Air University Multi-Modal Research Course on VR/AR and Related Technologies

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ABSTRACT

Numerous emerging technologies have recently brought-about affordable capabilities that need to be more thoroughly explored for their practical application within the national security enterprise. In 2018, Air University (AU) chartered the Innovations in Learning Sciences Research Task Force (ILS RTF) to support AU colleges, schools, and centers in the quest to research the application of emerging technologies and innovative learning practices within the national security enterprise. This intrinsic case study describes the planning, execution, and deliverables of AU's prototype graduate research course on the subject of emerging technologies and their practical applications to learning, operating, and leading in national security. The 6-credit-hour class curriculum investigated virtual reality (VR), augmented reality (AR), haptic devices, 3D printing & related technologies as well as myriad learning theories including experiential learning, social constructivist learning, situated cognition, and connectivism. The class integrated efforts of eight AU agencies, three master's degree programs, and multiple educational and non-profit partners. Seventeen O4-O6/civilian-equivalent students completed the 60 contact hours (10 resident students in-person, and 7 distance students live synchronously via VR and webinar.) An hour or more of each synchronous 3-hour class took place "inside VR" using Oculus Rift CV1 devices connected via multi-user VR co-presence platforms including Rumii, Engage, AltSpace, and others. The students also conducted a field research trip to the Lobaki XR Academy to interact hands-on with dozens more developmental haptic devices and VR/AR applications. Each student authored a master's research thesis on how DoD, interagency, and/or allies could apply VR/AR and related technologies (collectively referenced as XR) to learning, operating, or leading within the student's native area of national security expertise. This paper reveals links to the resulting body of over 400 pages of graduate research in the area of XR applied within 17 national security fields.

ABOUT THE AUTHORS

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INTRODUCTION: WHY? RESEARCHING EMERGING TECH APPLIED TO NATIONAL SECURITY

With recent advances in consumer electronics, a new generation of low-cost interactive tools is now available to use in the learning and operating environments. Such affordable technologies include virtual reality (VR), augmented reality (AR), mixed reality (MR), haptic devices, 360-video, [all collectively referred to as extended reality (XR)], and 3D printing. Because these technologies have become readily available in the consumer market only lately (essentially, within the most recent 3-5 years), the range of possibilities for using the technologies for learning and the broad potential for their practical application in the national security arena is vast and needs to be further examined. Additionally, the implications of how using these tools will impact the operational and socio-cultural environments – as well as the significance thereof to national security leaders – have not yet been thoroughly evaluated. This intrinsic, qualitative case study details an academic undertaking by the US Air Force's Air University (AU) to evaluate potential use of the subject technologies to inform the practice of learning and operating in the arena of national security.

BACKGROUND:

In 2018, the US Air Force's Air University, headquartered at Maxwell Air Force Base, Montgomery, Alabama, (reporting to the Air Education and Training Command), in consideration of the strategic need to research emerging consumer technologies and the expanded possibilities provided by other recent process improvements in the field of learning, chartered the Innovations in Learning Sciences Research Task Force (ILS RTF). The mission of the ILS RTF, chaired by the 2-star AU Vice Commander, is to provide leadership support (funding, facilities, advocacy, etc.) to AU's colleges, schools, and centers to engage in teaching, research, and scholarship in the area of better understanding advanced learning technologies and learning process innovations. The ILS RTF became a vital mission enabler to support a key "Strategic Environment" component of the AETC Strategic Plan, "Emerging Technologies"…

> "Technology is changing the way we live and learn, opening exceptional opportunities … we will design, manage and sustain a force development infrastructure that leverages emergent technology where and when appropriate to include: abundant computing devices, flexible classroom designs, innovative visual displays, games and simulations, collaborative tools, and mechanisms that both assess and track Airmen's learning efforts. We must also exploit the incredible innovations in artificial intelligence (AI), virtual reality (VR) and augmented reality (AR)" (AETC Strategic Plan, 2018)

A group of AU faculty with expertise in emerging technologies and educational innovation from multiple colleges, schools, and centers resolved to collaborate in the development of an innovative multi-program master's-level course under the auspices of the ILS RTF to engage students in the process of researching these innovations. The professors represented the eSchool of Graduate Professional Military Education (eSchool), the AU Teaching and Learning Center (TLC), the Muir S. Fairchild Research Information Center (MSFRIC), the Air Command and Staff College (ACSC), the Air War College (AWC), and the Air Force Chaplain Corps College (AFCCC). Each of the associated partners provided an aspect of the collaboration that uniquely enabled the protype course to be conducted beginning in August 2018 and concluding in May 2019.

WHO? (THE STAKEHOLDERS): ASSEMBLING THE "XR RESEARCH COURSE" PARTICIPANTS

During the year leading-up to chartering the ILS RTF, it was known among AU's "Academic Circle" that a "research task force" of this nature was in the works. AU's concept of an RTF in previous years had been such that a sponsoring command or agency external to AU with interest in research of a particular subject area would provide research topics for students to evaluate and resources to engage in research-related activities. Such sponsoring commands/agencies included US Strategic Command (Deterrence RTF), Air Force Space Command (Space Horizons RTF), Headquarters

Air Force Deputy Chief of Staff for Intelligence, Surveillance, & Reconnaissance (Vigilance Horizons ISR RTF), and others. A graduate class numbering 10-15 resident students, typically half from AWC and half from ACSC, would spend an academic year under the tutelage of a group of AU faculty with expertise in the chosen subject matter, and each student would research a specific component of the subject matter in the process of producing his/her master's thesis on the topic. Upon completion of the research, the thesis papers would be submitted to the respective sponsoring command along with a presentation from representatives of the class of students who conducted the research. Five to seven such RTFs would be conducted each academic year. Through the RTFs, multiple tough problems have been investigated in the past resulting in long-term commitments from sponsoring commands to continue to support and obtain benefit from this rigorous scholarship process (AU Research Areas of Interest, 2019).

According to the International Society of Learning Sciences, the concise definition of "Learning Sciences" is: "… the interdisciplinary empirical investigation of learning as it exists in real-world settings and to how learning may be facilitated both with and without technology" (ISLS, 2019). An organization with a direct stake in Learning Sciences is AU proper (and its parent command, AETC); thus, it was determined that for the first time, in academic year 2018 (AY 18), AU would be the sponsoring command for the new ILS RTF. Given availability of leadership and funding support for such research endeavors, a group of AU professors with interest particularly in researching the "… with technology …" component of learning sciences, chose to collaborate and brought together a partnership of academics who were interested in leading the development of a course to use support from and provide input to the ILS RTF.

AU Agencies as part of the "XR Research Course"

(1.) eSchool of Graduate PME. Several faculty members who volunteered to lead the ILS RTF were representatives of the eSchool of Graduate PME where applied technology is a requisite part of the primary mission. Over 12,000 AU students engage in education through the eSchool via distance learning from locations across the globe. The master's degree program offered by the eSchool is the Online Master's Program (OLMP). eSchool faculty participants wanted to investigate the application of emerging XR technologies with respect to aspects that are unique to distance learners. Thus, the idea to include OLMP students in the ILS RTF course was incorporated from the initial planning phase. Integrating distance learning and residence students into the same class was highly significant, in that this combination would be a "first-ever" experience for Air Force officer PME. Synchromodal learning is described as a format in which live students and distance students participate in a synchronous learning experience (Bell, Sawaya and Cain, 2014). The eSchool's Major Kris Kripchak led development of the process to enable distance students to interact with the instructor and class live via Adobe Connect; simultaneously, in the classroom a widescreen projected video of each distance student and broadcasted full-duplex audio of the webinar session. While not interacting via webinar format, the class interacted in immersive 360° virtual co-presence using multi-user VR platforms.

(2.) AU's Teaching and Learning Center (TLC). The TLC is the agency charged with the ongoing mission of leading the university in investigating new learning processes and technology. The mission is accomplished through a multitude of programs, many of which are oriented toward faculty development. The TLC Director, Dr. Anthony Gould, was identified by the ILS RTF Chair to be the ILS RTF Director, and was charged with providing regular updates on the efforts within the task force as well as overseeing the task force's budget. A key aspect of the partnership provided by the TLC was managing funding for student travel and purchasing equipment including high-end gaming laptops, Oculus Rift CV1 virtual reality devices, and multiple pieces of supporting gear. Dr. Gould also contributed directly to the content of the course by leading numerous sessions of content on the process of conducting research as well as serving as thesis advisor to multiple students throughout the academic year (TLC, 2019).

(3.) Muir S. Fairchild Research Information Center (MSFRIC). Colloquially known as the "AU Library," MSFRIC became the facility epicenter of ILS RTF activity. MSFRIC Director, Dr. Mehmed Ali, joined the ILS RTF partnership by offering space, additional funding, and qualified manpower support. Geographically located in the middle of Maxwell's Academic Circle, MSFRIC is a convenient location for a multi-school class. Beyond classroom and innovation lab space, MSFRIC allocated additional funds for computers, VR devices, a 3D printer, and several other developmental technology items. MSFRIC also provided an expert on the process of research as a consultant to the class. As the "keepers of the keys," MSFRIC staff provided continuous access to the "VR Classroom" and the "Innovation Lab" by students and faculty whenever the facilities were needed (MSFRIC, 2019).

4.) Air War College (AWC). AU's college that administers the resident senior PME (attended by O-5/O-6's and civilian equivalents) is AWC. AWC students take a semester-long elective for the two semesters of their academic year. If an AWC student chooses to participate in a research task force, that becomes the student's elective for both semesters, in addition to becoming the subject for the student's year-long professional studies paper (a.k.a. "thesis" paper.) AWC leadership and staff were consistently supportive of AWC student participation in the XR Research class and gave them wide latitude to conduct research activities to include the three-day field research trip to Jackson, MS, to evaluate a host of developmental XR devices (AWC, 2019).

(5.) Air Command and Staff College (ACSC). AU's college that conducts intermediate-level resident PME (attended by officers in the grade of O-4 and civilian equivalents) is ACSC. ACSC provided students to participate in the class, as well as key leader, Lt Col Andy Clayton, Ph.D., who volunteered his efforts to instruct a component of the syllabus in his area of expertise: a mixed-reality, scenario-based, interactive leadership exercise. Clayton's contribution was key to demonstrating to students the value of this "human-in-the-loop" interactive platform that serves to help learners develop "soft skills" (ACSC, 2019).

(6.) Air Force Chaplain Corps College (AFCCC). Another of the colleges belonging to AU is AFCCC. With guidance from "on high" – Chaplain (Maj. Gen.) Steven A. Schaick, AF Chief of Chaplains – the AFCCC had been interested in investigating the potential for integrating VR/AR into AFCCC chaplain education & training programs. In an effort to obtain a better understanding of the technologies and capabilities, AFCCC requested a slot in the class for one of their chaplain faculty members, Major David Merrifield. While Merrifield technically "audited" the class for the learning experience, he completed all aspects of the course to include the thesis paper, which was focused on informing the Chaplain Corps College on the applicability of VR in their syllabus: particularly 360-video used to learn about chaplain readiness (AF Chaplain Corps College, 2019).

Student Participation in the "XR Research Course"

While participants in the XR Research Course were all volunteers, diversity of the class composition was manifest through a broad range of criteria. Male and female students were included in both the residence and distance categories; likewise, the racial make-up of the class included Caucasian, African-American, Asian-American, and Latino. Given that AU hosts both US and international officers in the resident programs, the class included students from US, Canada, and Chile. From a sponsoring-organization perspective, diversity was broad, including civilian officials from the Office of the Secretary of Defense, the US Agency for International Development, the Department of the Navy, Department of the Air Force, and US Cyber Command. Active duty officers included those with affiliation in the US Army, US Air Force, US Air Force Reserve, Air National Guard, Canadian Armed Forces, and the Chilean Air Force. The demographic classification with the broadest range of diversity was that of career specialty: fully all 17 of the students hailed from a different career specialty. From fighter pilot to chaplain, foreign service officer to maintenance, mobility pilot to security policy, the range of career specialties represented among the group of 17 mid- to senior-career professionals could not have been more diverse.

From the degree program perspective, three separate master's degree programs were represented. The Master of Strategic Studies in residence is the degree program in which AWC students were participants. The ACSC students were participants in the Master of Military Art and Science via residence, and the eSchool Online Master's Program (OLMP) students were engaged in the degree of Master of Military Art and Science via distance learning. Just as with a traditional civilian university, while the three degree programs have varying overall program constructs, in the area of elective courses, students frequently overlap in spheres of interest. Such was the case in this research elective course: students from all three degree programs volunteered to participate.

The inclusion of both residence and distance students in the same class, did involve a unique set of requirements that had to be considered. Foremost was the fact that distance learning students in OLMP participate in a fully "Bring Your Own Device" (BYOD) format. This factor, combined with the fact that the course would involve substantial use of virtual reality throughout the synchronous in-class portion, required that the OLMP participants would need to already have ready-access to a virtual reality platform at the outset of the class. Also, OLMP students would need to have webinar capability via the chosen webinar platform, Adobe Connect. To determine the degree this situation would be feasible, the eSchool conducted a survey of the student population in spring 2018 in which students were polled on the subject of whether they owned or would be able to obtain access to specified virtual reality and webinar hardware. In surprisingly strong response to this question, over 15% of the OLMP population either already had

access – or would immediately be able to obtain access – to a specified virtual reality device to enable them to participate in a course that required it. A frequent student comment on the survey was, "…that would give me just the rationale I need to go ahead and invest in VR." And, given that webinar capability was standard on practically all computers in 2018, none of the students noted that as a limiting factor.

The call for student participants from the full-time resident programs produced a combined number of 10 students (including the slot reserved for AFCCC). On the OLMP side (where all students work full-time jobs), the formal call for volunteers included a couple atypical caveats: first, the student would require access to VR equipment; and, second, the student would need to have supervisor permission to attend synchronous class sessions for three hours about once per week for 20 weeks (mostly during the duty day, depending on the student's time zone). Originally, the plan was to provide 5 slots for OLMP students; however, within 48 hours of the call for volunteers, 16 OLMP students had responded. In face of the large response, the course faculty decided to expand the number of OLMP slots to seven, given that seven of the 16 were in their second-year of the OLMP degree program. The remaining 9 students were pledged to have priority to take the elective class if offered again next year.

Partner Participants Outside of the Air University

In the field of emerging technologies, the current state of the art is rapidly and continuously changing. Due to the dynamic nature of the subject matter, the course designer faculty members chose to rely upon several outside partners to provide the class with the most current, relevant knowledge on the field. Partners from outside AU included government, commercial, educational, and non-profit participants.

1.) Pilot Training Next – AETC chartered a prototype program in Austin, TX, to teach undergraduate pilot training (UPT) using consumer VR along with bio-feedback, haptics, AI, and self-paced, competency-based learning as tools to streamline the production process for UPT. The program had completed its first class of students at the time that the XR Research Class began, which made it a unique case study for the class to analyze for possible lessons-learned and applicability to other areas in national security. The Deputy Director of PTN, Maj Scott Van der Water, provided the class with a webinar presentation on the current status of the PTN program (Pilot Training Next, 2018).

Pilot Training Next Student

2.) Lobaki Foundation – Mr. Vince Jordan leads an initiative that began in Clarksdale, MS, and is expanding across the southeast, in which "XR Academies" operate to teach less-privileged young people to use the Unreal game engine to build XR content. Lobaki involves developer/teachers in the quest to teach high-tech skills to the next generation to enable them to improve their chances for success in life. Expertise as "content developers" as well as a track record in innovation and social entrepreneurship that Lobaki Foundation offers made them an ideal partner for several of aspects of the XR Research class (Lobaki, 2019).

3.) MGMWERX – MGMWERX was created through a partnership agreement between DEFENSEWERX and the AF Research Laboratory and is located in Montgomery, AL. The mission of MGMWERX is to support the education initiatives provided at AU and to augment the university's programs in a way to encourage high-quality, innovative research and to encourage new ideas that further support issues that are important to the Air Force. MGMWERX hosted an event in which all 17 students provided public presentations on their research to over 40 leaders of small businesses who had direct interest in the research and engaged in two-way dialog on possible future collaboration (MGMWERX, 2018).

4.) Virginia Serious Games Institute (VSGI) at George Mason University (GMU) & C2 Technologies, Inc. – During the execution of the class, in an interrelated initiative, the eSchool worked with its instructional delivery contract partner, C2 Technologies, to commission a study on XR-related and learning-process-related initiatives for the eSchool. The study, overseen by eSchool's Lt Col Chris Willis and produced by VSGI (known for expertise in digital learning), evaluated current eSchool XR-related projects and suggested future initiatives in which XR and other emerging technologies and innovative learning processes could enhance educational outcomes. Investigators for the study interacted with students in the class, evaluated execution of a class session, and analyzed content of the class syllabus. In the final proprietary report, the assessment of VSGI was that the XR Research class was a model innovative course that should be benchmarked by other graduate education programs (C2 Technologies, 2016).

5.) Doghead Simulations – A critical tool to implementing the XR Research class was the ability to bring distance learners into shared virtual space with each other and fellow residence learners by using multi-user virtual co-presence platforms. Doghead Simulations, of Orlando, FL, provided the class access to its multi-user co-presence platform known as Rumii. During multiple lessons, students used Rumii as the platform to "attend" the class session and to conduct small-group "break-out" sessions in which they collaborated with peers to work on shared projects. The company's CEO, Mat Chacon provided the class with an "in-world" live presentation to demonstrate aspects of the platform and to obtain the students' feedback on Rumii as a learning tool (Doghead Simulations, 2019)

6.) Immersive VR Education (IVRE) – The award-winning Dublin, Ireland-based company has produced multiple successful educational VR content projects. IVRE developed the highly-acclaimed *Apollo 11* and *Titanic* immersive VR experiences: both utilized by the class. Beyond those successful apps, IVRE offers the field of education a user-friendly multi-user co-presence platform known as *Engage*. The Engage platform provides educational users a variety of functionalities that allow easy collaboration over a broad range of digital content. The pre-rendered asset library makes it easy for users to import immersive digital effects, which proves to be impactful when a small group of geographically-dispersed students work together to present results of their group projects. CEO Dave Whelan and Engage Project Lead, Mike Armstrong, both attended sessions with our XR Research class to give highlights of where the Engage platform was going in the future as well as to obtain their feedback on IVRE's products (IVRE, 2019).

WHAT? – THE COURSE CURRICULUM

The AU faculty members who collaborated to build the XR Research Course established from the beginning that the primary goal would be to produce graduates who had gained hands-on competency and produced scholarly writing that demonstrated them as thought leaders in applying XR, emerging technologies, and innovative learning practices into their own fields of expertise. Every student participating in the three AU master's programs was already a mid- to senior-career expert in a particular professional field. Given that consumer XR and related technologies are so recent, a basic assumption was also that the class would need to begin from a minimum/novice-level of previous experience with XR. A second key goal of the course would be to ensure that an appropriate return on investment was provided to the RTF sponsor (AU Vice Commander.) Typically, other RTF outputs to their RTF sponsors included the collection of thesis papers written by the students and an overall outbrief on the RTFs key findings – the goal of the XR Research Course faculty team was to deliver that and more. The third main goal was that of gaining XR/emerging tech experience among the faculty & staff participating in the delivery of the course, (e.g. how could we expand the horizons for AU faculty and staff experience by using course delivery technologies while still guaranteeing the same high level of student learning and engagement?)

In order to ensure that all three programs' degree requirements would be met, the course developers analyzed the elective course requirements and the research/thesis requirements for all three programs concurrently in light of the general requirements that exist for an RTF class. A central primary deliverable for all three programs, and a specified deliverable requirement for an RTF course is the student's production of a research thesis as a part of the course. In addition, program requirements specified the page-count of professional readings required, the minimum number of graded deliverable products, and the number of student contact hours. By making the course slightly more rigorous than any one program's requirements, it was determined that a single, common syllabus could be used consistently for all students, regardless of their degree program of enrollment.

In framing the course content, the course designers started with three primary questions. First: which primary content areas would lead graduate students to becoming thought leaders in the area of using XR and related technologies for learning in their pre-established field of expertise? Second: which areas with regard to XR/emerging tech and educational practice would provide the most value to the RTF sponsor (Air University) as recompense for sponsorship support? And, third: how can the course delivery experience offer a degree of development for the faculty members involved in implementing the course to improve "organizational learning" within AU for future course offerings using XR. With these three questions in mind (developing student thought leaders, ROI to the RTF sponsor, and developing faculty competence), the course designers began to identify subject matter content and ideas for delivery based upon their professional expertise. The three PhD-level course designers' academic backgrounds were in the areas of Virtual Reality Applied in Education, Educational Technology, and Electrical Engineering.

The first and the third questions (developing student thought leaders, and developing faculty competency) were recognized as having the ability to deliver on the second question (ROI to the RTF sponsor) – i.e. by producing AU graduates as thought leaders and developing AU faculty members with competence in using XR/emerging tech as learning tools, along with delivering the 17 master's thesis papers on the subject, the sponsor (AU Vice Commander), would recognize substantial return. Likewise, the third question (developing faculty competency) would also be delivered upon by achieving the goal in question one (developing student thought leaders), as the use of the technologies in delivering the class would require multiple AU staff members to utilize the technologies and be involved in the process, thereby gaining hands-on competence in XR. (Eight AU faculty members, led by Lt Col Brandon White rose the level of expert in using and demonstrating XR technologies for use in learning.)

Reflection on the three primary questions/goals and condensing them down to the one primary area (that of leading students to become thought leaders in XR/emerging tech applied to learning in their field of expertise) led to the determination that three main subject areas would need to be the curriculum focus of the course: theory/practice in learning, XR/emerging technologies application, and the practice of conducting research. With these three main areas in-focus, each of the 20 instructional periods was designed to include learning experiences to help the learner build understanding in each of the three areas.

Subject Matter

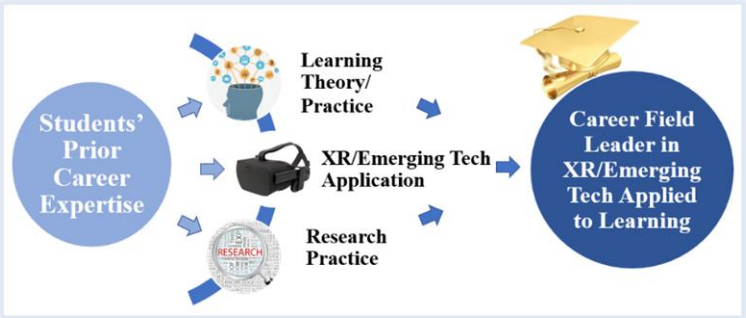


Figure 1. Subject Matter Concept Map for XR Research class: Developing Leaders in Emerging Tech Applied to Learning

Under the main area of learning theory/ practice, the expert course developers began with a question of which theories from the realm of educational theory, educational psychology, and educational practice have the most relevance with regard to using XR/emerging technologies. Specific areas chosen for investigation during the course included as examples: learning sciences, learning engineering, experiential learning, constructivist learning, behavior theory, cognitive theory, humanism, situated learning, anchored instruction, connectivism, problem-based learning, social development, communities of practice, Bloom's taxonomy, andragogy, gamification in learning, and several others. The overarching goal was to have the students develop a comprehension-level understanding of each of the theories/practices so that they could individually choose (with faculty guidance) which ones were most germane to the particular line of inquiry they desired to research. Then, as their research proceeded, they would develop a deeper application-level understanding of the learning theories/practices chosen in order to relate them to learning in their area of expertise. Students were also encouraged to bring-in and address theories or practices that had not already been identified by the course designers in an effort to expand the list of potential theories for all to consider.

In the area of XR/emerging tech application, the course designers determined to start with an assumed baseline of students having no previous knowledge in this area. Thus, beginning with the basics and working toward more complex concepts was the plan. Early blocks of instruction and guided discussion included topics such as how VR works from a technical perspective (frame rates, tracking, directional audio, etc.) and how the mind can be "convinced" into believing the virtual world is "real" (the range of human senses, process of sensory perception, presence, immersion, embodiment, etc.). Once students became proficient in the basic operation of single-user VR, the class moved on to multi-user co-presence, where the vast majority of the class's VR time was spent. Later sessions involved aspects such as being able to evaluate safety and physiological considerations for XR use, curating off-the shelf XR content, producing and editing 360-video content, understanding the process of computer-generated 3D XR content development, and applying their understanding to produce a 3D-printed artifact.

In the realm of research practice, the assumed baseline was that students had not previously written a master's thesis-level paper. As such, several sessions were spent discussing the processes of developing the problem/thesis statement, analyzing the professional literature, building the research plan and outline, identifying good sources, formatting the thesis paper, the process of writing, and constructing a bibliography. Between the MSFRIC Research Librarian, Lynda Wyckoff, and TLC Director, Dr. Anthony Gould (who has published several professional works), the students had strong faculty guidance on the process of conducting student research.

Course Materials

A pivotal resource that was provided as a student reference was Hale & Stanney's *Handbook of Virtual Environments: Design, Implementation, and Applications*. This 50-chapter, 1,456-page reference book provides readers with some of the most robust research in the field of Virtual and Augmented Reality. From explaining how olfactory senses can be used in virtual worlds to product liability issues with VR/AR devices; from clinical applications of VR to using VR for cultural awareness: regardless of one's area of expertise, there is something relevant available in the *Handbook of Virtual Environments*. Also, because *the Handbook* is a peer-reviewed, scholarly resource, each one of the 50 chapters includes a resources list of dozens of other scholarly sources that can enable a researcher to take their inquiry to the next level (Hale & Stanney, 2015).

In addition to *the Handbook*, students were assigned to research peer-reviewed articles in the MSFRIC online journals database using resources like Academic Search Premier, EBSCO, JSTOR, Lexis Nexis, etc. In their searches for scholarly literature, each student brought an average of 12 peer-reviewed or current technical publications in to share their findings with the class. The discussion of ideas uncovered in the scholarly literature often took place as part of an "in-world" multi-user co-presence session (using Rumii, Engage, AltSpace, or other co-presence platform).

Another book assigned to the class included Dr. Jeremy Bailenson's *Experience on Demand*. The instructors and class members consistently agreed that this is the ideal written source to first introduce a person to the phenomenon of Virtual Reality. Based in part on research conducted at Stanford's Virtual Human Interaction Lab (founded by Bailenson), *Experience on Demand* covers the psychological and sociological underpinnings of VR. The third assigned reading for the class, *Future Presence*, by editor of Wired Magazine, Peter Rubin, focuses on how VR will impact popular life and culture, which served as valuable material for class conversations on the socio-political aspects of technology transformation. Lastly, the fourth book – assigned, in part, for the students' enjoyment – gives perhaps a reflection on the possibilities for the future: the already-cult-classic, *Ready Player One*, by Ernest Cline. In the dystopian future described by Cline, students attend school inside the virtual world; real friendships are built in VR; and people live more of their lives "connected" than they do "off-line" (Bailenson, 2018), (Rubin, 2018), (Cline, 2011)

HOW – INSTRUCTIONAL METHODS/LEARNING ACTIVITIES

The notion of using XR tools in the learning environment logically leads one to the idea of educational transformation. What XR brings to the learning environment is the ability to deliver a first-person experience from outside of the traditional education & training milieu (i.e. beyond the classroom/lecture hall). Instead of a teacher giving a classroom lecture about the Battle of Gettysburg, why not situate the class in the middle of the Battle of Gettysburg while the battle is taking place? The instructional points could still be revealed – albeit with much more situated relevance. After reading Sun Tzu and Clausewitz, instead of just having a guided discussion on the principles as the capstone, perhaps construct mock battles in a virtual environment to demonstrate the similarities and differences between the strategies to enable the discussion to attain a higher level of learning. With XR, learners are empowered to become the agents to build digital artifacts and interact with the digital content to construct shared meaning of the concepts (Millican, 2017). These kinds of examples are what inspired the course designers to construct the XR Research course as a series of immersive, connected experiences.

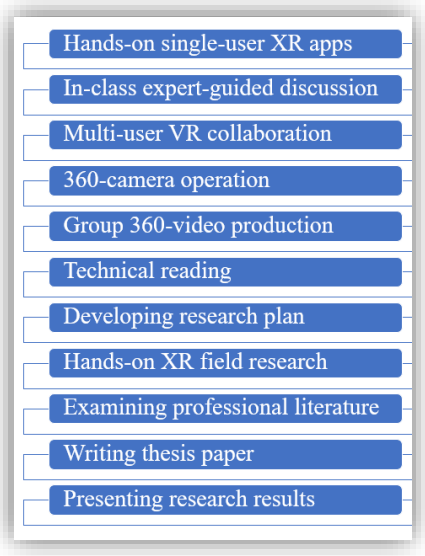


Figure 2. Instructional Methods/Learning Activities Used in the XR Research Class

The series of class activities began with hands-on use of the Oculus Rift CV1 Head Mounted Display (HMD) device. Students were led through several activities that simply enable them to become familiar with the operation of the device and enable them to become comfortable with being inside the virtual environment and engaging with VR content. These single-user VR experiences range in level of difficulty from easy to challenging. Among factors that were considered were that roughly 20 minutes is about the extent that a person should stay in VR initially. The more times a person has been in VR, the more likely their senses can tolerate a longer session. Our method of introducing the students was a single 20-minute session the first week (as a part of the 3-hour class), two 20-minute sessions the

second week (separated by over an hour outside the HMD conducting guided discussions on the VR experiences), and then three 20-minute sessions the third week (again separated by about 30-40 minutes of guided discussion between sessions). By the fourth week, all the students were fully acclimated to using VR and were ready to move-ahead with more challenging interactive content.

The more advanced VR sessions were those using multi-user VR (Rumii, Engage, AltSpace, High Fidelity, etc.) The game-changing capability that the multi-user sessions gave was that the distance students and the residence students became "present" inside the same space. Often, when interacting inside multi-user space, resident students would actually forget who was and who was not physically present in the classroom – because in their minds, "present reality" had transferred to inside the virtual space. This phenomenon of virtual co-presence was transformational to the class as it enabled students hundreds of miles apart to collaborate in small groups as a cohesive project team.

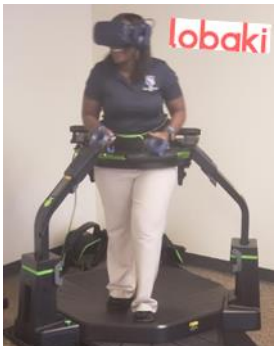
To give the class a sense of appreciation for what 360-video can provide, and an understanding for the skill sets involved in producing good quality 360-video, the students were taught how to operate a simple 360 camera and they conducted self-paced tutorials on how to produce finished 360-videos. The class was divided into 4 groups (each with distance & residence students both) and each group built an educational 360-video as a project team. Subjects of the videos included: *The Selma-Montgomery March* (filmed on-site at the bridge in Selma); *A Day in the Life of a War College Student* (filmed at Academic Circle and at AWC); *Dexter Avenue King Memorial Baptist Church* (filmed at the church in Montgomery); *Off-duty Time as an AU Student* (filmed in various off-duty locations around Maxwell/ Montgomery.) Each of the project groups shared their final projects "in-world" with the entire class. The use of multi-user VR platforms was the conduit by which the distance & residence students collaborated throughout the project: sharing milestone updates, passing along the latest edits of 360-video, audio and text overlays, etc.

A substantial portion of the XR Research class students' time was spent outside the synchronous class sessions doing the technical readings for the class and conducting field research in the professional literature. By about half-way through the first semester, when students had focused-in on their planned research topics, we started working on developing research plans. As is normally the case for master's-level student research, the majority of the data collection was from the professional literature, so the main focus of the research plan related to connecting with the right sources of information to demonstrate the key points to be made in the thesis.

AWC Student, Lt Col Ismael Barrenechea, F-16 Pilot, Chile, evaluates ICAROS simulator

XR Field Research

For field research, the class sent 20 people: distance students, residence students and faculty members, to the Lobaki XR Academy in Jackson, MS. In addition to commissioning the Lobaki Foundation to duplicate the original Clarksdale XR Academy at over 40 schools, the governor of Mississippi has funded the Lobaki Foundation to set-up a central XR Academy in the capital city of Jackson. At Lobaki's central XR Academy, every known developmental XR device is maintained for public demonstration. This central location enables developers from across the state to evaluate development kit assets to determine whether they would like to develop content for the devices. Examples of devices evaluated by the class include: the ICAROS free-flight simulator, the Virtuix Omni 360-degree treadmill, the HTC Vive wireless adapter, a full-body motion-capture suit, Leap Motion controller connected to HTC Vive, Microsoft HoloLens, Magic Leap AR headset, and many others. Another value-added experience for the class at Lobaki was the opportunity to interact personally with some of the young people whose lives had been changed to having a bright future by learning developer skills at the XR Academy.

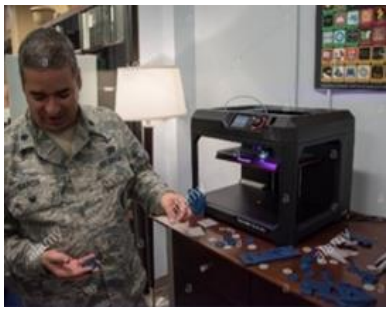


OLMP Master's Student, Monique Brisson, Electrical Engineer, evaluates the Virtuix Omni

The field research trip to Lobaki XR Academy, conducted about three-fourths way through the first semester, also was the first time the XR Research class distance students and residence students happened to be in the same physical location together – likewise, the first time that the distance students had met each other in physical presence. The students all commented that it seemed like they knew each other on a level beyond how one typically would know a fellow distance learner. Their feedback was that the ability to collaborate with each other in virtual space had given them a better sense of their

classmates' personalities than if they had only collaborated via flat-screen webinar or bulletin board. This unique experience presents some real opportunities to any distance learning program that would like to introduce social connectedness into the learning environment (an aspect which all traditional distance learning programs could use.)

In addition to the trip to the Lobaki XR Academy, a great deal of the student field research was conducted at home station and in the virtual world. One block of learning that produced an atypical deliverable for a PME course was the block of instruction in 3D Printing. AU's 3D Printing Specialist, Lt Col Carlos Garcia, guided students through a single-user VR application that enabled them to build their own digital icon in 3-D: some built airplanes, one designed a beaver holding a Canadian maple leaf; others built abstract 3D sculptures. After the renderings were complete in-world, they were saved and printed on the innovation lab's 3D printer. The entire lesson demonstrated the process of going from an idea in one's head to a tangible 3D-printed model of the idea without needing paper, a molding, or even a manual tool (other than VR, the PC and the 3D printer with filament). Practical applications for this emerging technology were many in the eyes of the students: foremost was the ability to 3D print certain parts on demand rather than having to rely on delays from the supply system. Also, the ease with which one could print a utility object that did not yet exist in the system was a focus of discussion.



Instructor, Lt Col Carlos Garcia, examines a student's 3D Printed artifact

Student Thesis Papers

In addition to 360-videos, student presentations, and developing VR content, the foremost student deliverable from the class was the student thesis paper. The intent of the paper was for students to integrate concepts learned in the course with their own pre-existing expertise in some area of national security to inform their respective community of practice on the notion of using XR/emerging tech as learning tools. The process of building the student thesis papers was iterative through the first "in class" semester as a partial deliverable was submitted every 2-3 weeks to provide an opportunity for formative assessment on each student's progress (problem statement, annotated bibliographies, outlines, drafts, etc.) Another valuable component was the opportunities built into the syllabus for students to provide each other with "peer review" feedback. The peer review process was a two-way opportunity: first, for the student to obtain other students' recommendations for their deliverables, and second, for each student to have an opportunity to see how others in the class were interpreting theories and concepts to potentially inform their own thinking.

In a collaborative effort with MGMWERX, all students assembled at the MGMWERX facility in downtown Montgomery to present the status of their research to interested professionals affiliated with the MGMWERX community. Even distance learning students were flown-in for the presentation event. Each student provided a synopsis of the research they had been conducting and answered questions posed by the audience. Several connections were made at the MGMWERX event in which innovative entrepreneurs became subject matter collaborators with the XR Research class members.

As referenced in Figure 4, the primary intended student outcome of the class, (that of having XR/emerging tech applied to learning of professional practice) was thoroughly achieved: every one of the 17 papers focused explicitly on how to use XR/emerging tech for learning in their chosen professional field. There were several cases in which the secondary intended outcome was also realized (XR/ emerging tech applied directly to practice.) The secondary outcome papers were those in which the student's field would not only be impacted from improvements to learning, but also improvements in regular operations: pre-mission rehearsal for aircrews, post-mission fighter engagement debriefs, common operating picture for ISR are a few. A full list of all the student research papers is included at Table 1.

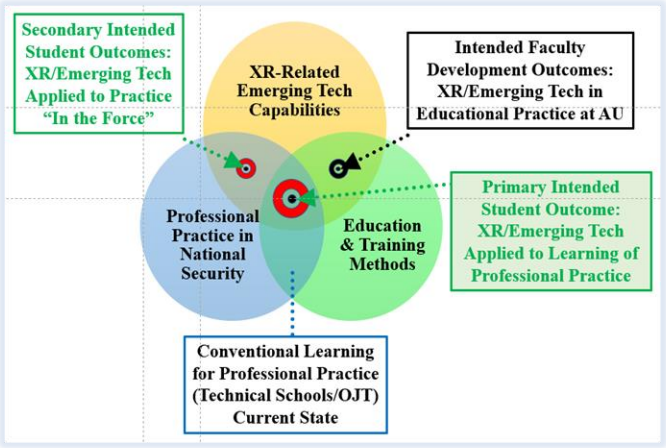


Figure 4. Intended Outcomes

CONCLUSION

The graduate course "XR Technologies: Practical Applications in the National Security Enterprise" provides an initial foray into the area of applying XR/emerging technologies to the process of learning and operating in national security. Each of the student papers produced in the class offers a field of national security practice a degree of expert analysis of how these tools can improve the process of learning and/or operating. Likewise, the process of administering the class enabled eight faculty members of AU to develop a degree of practical competency with the ability to use the emerging technology tools for educational practice. Through all of the partnerships that were formed and strengthened through the execution of the course, the framework is in place for continued delivery of this one-of-a-kind program. Of the 17 students enrolled in the class, each of them produced a value-added research work that has been accepted as a section of a scheduled AU compendium of VR/AR Research from Academic Year 2019.

A download of each of the below outlined thesis papers can be obtained at the following link:

www.VRexLearning.com/student-papers

Table 1. Student Research Papers Produced by the Class

Paper Title	Author, Specialty
Air War College, Maxwell AFB, AL, (Resident Students)	
Augmented Reality Collaborative and Analytical Tools for ISR Operations	**Col Brendan Cook**, Royal Canadian Air Force, ISR Pilot
Leveraging Virtual Reality to Maximize Pre-Deployment Cultural Awareness	**John Allelo**, US Agency for International Development, Foreign Service Officer
Hand/Finger Tracking and Haptics: the Next Phase for Pilot Training Next?	**Lt Col Timothy Mach, USAF**, Mobility Pilot
Virtual Reality as a Tool for Insider Threat Mitigation and Background Security Investigation Improvement	**Melissa S. Walker**, Office of the Secretary of Defense, Information Management Officer
Ready Pilot One: Using VR to Help Solve the Pilot Absorption Problem	**Lt Col Charles Gilliam, USAF**, Mobility Pilot
The Potential Use of Virtual/Augmented/Mixed Reality for Strategic-Level Decision Making	**Lt Col Ismael Barrenechea**, Chilean Air Force, F-16 Pilot
Virtual Reality for Remotely Piloted Aircraft Training	**Calvin Chang**, Department of the Navy, Engineer
Air Command & Staff College, Maxwell AFB, AL, (Resident Students)	
Virtual Reality (VR) inclusion in Army Combined Arms Training Centers (CTCs)	**MAJ David Dens, USA**, Modeling, Simulations, and Battle Command Systems Officer
The Haptic Soldier: Identifying the Missing Virtual Reality Components to Support Cognitive Training	**MAJ Cody Pilger, USA**, Engineer
eSchool of Graduate PME, Online Master's Program (Distance Students)	
Time to Put Down the Sticks and Put on the Headset … Training Fighter Aircrew in the 21st Century	**Maj Benjamin Lee, USAF**, F-15E Weapons System Officer, 4 FW, Seymour-Johnson AFB, NC
Virtual Reality as a Mission Familiarization System for Deployed Mobility Aircrew	**Daniel Delaney**, Command Foreign Disclosure Officer, USCYBERCOM, Ft. Meade, MD
Bringing the Classroom to Your Living Room – Distance Learning through Virtual Reality	**Major Joel Oyama, USAFR**, Aeromedical Evacuation Flight Nurse, 446 AES, JBLM, WA
Utilizing Simulated Environments to Increase Effective Communication among Distributed Teams	**Monique Brisson**, Electrical Engineer, Air Force Research Lab, Wright-Patterson AFB, OH
Virtual/Augmented Reality in Air Force Technical Training	**Joshua Booth**, Maintenance Operations Flight Director, 45th Range Squadron, Patrick AFB, FL
Extended Reality for Pre-Mission Training and Planning	**Mariah Genco**, Senior Intelligence Analyst, 548th ISR Group, Beale AFB, CA
Critical Choices for Combat Medics, Training in Virtual/Augmented Reality	**Maj David Morgan, USAFR**, Critical Care Air Transport Team Nurse, 94 AW, Dobbins ARB, GA
Air Force Chaplain Corps College (Resident Faculty)	
Religion, Readiness, and Virtual Reality: Implications for the Air Force Chaplain Corps College	**Maj David Merrifield, USAF**, Chaplain, USAF Chaplain Corps College

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