and may include potential research considerations across the full spectrum of the instructional design and technology discipline.

Conclusion

This study's scope, design, and methodology span across disciplines from both industry and academia to address a specific instructional challenge within a specific vocational context. As such, it ultimately challenging to evaluate the true validity of these results. Only through additional inquiry will we ultimately find more conclusive evidence for the claims made within this study.

With that being said, I feel the methodology used within this study stands as a potential framework which may be easily leveraged to conduct repeatable trials into the inquiry of instructional effectiveness and transfer. Such a framework stands to address some of the long-standing critiques researchers of instructional design face surrounding the lack of empirical methods to evaluate differing instructional experiences.

Armed with better methods of experimental inquiry, instructional design researchers stand a better chance in discovering evidence relative to differing instructional variables. New technologies and novel uses of existing training methods will likely always be a focus of inquiry for instructional designers within the industry. Ultimately, it is my sincerest hope that this study provides practitioners with the guidance necessary to make evidence based instructional design decisions and researchers with a potential framework to further enhance the scientific inquiry of instructional design and technology.

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APPENDIX I - INSTRUMENTS

Oil Filter Procedure Knowledge Check Items

1. The filter element housing is removed with:
   a. Pliers
   b. Puller tool
   c. Screwdriver
   d. Magnet

2. **True/False** Final installation of the oil filter housing cover includes self-locking nuts tightened to a specific torque value/range

3. **True/False** O-rings and packings used with the oil filter can be re-used if inspection reveals no defects.

Borescope Procedure Knowledge Check Items

1. During inspection, rotation of the prop will result in _______________ rotation of the turbine wheel.
   a. Equal
   b. Slower
   c. Faster
   d. Opposite

2. **True/False** To decrease the field of view, press the control stick/yoke firmly into the controller.

3. The borescope tip for the turbine wheel inspection is inserted into the:
   a. Fuel injector port
   b. Exhaust tube
   c. Igniter plug port
   d. Intake tube

Ignition Lead Inspection Procedure Knowledge Check Items

1. What is the status of the connectors during the ignition lead tests?
   a. Both connectors disconnected from the system.
   b. Test connector disconnected from the system; other connector connected to the system.
   c. Both connected to the system.
   d. Test connector connected to the system; other connector disconnected from the system.

2. **True/False** During installation, the external braiding can rotate with the coupling nut by a maximum of +/- 5 degrees.

3. Choose the correct method of testing the ignition leads from the following.
    a. Push/insert multimeter probe tip into external braiding
    b. Push/insert multimeter probe tip into cannon plug.
    c. Connect multimeter probes to voltage inputs and measure voltage drop.
    d. Identify, select, and attach the correct pin/adaptor to the test probe for insertion to the cannon plug

Pre-Practical training Questionnaire

1. Which gender do you most closely identify with?
    a. Male
    b. Female
    c. Other
    d. Prefer not to answer
2. How often do you play on computer-based video games with either mouse and keyboard or gaming controller?
    a. Never
    b. Not often
    c. Once or twice a month
    d. Once or twice a week
    e. Daily
3. I am familiar with using a gaming controller (example: X-Box, PlayStation, or the like)
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
4. Do you own a video game console?
    a. Yes
    b. No
5. How often do you participate in virtual reality headset experiences or games?
    a. Never
    b. Not often
    c. Once or twice a month
    d. Once or twice a week
    e. Daily
6. I am familiar with using a virtual reality headset and associated controllers.
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
7. Do you own a VR Headset?
    a. Yes
    b. No
8. I am prone to motion sickness.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Not Frequently
    e. Never
9. Prior to enrolling at Embry Riddle's AMS program how often did you participate in maintenance type activities (tinkering, fixing, repairing)?
    a. Never

  b. Not often
  c. Once or twice a month
  d. Once or twice a week
  e. Daily

10. I have experience in the following activities (select all that apply)
    a. Building or repairing drones
    b. Working on automobiles and motorcycles
    c. Building computers
    d. Working on robotics
    e. Building miniatures for tabletop games
    f. Building websites or programs (coding in general)
    g. Woodworking
    h. Other Hands-on Activity
        i. Please describe

Instructor Grading Task Sheets

		Step	Completion Time	Manual/Task Card Compliance	PPE & Safety	Part & Equipment Handling	Tool Usage	Faculty Intervention	Interpretation of Results	Score
			x/5	x/5	x/5	x/5	x/5	x/5	x/5	x/35
Aircraft Preparation		1								
		2								
		3								
Oil Filter	Removal	1								
		2								
		3								
		4								
		5								
	Install	1								
		2								
		3								
		4								
		4b								
		4c								
		5								
Ignition Harness		1								
		2								
	Disconnect	3								
		4								
	Service Check	5								
		6								
	Re-connect	7								
		8								
		9								
Borescope	Inspect	1								
		2								
		3								
		4								
		5								
Aircraft Closeout		1								
		2								
		3								
		4								
										X/???

Evaluation criterion

Time

Following Manual/Task Card - Out of order, disregard notes, improper data completion

Part & Equipment Handling - Roughness, parts segregation

PPE & Safety - PPE use & unsafe methods

Tool Usage - Puller, torque check, misuse of tool, Incorrect tool inventory/shadowing

Faculty Intervention

Interpretation of Results

Notes

Make Safety/PPE requirements clear to participants

Oil Filter - Safety glasses, gloves

Ign - Safety glasses

Borescope - None

Oil Filter * PRINT OUT MM (PDF pages 992-998)

Ign * MAKE OWN CUSTUM MM page for applicant to reference. (PDF page 824 for exciter box fig, 849 cable routing fig, 844 for step 1, 861 for step 2

Post Training Questionnaire

1. The headset driven VR experience gave me a level of motion sickness or general discomfort
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
2. The Headset driven Virtual Reality Oil Filter training activity was easy to use and controls were intuitive
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
3. The PC Based Borescope training activity was easy to use, and controls were intuitive
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree

The following questions pertain to the final Transfer Task portion of the study

4. I felt prepared to perform the Oil Filter Task
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
5. I felt prepared to perform the borescope task
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
6. I felt prepared to perform the ignition lead task
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree

The following pertain to future training experiences

7. I am interested in training using the headset VR experience again
    a. Strongly Disagree

   b. Disagree
   c. Neutral
   d. Agree
   e. Strongly Agree

8. I am interested in using the PC based experience again
   a. Strongly Disagree
   b. Disagree
   c. Neutral
   d. Agree
   e. Strongly Agree
9. I am interested in using the Part Task Training experience again
   a. Strongly Disagree
   b. Disagree
   c. Neutral
   d. Agree
   e. Strongly Agree
10. The VR Based experience met your training expectations
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
11. The PC Based experience met your training expectations
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
12. The Part Task Training experience met your expectations
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
13. Please rank your preference for future training experiences
    a. Headset VR
    b. PC Based
    c. Part Task Trainer

APPENDIX II – IMMERSIVE MEDIA EXAMPLES

Figure 36

Depiction of PC-IM and VR Based 3D Rendering

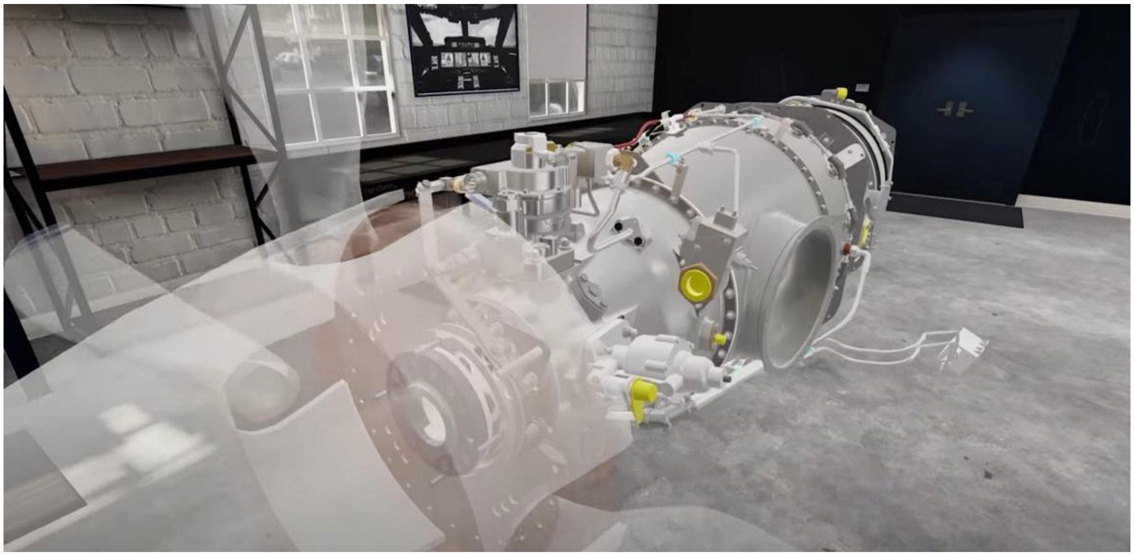

Figure 37

Image of HP Reverb 2 Virtuality Reality Headset Mounted Display (HMD)

Figure 38

Representative Photograph of VR exercise