A Multi-method Learning Framework for Multi-capable Airmen

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ABSTRACT

The Air Force is transforming the way Airmen learn through opportunities that allow Airmen to train as they fight using experiential and multi-modal options. Concurrently, the Air Force is rapidly adapting to the challenges of the future security environment, where it should draw upon situated learning (SL) theory (Lave & Wegner, 1991) as a framework for training Multi-capable Airmen (MCA). Supporting the concept of Agile Combat Employment (ACE) through deploying in smaller, agile teams, MCA must perform tasks outside their core specialty, and a recommended method for training MCA to perform these new tasks is through SL-based training. The Air Force is also accelerating change through increased use of virtual reality (VR) technology, which is well suited to experiential learning (EL) (Kwon, 2019). However, these new methods introduce new challenges to the Air Force. A review of literature finds that most VR applications focus on learning outcomes without supporting learning processes like EL (Fromm et al., 2021). Few studies exist on combining SL and EL using VR-based training. The Air Force is increasing its use of EL, yet it must go beyond the mode of the VR experience and leverage all four learning modes as described in Kolb's (1984) EL theory. By designing SL-based VR training around EL as a process, MCA will be able to cycle through the four learning modes (i.e., concrete experience, reflective observation, abstract conceptualization, and active experimentation) which can accelerate new skills by allowing them to learn from their own virtual experiences (Kolb & Lewis, 1986). Drawing on data available through open source, the paper develops best practices for SL and EL integrated with VR technology. This analysis will develop principles to inform and guide MCA instructional design and present recommendations on how to establish effective MCA training.

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BACKGROUND

While conducting extensive counterinsurgency and stability operations over the past 20 years, the U.S. Department of Defense (DoD) recognizes that during this period the Nation's adversaries made significant investment in military modernization, resulting in new disruptive technologies with the ability to place effects over great distances across all domains with the potential to severely limit our ability to project power globally. During this period, the Air Force primarily conducted centralized operations from main operating bases (MOBs) from which it was able to project air power. Adversaries can now challenge this capability with sophisticated air and missile defense systems, requiring the Air Force to adopt new concepts of movement and maneuver that will provide increased agility and survivability. To facilitate this new scheme of maneuver, the Air Force is employing the concept of Agile Combat Employment (ACE) which will present enemies with multiple dilemmas from multiple domains through a rapid operations tempo that will disrupt enemy capabilities (Department of the Air Force [DAF], 2021). Through the dispersion of combat power from centralized MOBs to distributed operations, ACE will provide more options to commanders through freedom of maneuver and increased survivability. ACE carries out this by complicating enemy targeting through the ability to operate with lean and agile forces operating across multiple locations with pre-positioned equipment and scalable support packages.

A foundational element in the doctrine of ACE is the employment of multi-capable Airmen (MCA). These military personnel will train in cross-functional teams to provide combat support and combat service support for ACE force elements (DAF, 2021). They will be enabled by cross-utilization training and will be able to operate independently in an expeditionary environment. The challenge facing the Air Force is the ability to train Airmen with just-in-time methods so they can perform expeditionary tasks outside their formally trained skillset at high performance levels without benefit of institutional training. Some Airmen attend formal training at the Air Force Expeditionary Center's MCA Expeditionary Skills Training course, but not all will be able to attend this initial qualification training. Those Airmen who have not attended participate in hands-on training at various organizations around the Air Force. Since just-in-time novel task training is a key principle of MCA, the Air Force faces challenges in finding approaches, methods, and tools that can maximize the transfer of training in an abbreviated period. To prepare Airmen for these critical tasks, the Air Force requires deployable mission-relevant training solutions that use multiple technologies that are well integrated. Technology is only one aspect, but the Air Force should integrate well-established learning theories with technologies that immerse MCA in realistic training scenarios with high levels of fidelity through virtual environments.

INTRODUCTION

The purpose of this position paper is to propose a research-based theoretical learning model for use in Air Force point-of-need training for MCAs that must perform expeditionary tasks outside their specialty in support of ACE. The model integrates situated learning (SL)-based virtual reality (VR) training, using experiential learning as a process in MCA instructional design. The Air Force continues to improve training and education as a critical Force Development enabler that prepares Airmen for the future security environment. This has broad implications for military training and education programs.

In military training and education, particularly in occupational specialties with both higher training risk and significant resource requirements (e.g., Special Warfare, flight training), experiential training and education programs continue to account for an increasing part of Air Force curriculum. What is not clear is how to best design Airmen learning experiences, especially technology-based experiences such as VR. Although VR technology-related studies continue to add to the body of knowledge, there is a lack of clear understanding about the learning theories supporting learning through VR, how VR facilitates knowledge transfer and transfer of training, and the effectiveness of VR training, especially in an expeditionary context where just-in-time learning is well-suited. The Air Force recently published Doctrine Publication (AFDP) 1, *The Air Force*, which describes the need to accelerate change by creating innovative "concepts and technologies that will develop new best practices to shape future doctrine" (DAF, 2021, p. 1). AFDP 1 states that MCA will perform tasks outside their assigned career specialties in contested, degraded environments. MCA will also execute Mission-Type Orders through the doctrine of Mission Command, the central concept being centralized control and decentralized execution. Given the challenges of training MCA in unfamiliar tasks in the Mission Command environment, this paper proposes a research-based theoretical model for MCA based on well-established education theories that take advantage of advances in virtual reality technologies. This will add to the body of knowledge by expanding current understanding of how students learn through experience in context in VR. The next section discusses the two learning theories that frame the proposed learning model in this paper: Situated learning and experiential learning theories. By combining the elements of these two theories into a hybrid model, the Air Force will be postured to deliver evidence-based training to MCA in high fidelity immersive environments that can foster rapid training transfer. The ability to increase both training transfer and knowledge retention will enable the Air Force to adapt to rapid changes necessary for competitive advantage.

THEORETICAL BACKGROUND

Situated Learning Theory

Building upon the theory of situated cognition (Brown et al., 1989) which centers around the concept that knowing is inseparable from doing and the importance of learning in context, Situated Learning Theory (SLT) is an instructional approach developed by Lave & Wenger (1991), and states that learning occurs within authentic context, and students are more inclined to learn when they actively participate in the learning experience. SLT also promotes the concept that students learn better in groups while immersed in real-world experiences. Knowledge or training transfer can be optimized by presenting the material in realistic contexts (Lave & Wenger, 1991). For the desired behaviors to become instilled in the learner, SLT highlights collaboration and social interaction, where learners participate in communities of practice of shared situated learning. Trainees learn by socialization, visualization, and imitation. In SLT, Lave and Wenger (1991) assert that traditional classroom learning emphasizes the transfer of abstract learning that is devoid of context. A model of SLT (Figure 1) shows a community of practice near the center of the circle, representing expertise. The novice is at the periphery, and as a member of the community of practice, moves toward the center through interaction and support with experts (Lave & Wenger, 1991)

Figure 1. Model of Situated Learning Theory

For further reading, there is extensive literature on Communities of Practice and the application of a community-based approach to knowledge (Wenger, 1998; Wenger et al., 2002).

Experiential Learning Theory

A complement to SLT, Experiential Learning Theory (ELT) (Kolb, 1984) builds upon the work of Dewey (1938), Lewin (1951), and Piaget (1974), and is based on the concept of gaining knowledge through experience. An influential and often cited model in the military training and education literature, ELT describes learning as a continuous process based in experience. ELT-based learning is conceived as a process, and not a series of outcomes (Kolb, 1984). According to Kolb (1984) individuals must move through a four-stage cycle involving four adaptive learning modes: concrete experience, reflective observation, abstract conceptualization, and active experimentation. The experience element only represents one of the stages of ELT, and learning does not take place through experience alone (Fromm et al., 2021). The experience enables more than the transference of information by changing the way Airmen will think. This contrasts with the pedagogical model of lecture-based instruction, which finds increasing criticism among adult learners for its passivity and lack of realism (Hoover et al., 2010). Learners must cycle through the four stages of experiential learning with high degrees of immersion and interaction for experiential learning to take place (Stieglitz et al., 2010). Figure 2 is a representation of Kolb's (1984) experiential learning model, and shows the four stages starting with *concrete experience*, where, in an Air Force context, Airmen are introduced to a new experience or reinterprets an earlier experience. In this stage, Airmen would interact with the tasks presented to them and allow them to begin to construct their own learning experience, recognizing that adults learn best by active engagement (Knowles, 1984a; 1984b). During the *reflective observation* stage, Airmen reflect, recall, and re-engage their experiences to gain new insights and knowledge, using the lens of their understanding of the experience and what it means. In the *abstract conceptualization* stage, Airmen then begin to form new ideas and adapt their thinking based on their new experiences. In the *active experimentation* stage, Airmen now apply the new knowledge to their environment, ready to continue the cycle again.

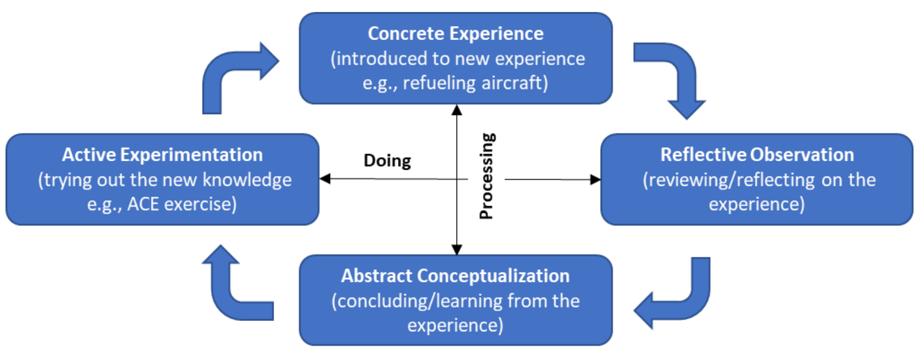

Figure 2. Stages of Experiential Learning Adapted from Kolb and Kolb (2017)

Figure 2 also shows the learning cycle in ELT formed around two opposing dialectics of action/reflection (doing) and experience/abstraction (processing), and the combination of these two learning phases facilitates the learning between people and their environment (Kolb & Kolb, 2017).

Interaction and Immersion

Stieglitz et al. (2010) developed a framework (Figure 3) that illustrates two dimensions that classify learning arrangements in virtual worlds: the degree of interaction and the degree of immersion. Against the background of the experiential learning theory, the framework suggests that only with high degrees of interaction and immersion can experiential learning take place. Technologies such as VR support contextualized, interactive, situated and experience-based learning by creating an environment of interaction and immersion, which allows instructional designers and facilitators to create experiential-based training. When immersion and interaction are high, a higher degree of learning transfer takes place from the concurrent effects of experiential, procedural, auditory, and visual learning (Stielgitz et al., 2010). The digital environments in VR can foster experiential learning through their ability to leverage the full potential of interaction and immersion (Stieglitz, et al., 2010).

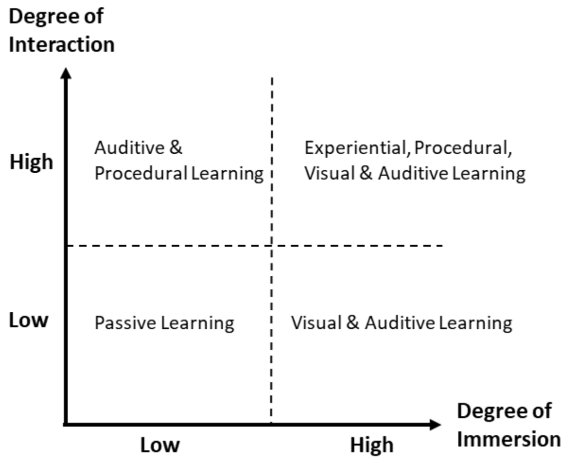

Figure 3. Framework for Learning Arrangements. Adapted from Stieglitz et al. (2010).

For further reading on the combined effects of interactivity and immersion in VR learning, see the Cognitive Affective Model of Immersive Learning (CAMIL) framework discussed in Petersen et al., (2022).

THE VR ENVIRONMENT

The previous section discussed the learning theories, and this section will examine elements of the immersive environment when using VR. Some of the fundamental characteristics of VR technologies relate to the spatiotemporal elements of visual immersion, interactivity, and spatial presence (Radianti et al., 2020; Ryan, 2015). The following section discusses these elements in the context of preparing MCA to support ACE operations.

Table 1. Spatiotemporal Elements of VR

Elements	Description
Visual Immersion	Witmer and Singer (1998) assert that immersion is a prerequisite to presence. Immersion refers to the degree to which visual environments can produce an illusion of reality where MCA perceive they are participating in a comprehensive, realistic experience (Dede, 2009).
Interactivity	Being able to recognize an object, then being able to move or manipulate the object are elements of interactivity (Lee, 2004) such as the ability of Airmen to modify virtual objects while immersed in a virtual airfield, such as moving auxiliary power units, setting up antennas, or removing aircraft panels.
Spatial Presence	Although a complex construct with a lack of standardized terminology, Lee (2004) defines spatial presence as “a psychological state in which the virtuality of experience is unnoticed”. In the context of VR environments, presence refers to a psychological state where individuals experience virtual objects as actual objects (Hruby et al., 2020; Lee, 2004).

VIRTUAL REALITY IN MILITARY TRAINING

VR is an increasingly popular teaching modality made possible by improvements in VR hardware and software advances and has been shown to be an effective means for training cognitive and psychomotor skills, especially in high-risk training environments (Renganayagalu et al., 2021). The costs and risks to train certain tasks in live environments outweigh the benefits for some areas of military training such as live fire, aviation, and medicine. Immersive technologies such as VR can create training environments with the right level of fidelity to achieve the desired learning outcomes at lower cost and minimal risk. VR offers unique affordances for learning transfer, such as visual fidelity, learner interaction, and presence (Dalgarno & Lee, 2010). Immersing a trainee into a high-fidelity visual environment that replicates real world conditions can foster an elevated level of trainee behavioral fidelity that improves training transfer (Xie et al., 2021). Employing situated learning through virtual reality is shown to enhance learning transfer through real world simulation (Xie et al., 2021; Dede, 2009). Modern high-resolution VR head mounted displays can create a remarkably high level of immersion that turns first-person perspective into highly realistic interactions in the virtual environment. Learners who used VR head mounted displays were found to develop better cognitive, psychomotor, and affective skills through increased engagement while using these displays (Jensen & Konradsen, 2018).

Recent advances in computing power, specifically central and video processing capability, along with VR hardware and software technologies, have enabled the military to rapidly advance the development of high-fidelity training environments that can accurately re-create a given operating environment. Each of the military services continue to expand their use of VR training, and one of the more prolific examples is aviation-related training. The Air Force and Navy have published findings on their use of virtual reality in training, and the results are positive (Thurber, 2021; Mishler et. al., 2022).

Military VR Training Program Reviews

Navy Project Avenger

The Naval Air Warfare Center Training Systems Division (NAWCTSD) conducted a training effectiveness evaluation for their Project Avenger, an experimental Navy program designed to address growing pilot shortages and explore methods to improve pilot training effectiveness using VR (Mishler, et al., 2022). Regarding student performance, the study showed that Avenger students as compared to current flight program students achieved similar or higher flight grades in fewer events. Regarding efficiency, the Avenger program was shown to be more efficient in terms of being able to train more costly events in VR, as well as using VR to reduce both the time to train and number of required syllabus events (Mishler et al., 2022). The study limitations include a small sample size, and lack of data on how the Avenger students performed in advanced training.

Air Force Maintenance Training Next/Tech Training Transformation

The Air Force's Air Education and Training Command created a VR training system for Airman technical training as part of their Tech Training Transformation project (Thurber, 2021). This project introduced VR into the Crew Chief Fundamentals Course which trains 4,500 Airmen each year, where trainees would examine tools and perform simulated aircraft maintenance in a high visual fidelity VR environment. The end of course assessment revealed that the differences in Airmen performance in the traditional course versus the VR course were not significant. A significant finding was the VR-trained Airmen finished the course 46% faster than the traditionally trained Airmen (Thurber, 2021).

EDUCATION AND TRAINING CHALLENGE

The challenge to the Air Force is preparing MCAs to perform expeditionary tasks outside their normal specialty in adverse and contested environments without the benefit of traditional, centralized classroom instruction. Since 2020, the Air Force Expeditionary Center has trained Airmen in their Multi-Capable Expeditionary Skills Training Course at Joint Base McGuire-Dix-Lakehurst, New Jersey, and some decentralized MCA training also occurs at the Wing level across the major commands. The Air Force conducts MCA training using traditional methods, with classroom instruction followed by the opportunity to get hands on experience with actual weapons systems and equipment. There are few options available to train Airmen to perform new tasks with unfamiliar equipment, as the ability to train with actual weapons systems is limited, creating a capability gap. SLT-based VR training using ELT as a process can address this gap. Although training on actual weapons systems and equipment is a critical element of all military training, not all tasks need to be performed on live equipment all the time. MCA learning activities can be situated in context, and the experiential approach to learning within context has immense potential to develop the required MCA skills and behaviors through the ability to conduct just-in-time training at the point of need, without the requirement to disrupt operations with frequent access to weapons systems and support equipment.

Although the above examples highlight the measurable positive value of VR training, it is not universally appropriate for all specialties or all types of education and training. This paper addresses VIMS as a significant challenge for some VR users which not all users will overcome, making VR an unusable modality for those individuals. Although the hardware and software may be ready to provide high-quality VR training, many VR systems currently in use cannot connect to military networks due to cybersecurity requirements, limiting training opportunities in classified environments. In respect to training transfer, well designed VR instruction is essential, as the simulation must be realistic and relevant to foster high levels of training transfer. VR training can be engaging with measurable impact, but VR instructional design is different from traditional military classroom instructional design and designing for experience only without context and community described in SLT and incorporating all four phases found in ELT, the students may be challenged to achieve their learning objectives and demonstrate high training transfer. The next section addresses additional challenges in MCA education and training.

Challenges and Limitations

Experiential training in the military is not well-defined. As such, there is little evidence in the military training literature that address the ability of experiential learning to achieve the designed learning objectives, and this paper addresses this gap. A review of the medical literature finds a rich and growing use of VR in medical education and training (Duarte et al., 2020; Pottle, 2019). A study by Xu et al., (2021) reviewed 17 studies consisting of over 1,000 participants that showed VR training using head mounted displays improved medical education efficiency through improving student satisfaction and motivation, which resulted in improved learning outcomes. The study (Xu et al., 2021) found a remarkably high degree of knowledge transfer from VR to real world application, although visually induced motion sickness (VIMS) was found to be a limitation. VIMS is a phenomenon similar to motion sickness, which is typically induced by a mismatch between a user’s visual and vestibular systems, resulting in an unsettling/disassociated sense of where the physical body is relative to the virtual environment. Although VIMS is outside the scope of this paper, techniques are continuously being developed to reduce or prevent VIMS in virtual environments (Keshavarz, 2016; Peck et al., 2020).

As a socio-cultural approach to learning, SLT is based on the concept of learning in a contextual environment versus a classroom, where learning is not a traditional transfer of knowledge but the creation of knowledge through a situated or context-based environment (Lave & Wegner, 1991). However, although situated learning is powerful, its use in training and education settings is limited due to the challenges with creating real-world environments in context (Dede, 2009). In SLT, learners participate in a community of practice where they can learn most effectively within their community. In this paper, the community of practice is the MCA community, where Airmen share experiences, solve problems, and build trust. Although MCAs will be designated from numerous Air Force organizations around the world, the Air Force will have to create a cloud-based collaboration environment that will have the ability to foster social capital as Airmen share the MCA domain of knowledge as learning occurs socially across Air Force MCAs.

RECOMMENDATION

SLT-Based Learning Using ELT as the Learning Process

What does this mean for military training and how these theoretical perspectives can be applied to optimally support ACE? By designing SL-based VR training around EL as a process, the research-based theoretical model shown in Figure 4 (below) represents an evidence-based framework for the Air Force that can leverage advances in VR technologies to create high-fidelity training environments that are situated in context and reinforced by an MCA community of practice. By developing high-fidelity VR environments with high degrees of immersion and interaction (outer ring), MCAs surround themselves in realistic environments that create a sense of immediacy and control, where they learn by doing and reflect on their experiences to improve their expeditionary task skills (inner ring). By interacting with MCA in a community of practice, experts can facilitate the creation of new knowledge through the transformation of experience (Lave & Wenger, 1991; Kolb, 1984). Instructional designers, using the well-established ADDIE process, can develop training experiences specifically designed with high levels of immersion and interaction that meet required learning objectives that focus on the critical tasks MCAs will encounter in the operational environment. By adopting this model, the Air Force can leverage VR capabilities shown to improve recognition of new concepts, understanding, and performance (Slavova & Mu, 2018).

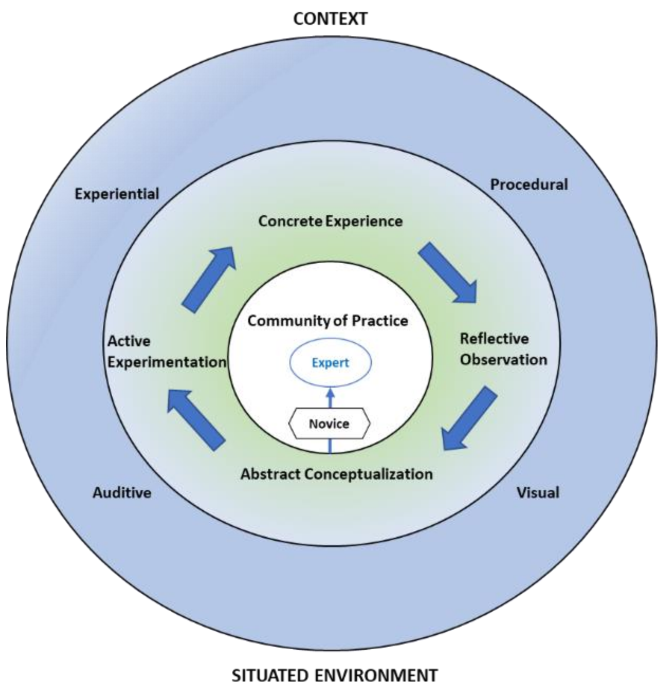

Figure 4 Research-based Theoretical Model for Multi-capable Airmen

Integrating SLT with ELT as a process relies on MCAs participating in training experiences that are part of the ELT process model. As previously discussed, experience alone does not translate to knowledge creation. Air Force instructional designers will collaborate with VR developers and ACE subject matter experts to create meaningful virtual experiences that mimic ACE operations. Through the process of self-reflection in context with the support of experts and fellow MCAs in a community of practice, MCAs can gain a better understanding of the ACE environment and expedite proficiency gains in expeditionary tasks. With the optimal development team, this model can foster a strong increase in training transfer, as the VR environment will be closely representative of reality (Cooper et al., 2021). MCAs will be able to engage in task training at the point of need without the need for access to actual Air Force weapons systems, equipment, or field training sites.

The VR Operating Environment

As the Air Force continues to employ the ACE concept, Airmen will be able to adapt to meet the emerging needs of ACE operations with the ability to train in a realistic environment. A realistic virtual environment such as a small airfield in Eastern Europe or an island in the Indo-Pacific theater can be created in VR to the required level of detail. MCAs can don their head mounted display and select from a menu of options based on the specific training needs.

They can learn how to set up communications, establish perimeter security, and learn how to rearm and refuel various aircraft types. The virtual environment can be designed with embedded videos where MCAs could watch a video recording of the live event, and then conduct multiple iterations of those tasks, or even embed stereoscopic video by blending in the video with the modeled environment, creating additional realism through layered effects. The virtual environment can be designed with interactive cues, prompts, and tutorials that will allow MCA to virtually experience performing the various ACE-supported tasks to standard, which can be monitored by training instructors and supervisors.

Establish an MCA Community of Practice

Fundamental to the proposed research-based theoretical model is the community of practice. SLT focuses on how the learning situation affects the learning process and places the learner where they learn in context with social co-participation. There are numerous examples of thriving communities of practice across DoD, such as the ones that support the Defense Acquisition Workforce sponsored by Defense Acquisition University. AETC hosts the Learning Professionals Communities of Practice, which advances force development through collaboratively fostering the continuum of learning where Airmen can share ideas and spark innovation. The Air Force could provide a cloud-based space where Airmen can collaborate and share ideas and lessons learned. As previously described, in the social nature of human learning, MCAs will benefit from a community of practice where they will share a common interest with other Airmen charged with the same mission across the Air Force.

CONCLUSION

As the Air Force continues adapting to the future security environment, it requires the capability to train Airmen with evidence-based techniques and methods that improve training transfer, increase retention and proficiency, and allows them to train in a high-fidelity virtual environment that eliminates the need for access to weapons systems and equipment. This paper proposes a research-based theoretical model that leverages SLT and ELT. SLT is a socio-cultural approach to learning that focuses on Airmen participation in a community of practice to move from novice to expert, and ELT. This emphasizes that learning does not occur from experience alone, but as a process that includes reflection on the experience (Kolb, 1984). Lave & Wenger (1991) posit that no learning takes place that is not situated, and that those in a community of practice share common goals and benefit from the effective learning that takes place in the community. For MCA, this shared goal focuses on their roles in cross-functional teams, where they must perform expeditionary tasks in austere environments in support of ACE operations. By providing a contextualized high-fidelity virtual environment where MCA can practice performing these tasks at the point of need, while sharing and learning from those experiences across a community of practice, the Air Force will create the conditions for their success.

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