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Augmented Reality in Nurse Anesthesia Education

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Abstract

Research shows that the addition of extended reality (XR) in healthcare education is advantageous as it enhances the learning experience and improves students' knowledge and motivation to learn. Its use has been documented in nearly all areas of healthcare education but is much less explored in the realm of anesthesia. This research project focuses on a branch of XR known as augmented reality (AR) and its use as an adjunct learning tool in the curricula for nurse anesthesia. Keller's *Attention, Relevance, Confidence,* and *Satisfaction* (ARCS) Model of Motivation guided the design of this project to understand the impact AR technology had on second year student registered nurse anesthetists' (SRNA) motivation towards learning. Students used an AR mobile application to interact with a realistic anatomical structure of the human larynx and completed a related worksheet. A post-assessment Likert-type Instructional Materials Motivation Survey (IMMS) was used to assess AR's impact on learner motivation as it relates to each of the four ARCS model constructs. Each construct yielded a high average score amongst participants, thereby indicating a positive learning experience. The results imply that AR enhances current learning modalities and may directly influence students' motivation to learn. The evidence is supportive for the use of AR as an adjunct learning tool in nurse anesthesia education. Future studies are needed to evaluate the efficacy of AR as a result of its integration into curricula.

Keywords: Anesthesia, Augmented Reality, Extended Reality, Virtual Reality, Student Registered Nurse Anesthetist, Healthcare, Technology

Augmented Reality in Nurse Anesthesia Education

Section II: Introduction

Extended reality (XR) utilizes computer technology as a platform to create real-and-virtual combined environments with which a user can interact. Extended reality is a generic umbrella term that encompasses both virtual reality (VR – users are immersed into a computer-generated environment) and augmented reality (AR – cyber images are superimposed over the real-world environment). The use of this technology in healthcare education has proven to increase motivation for learning and enhance traditional learning styles.

Background and Significance of Practice

The need for XR in healthcare education is multi-faceted due to factors such as worsening provider shortages, rapid expansion of medical knowledge, and alternative learning styles of healthcare students.

Provider Shortages. A projected healthcare shortage of more than 100,000 providers is anticipated in the United States by 2030 (Dall, West, Chakrabarti, Reynolds, & Lacobucci, 2018). By this time, there will have been a 50% increase in the number of individuals reaching 65 years of age or older, making the aging population a primary determinant of this impending shortage (Dall et al., 2018). Since advancing age tends to be accompanied by an increased requirement for healthcare related services, not only will it be difficult to meet the needs of patients, meeting the educational and training demands of students will also present a challenge. An anticipated concern is that this provider deficiency will equate to a lack of available educators to efficiently train today's healthcare students (Dall et al., 2018). Therefore, it is of paramount importance to employ alternative and effective teaching strategies that meet current education demands and requirements for the learner population.

Expansion of Medical Knowledge. The U.S. Bureau of Labor Statistics has projected healthcare to be the largest and fastest growing industry of the decade (U.S. Bureau of Labor Statistics, 2015). Emerging technologies, complex multimorbidity and the aging population contribute to the obligatory growth of existing medical knowledge. A study in 2011 calculated an average time of 3.5 years for today's knowledge to double, dropping as low as 73 days by the year 2020 (Densen, 2011). For historical comparison, doubling of medical knowledge took more than 50 years in 1950 and seven years in 1980; a time when today's educators were in the student role (Densen, 2011). Conventional education strategies are challenged to up with the accelerated expansion of knowledge, calling for curricular innovation that is culturally relevant to meet the current challenges of healthcare education (Piper, 2012).

Millennial Learning Style. Millennials (defined as individuals born between 1981 and 1996) have begun to saturate the healthcare industry, currently occupying the largest portion of its learner population. As these students graduate, they will account for 75% of the workforce, providing them with a crucial role in the transformation of future healthcare (U.S. Bureau of Labor Statistics, 2015). Being "digitally native" and having grown accustomed to a rapidly changing environment, the Millennial generation may be best equipped to manage the accelerated learning demands seen with healthcare today. The generational yearn for participating in contemporary learning opportunities challenges the mainstream infrastructure of education to discover new ways of teaching that will maximize use of modern resources and adapt to revolutionary changes.

The demands of Millennial learners necessitate diversity in teaching strategies that support innovative ways of thinking and student engagement (Taekman & Shelley, 2010). This idea of active learning, however, is not new. Edgar Dale introduced his learning pyramid over 50 years ago, emphasizing that learners retain 90% of what they *do* and only 10% of what they *read* (Dale, 1969). Restructuring modern curricula to adopt active, learner-centered didactic strategies will foster meaningful learning and quality education for the Millennial healthcare student. Additionally, programs who adopt such models are likely to experience improved rates of retention and student satisfaction, a key factor in managing the current trends of American healthcare (Giddens, 2008).

Problem Purpose/Specific Aim

Extended reality is a cost-effective resource that creates a non-threatening, realistic environment in which one can repeatedly practice his/her skills (Badash, Burtt, Solorzano, & Carey, 2016). This constant exposure shortens the learning curve, allowing faster transitions to occur from classroom to clinical environments (Munro, 2012). It is evident that XR employed for healthcare education and training has overwhelming benefits, however, its advantages in the realm of anesthesia have not been fully explored.

Problem Statement

In order to investigate best teaching modalities to meet the demands of today’s healthcare education, a PICOT question was formulated. The question includes the population of interest, a proposed intervention, the desired outcome, and the project timeframe. The PICOT question is: does the use of extended reality enhance motivation for learning in the education and training of student registered nurse anesthetists.

Organizational "Gap" Analysis of Project Site

Marian University in Indianapolis, IN has been identified as the site for implementation of this project. The organization's nurse anesthesia program is in its infancy and does not currently utilize XR for learning purposes. The institution shows great potential in adapting new teaching modalities as it continues to develop the ideal curricula for optimal performance.

Section III: Literature Review and Framework

A review of the literature was conducted to identify how XR is being utilized in healthcare education and evaluate the perceived benefits among its users (see Appendix A). This project drew on the ARCS (*Attention, Relevance, Confidence,* and *Satisfaction*) model to further explore student motivation for learning through the use of AR in anesthesia education (Keller, 1987).

Literature Review

Methods. Initial review of the literature was completed using the database, PubMed. The terms 'extended reality', 'XR', 'immersive technology', 'mixed reality', 'haptic learning', 'augmented reality AND education', 'extended reality AND healthcare students', and 'virtual reality AND millennials' were searched to ensure inclusion of any synonymous terms that may have developed throughout its evolution. Due to the rapid changes associated with emerging technology and healthcare and for the purpose of maintaining validity, a five-year limit was applied to exclude literature published prior to 2013. Results were further restricted to only randomized control trials (RCTs) (level 2 evidence) and quasi-experimental studies (level 3 evidence) utilizing Melnyk and Fineout-Overholt's classification system (Melnyk & Fineout-Overholt, 2015). To confirm saturation of data, an additional manual search of the articles' references was conducted in the database Google Scholar. No new relevant articles were identified confirming saturation point had been met. A total collection of nine articles were chosen for this review, five of which were randomized control trials (RCTs) and four quasi-experimental studies.

Synthesis of Findings. Study samples included within the reviewed articles were currently enrolled medical students, nursing students obtaining a bachelor's degree in nursing (BSN) or an associate degree in nursing (ADN), and pharmacy students. The control or comparison groups in all nine studies represented different forms of conventional learning methods including one or more of the following: mannequin simulation, computer-based learning (CBL), classroom lecture, written material, and problem-based learning (PBL). Computer-based learning was identified throughout the literature to include web-based educational material of two-dimensional images, video demonstrations, and/or online textbooks. Problem-based learning employs a facilitator that leads a discussion for a small group of students on a patient-case scenario in which several therapy options are discussed and each clinical decision made by the group alters the subsequent therapy choices (Al-Dahir, Bryant, Kennedy, & Robinson, 2014). The experimental group was assigned various modalities of XR technology including virtual, augmented, and high-fidelity simulation.

Critical appraisal was done, in isolation, by two graduate researchers with near-identical levels of content expertise. For sake of homogeneity and analogous evaluation, generic categorization of studies into major themes was necessary. After full analysis was complete and each study was categorized under a major theme, analytic discussion commenced, and findings were revealed. The outcomes identified within the literature can be aggregated into the following themes: cognition, psychomotor performance, and perceived experience.

Cognition. Cognition was assessed by the researchers in five studies (two RCT and three quasi-experimental) to evaluate knowledge acquisition or retention by administering pre-tests and post-tests before and after the training. Pre-tests were employed to determine students' baseline knowledge and identify any cognitive differences that existed between the groups. A difference in pre-test results was found in only one study by Smith et al. (2016) that compared efficacy of XR to written instruction for teaching nursing students the skill of decontamination. In this study, unsupervised pre-tests were administered to 108 BSN students. The pre-test scores were significantly lower in the XR group which indicated a baseline cognitive advantage existed in the comparison group (Smith et al., 2016). Despite the XR group's inherent handicap, mean post-training scores were numerically superior compared to the control group. Therefore, it is implied that XR training was an effective method for improving learning outcomes among nursing students for teaching the skill of decontamination (Smith et al., 2016).

The XR groups in all five of the studies measuring cognition showed an improvement from their pre-test to post-test scores. However, when comparing the post-test scores between the study groups, one RCT by Al-Dahir et al. (2014) reported that the XR group scored significantly lower ($p = .001$) than the control group. This study assessed clinical decision-making in a patient case scenario utilizing either PBL or XR as the teaching method among 108 pharmacy students. Participants allocated to the PBL group were further divided into groups of six to eight students and were tasked with navigating through a patient case scenario by participating in a discussion exercise. Each student in the XR group independently completed a virtual computer-based simulation of the same patient case scenario. Knowledge application of the case subject matter was assessed after the experience, which revealed significantly lower scores in the XR group ($p = .001$). The authors postulate that this finding could be attributed to the fact that the students had previously participated in PBL scenarios as part of their curriculum and were therefore accustomed to it. Another limitation of this study was that more students assigned to the PBL group were enrolled in an internal medicine rotation and therefore may have had prior exposure to a similar patient case ($p < .001$). The study concludes that both learning methods were effective (Al-Dahir et al., 2014).

Two quasi-experimental studies compared XR simulation with a high-fidelity mannequin simulation to evaluate learning outcomes between the two activities (Cobbett & Snelgrove-Clarke, 2016; Haerling, 2018). The study by Cobbett & Snelgrove-Clarke (2016) compared two maternal clinical scenarios experienced by 56 BSN students randomly assigned to either a high-fidelity mannequin simulation or the XR simulation. This study had the experimental and comparison groups switch after the first scenario so that the mannequin group would be assigned to the XR simulation for the second scenario, and vice versa. The authors concluded that since the post-tests scores demonstrated no significant difference between the groups with each scenario, that neither educational approach was more advantageous than the other in terms of cognitive outcomes. The limitations of this study include its small sample size and use of unvalidated pre-test and post-test assessments (Cobbett & Snelgrove-Clarke, 2016).

Haerling (2018) compared cognitive outcomes among 81 ADN students assigned to participate in either a professionally facilitated group simulation or an independent web-based XR scenario of a patient presenting to the hospital with respiratory complications. A debriefing session was then provided via the students’ respective training method. This was noted as a limitation of the study given that the differences in feedback were not controlled for, potentially impacting the learning outcomes and obscuring the validity of the data. Following the debriefing, students took a post-test which showed no differences in results between the XR group or the control group, however, both methods contributed to significant improvement in pre-testing knowledge ($p < .05$) (Haerling, 2018).

An RCT by Stepan et al. (2017) was the only study that did not utilize a simulated patient scenario to measure cognition. Instead, computed tomography (CT) and magnetic resonance imaging (MRI) were used to create a three-dimensional digital model of the brain. A VR head-mounted display (HMD) was used to view these images which allowed 64 medical students to experience an immersive and interactive environment to learn neuroanatomy. While the XR group used the HMD, the control group was given traditional online textbooks to study anatomical structures of the brain. A post-test found that both educational methods resulted in equivalent learning outcomes. However, a post-experience survey found that students felt they devoted a substantial amount of their allotted training time on familiarizing themselves with the XR technology. Recognizing that there was a learning curve disadvantage for the XR group, the authors acknowledged that cognitive tests scores may have been higher if the students had received a satisfactory orientation period. Additionally, the researchers assessed students' knowledge retention by administering a quiz eight weeks after the training, to which the researchers did not discover a significant difference between the groups. This study was well randomized and the authors report that the sample size met their recruitment goal (Stepan et al., 2017).

Psychomotor Performance. The theme of psychomotor performance relates to outcomes that evaluated overall skill performance, dexterity, skill completion time, skill retention, and proficiency in advanced communication techniques. Skill performance was measured in four RCTs and two quasi-experimental studies by using a checklist or performance rubric. Five of the six studies reported better performances demonstrated by the XR group when compared to the control group (De Oliveira, Glassenberg, Chang, Fitzgerald, & McCarthy, 2013; Aebersold et al., 2017).

An RCT by Kron et al. (2016) measured the most unique outcome of advanced communication skills by conducting a study in which 421 medical students were taught interprofessional communication principles by means of a CBL module or a XR human interaction scenario. Initially, each student in the XR group completed an intercultural scenario, received personalized feedback, and subsequently repeated the same scenario once more to evaluate performance improvement. They repeated this process with the interprofessional communication scenario. A major limitation of this study is that the control group was not provided an intercultural scenario as part of their training. The authors noted that this could have impacted the overall performance scores. Performance between the study groups was evaluated by having students demonstrate interprofessional communication in an objective structured clinical exam (OSCE) scenario with trained standardized patient individuals (SPIs) that scored them based on their verbal responses and nonverbal behaviors. Although the SPIs were blinded to the students’ exposure, this grading method could have resulted in scoring variations. Considering these limitations, results concluded that students in the XR group showed significant improvement in their advanced communication skills after receiving feedback in both scenarios ($p < .0001$). The OSCE grading scale used to measure performance had a small effect size and was therefore less likely to detect a statistical significance. As a result, the authors created a global composite score and conducted an analysis of variance to compare results between groups. This showed that performance in the XR group was significantly better when compared with the control group ($p = .014$) (Kron et al., 2016).

An RCT performed by De Oliveira et al. (2013) examined whether virtual upper endoscopic airway training improved dexterity among students operating a fiberoptic scope. All students received didactic training, but only the XR group had an additional 30 minutes of training using a virtual airway simulator on a mobile device. Students were then given 10 consecutive attempts to complete the skill on a mannequin in the presence of an instructor blinded to the study groups. In addition to a skills checklist, a global assessment score was used to evaluate the students' performance on their ability to manipulate the fiberoptic scope. The researchers found that students in the XR group performed the skill faster (p = .001), received higher skills checklist scores (p = .014) and had better global assessment scores. To eliminate potential bias related to skill experience, none of the participants in this study had prior exposure to this skill. The authors concluded that XR airway simulation improved the dexterity of novice medical students in upper airway endoscopy performed with a fiberoptic scope (De Oliveira et al., 2013). Smith and Hamilton (2015) also reported better performance scores among the XR group. In this RCT, all students received didactic instruction on urinary catheter insertion and were given times to practice the skill on a non-human model for one week prior to a skills evaluation. The experimental group additionally had remote access to computer-based XR. The study reports that an expert supervisor used a Fundamentals of Nursing Simulated Skills Evaluation Placement grading tool to assess student performance with catheter insertion on the non-human model. It is unknown if this instrument is validated or if the supervisors were blinded to the study groups. Results showed that performance scores were higher in the XR group compared to the control group, however, the difference was not significant. The authors also state that students in the XR group spent fewer time practicing with both the non-human model and XR combined (156.1 minutes) compared to the control group (182.5 minutes). However, the

XR minutes were self-reported which could alter the validity of the results. Another limitation of this study is its small sample of only 20 ADN participants, three of which were reassigned to the control group due to technical difficulties downloading the XR (Smith & Hamilton, 2015).

Aebersold et al. (2017) reported similar findings after conducting a quasi-experimental study that examined the use of XR as a training tool for teaching procedural skills to 69 BSN students. Nasogastric tube (NGT) insertion was taught to participants by providing them with either an iPad anatomy-augmented XR training or a module with didactic material and an animated video. Skill competency was evaluated by having students demonstrate successful NGT insertion on a mannequin. Two raters blinded to the students' exposure scored them using a validated skills checklist. Inter-rater reliability was determined at 0.95 prior to the skill demonstration. Results showed that the XR group scored significantly better than the control (p = .01). The authors disclose that the students had exposure to the skill prior to the study, and therefore, they suggest more studies are needed to determine effectiveness of XR for skills training among students with no previous experience. Nevertheless, the authors concluded that XR technology is an effective method for training nursing student on procedural skills (Aebersold et al., 2017).

Two quasi-experimental trials used a simulated patient case scenario to evaluate the efficacy of XR training (Smith et al., 2016; Haerling, 2018). Smith et al. (2016) evaluated BSN students' performance in a decontamination scenario following training with either XR or written instruction. The authors state that a performance rubric was completed by trained raters that were responsible for supervising the skill demonstration, but it does not affirm if they were blinded to the students' method of training. Although the XR group showed an initial performance advantage, their repeat evaluation at five months to measure skill retention demonstrated lower performance scores than the control group (p = .041). However, the XR group performed the skill faster in both the immediate and five-month retention testing periods (p = .015) (Smith et al., 2016).

The quasi-experimental study by Haerling (2018) that used SPIs to evaluate the students' performance after training with XR or a high-fidelity simulation showed that there were no significant differences noted between the groups. However, due to resource limitations, only 28 of the 81 students were selected to participate in the SPI portion of the study. The author recognized that due to the small sample size, the analyses would be less likely to identify a significant difference (Haerling, 2018).

Perceived Experience. Students' perceived experiences were commonly reported throughout the literature as measures of anxiety, self-confidence, motivation, and preparedness. Perceptions of the technology itself were stated as application preference, ease of use, and interactivity. There were seven studies to report on one or more of these outcomes as a means of analyzing the students' experience respective to their assigned learning method, four of which were RCTs and three were quasi-experimental studies. Overall, the results were variable with three studies reporting a significantly enhanced experience in the XR group (Kron et al., 2016; Aebersold et al., 2017; Stepan et al., 2017), two studies found no difference between the groups (Smith & Hamilton, 2015; Haerling, 2018), and two others reported worse experiences in the XR group (Al-Dahir et al., 2014; Cobbett & Snelgrove-Clarke, 2016).

Only one study evaluated motivation as an outcome (Stepan et al., 2017). After students' experience with either the XR or CBL teaching modalities, the students completed an Instructional Materials Motivation Survey (IMMS), a validated measurement tool that provided a total score encompassing results related to attention, relevance, confidence, and satisfaction. The results revealed that the XR group had a greater sense of motivation with significantly higher overall IMMS score compared to the control group ($p < .001$). This study also administered a subjective user experience survey using a visual analog scale to quantify the students' perceptions on how easy to use, enjoyable, and engaging the learning tool was, if they found it useful for learning, and whether they would recommend it to another student. The average responses exposed that the XR group had a better perceived experience in all domains ($p < .01$) except for ease of use, which revealed no significant difference (Stepan et al., 2017).

Results from one study using an attitudinal survey validated for internal consistency revealed students reported an overall more positive experience in the XR group ($p < .0001$) (Kron et al., 2016). Another study examined students' perception of clinical preparedness by utilizing a visual analog scale administered to the students after they completed the skill demonstration (Smith & Hamilton, 2015). The researchers found that students in the XR group felt more prepared for the skill demonstration compared to the control group (Smith & Hamilton, 2015). The difference was not statistically significant which may be attributed to the study's small sample size (Smith & Hamilton, 2015).

Self-confidence was measured in two studies (Cobbett & Snelgrove-Clarke, 2016; Haerling, 2018). The study by Haerling (2018) had participants complete a Satisfaction and Self-Confidence in Learning survey with a Cronbach's alpha measurement that validated internal consistency for both satisfaction (0.92) and self-confidence (0.83). The survey was completed before and after the intervention. Although the scores of the XR group did not differ significantly from the comparison group, both groups achieved better post-intervention scores, indicating that XR was as effective as high-fidelity simulation in improving students' satisfaction and self-confidence. Student feedback was obtained by the researchers indicating that more students in the control group (33%) experienced feelings of anxiety or nervousness compared to the XR group (11%) (Haerling, 2018).

The second study to have reported on self-confidence levels obtained findings contrary to the positive trends found in most of the studies analyzing perceived experiences (Cobbett & Snelgrove-Clarke, 2016). Although there was no difference found between groups related to their level of self-confidence, the XR group conveyed higher anxiety levels ($p = .002$) using the Nursing Anxiety and Self-Confidence with Clinical Decision-Making Scale. This instrument's Cronbach's alpha measurement validated high internal consistency for measuring anxiety (0.96) and self-confidence (0.97). These results could be partially attributed to the lack of orientation period provided to the students prior to the XR scenario, a significant limitation of the study reported by the authors (Cobbett & Snelgrove-Clarke, 2016).

The study comparing XR to PBL administered a survey using a Likert-type scale to evaluate students' experiences (Al-Dahir et al., 2014). An adequate Cronbach's alpha measurement (0.864) reported by the authors indicated that the survey was a reliable tool to analyze students' opinion of either teaching modality. More students assigned to the control group reported that the PBL learning method provided knowledge reinforcement ($p = .034$), as well as contributed to additional knowledge within the subject area ($p = .01$). However, both groups reported that they would recommend their assigned learning method to another student. Additionally, although not statistically significant, less students in the XR group felt they had adequate time to complete the task ($p = .065$). Students' perception on the adequacy of orientation to the XR technology was not assessed by the survey. This would have been useful to distinguish if the lack of time perceived by the students was attributed to an increased amount of time spent familiarizing themselves with the technology. Additionally, PBL is incorporated into the students' curriculum and therefore students were more familiar with this learning method, potentially influencing their overall reported experience (Al-Dahir et al., 2014).

Limitations. Perhaps the largest limitation to this literature review manifests in the identification of the authors as Millennial healthcare students. Unanticipated bias may be evident despite attempts to remain impartial. Another limitation lies in the infancy of the concept as it is still emerging for its use in educational training. By excluding articles written outside of North America, themes may have been missed that could benefit US healthcare. Additionally, although a five-year limit was placed in order to capture the most recent evidence of the concept, this tight of a time constraint may have resulted in missed relevant studies. Many of the studies report insufficient sample sizes thereby serving as a potential factor for the inability to reach statistical significance. Lastly, the studies in this review utilized convenience sampling and measured single, specific outcomes, thus limiting generalizability.

Conclusion. With Millennials comprising the majority of healthcare students, and the complexity of healthcare steadily increasing, an obvious call for restructuring traditional curricula is mandated. Extended reality is noted as one of the most innovative pieces of emerging technology today and is expected to proliferate throughout healthcare education. Defining features of Millennials and trends of population growth have targeted this generation to be the most impacted by XR. Many institutions have already begun to incorporate this modern technology into their curricula. This literature review uncovered some of the most common themes that have emerged through XR use in healthcare education: psychomotor performance, knowledge acquisition, and personal experience.

Seven of the nine studies found that XR had a significant, positive influence on healthcare learners' education and training. The modernized curricula in these studies proved superior to traditional education strategies; therefore, its use as an adjunct learning tool is recommended. Some studies found no difference in outcomes when XR was utilized, suggesting its equivalence to conventional learning modalities. The addition of XR can expand the armamentarium of medical learners therefore persistent recommendation for its use exists. Two studies reported fewer desirable results and criticized the use of XR in education (Al-Dahir et al., 2014; Cobbett et al., 2016). However, multifactorial causes related to participant characteristics may have influenced results and further research is warranted.

Overall, XR demonstrates the potential to enhance clinical preparation, improve motivation, and shorten the learning curve among healthcare students. The articles in this review provide data supportive of the use of XR in the education and training of healthcare students and revealed comparable outcomes to conventional teaching methods.

Framework

This project was developed through John Keller's ARCS Model of Motivational Design Theory to better understand the impact AR technology had on student anesthetists' motivation towards learning (Keller, 1987). The ARCS Model is a method used for improving the motivational appeal of instructional material (Keller, 1987). Based on this model, the AR project was optimally designed to grasp students' *attention*, be *relevant* to their learning, promote *confidence* with its use, and elicit feelings of *satisfaction* after completion (Khan, Johnston, and Ophoff, 2019). Presumably, the presence of these four factors will encourage students to become and remain motivated to learn. The increase in motivation to learn will promote self-employed erudition, which demonstrates a positive correlation with improved test scores and clinical performance (Stepan et al., 2017, p7).

Section IV: DNP Project Plan

The main objective of this project was to provide SRNAs with supplemental learning material using AR technology for the purpose of enhancing motivation and increasing authenticity of the learning experience.

Practice Gap Analysis Recommendation

The investigators hypothesized that incorporation of XR technology into SRNA education would enhance educational experiences, encourage active learning participation, and improve didactic motivation. This hypothesis was grounded in the ARCS Model of Motivation, which suggests learner motivation is enhanced when users engage in something that piques their interest, is pertinent to their studies, offers assurance, and leaves feelings of gratification. The AR application utilized in this study entertains kinesthetic and spatial instructional strategies that appeal to learners with informational processing styles to enhance the learning experience and improve motivation to learn (White, Dudley-Brown, and Terhaar, 2016).

Method for Translation

The need for this project was identified by the investigators through their personal experience and recognition of gaps in current education practice. Access to clinical resources is scarce and hands-on learning opportunities are limited. Extended reality is engaging and allows for knowledge reinforcement through repetition, and can be conveniently completed in the comfort of one's own home. Based on the stakeholder assessment and supported by the ARCS model of motivation, the need for complementary modalities to traditional learning has been expressed.

Stakeholder Assessment

Stakeholders who hold a vested interested with this project involve university healthcare students, faculty, and information technologists (IT). The primary interest of the student population is personal attainment of enhanced knowledge and increased interest and motivation for educational learning. Members of healthcare faculty are designated with the responsibility of incorporating these modern teaching modalities into their curriculum. Additionally, IT focuses mainly on the impact of service quality and its usability. Information technologists are available as expert resources to assist users in troubleshooting the AR application and promote efficiency and efficacy for student use.

Organizational Readiness

An analysis of the organization's strengths, weaknesses, opportunities, and threats (SWOT) was complete (see Appendix B). Internal strengths consisted of the novelty of the program and fluidity of its adaptive curriculum, the receptive nature of faculty to incorporate XR technology into current curriculum, and presence of a manageable class size. Internal weaknesses consisted of busy and demanding school schedules and elevated stressors associated with several recent program changes. External opportunities exist as AR can be applied to many areas of the University's health science students, especially those with kinesthetic and spatial learning styles. Threats concerning the project that may impede its progression include the scarcity of program funding for equipment that support the use of AR and lack of expert resources.

Setting

Implementation of this project took place on Marian University Indianapolis' campus, specifically in the Evans Center for Health Sciences. Reservations for the clinical lab room were made in advance so students were able to participate on a day in which they were scheduled to be on campus for class.

Participants

Participants for this project were student registered nurse anesthetists (SRNAs) currently enrolled in their second year of didactics at Marian University Indianapolis with a target sample of n=21. Participants were recruited via email and given a verbal reminder from their professor during class. All necessary information regarding the project's purpose was provided prior to the day of implementation. Participation was completely voluntary, and subjects were free to withdraw at any point throughout the study. Anonymity during participation was limited since subjects and researchers were familiar with one another due to being enrolled in the same program and hands-on assistance was mandatory.

Ethics and Human Subjects Permission

This project was reviewed by the Marian University Institutional Review Board (IRB) and deemed not to require human subjects' protection; therefore, the project was endorsed by the Leighton School of Nursing (LSON). Informed consent was obtained from all participants prior to project implementation. No forms were collected, electronically or physically, that elicited identifiable information in order to ensure confidentiality and anonymity of feedback.

Procedure for Implementation

The investigators for this project explored multiple AR applications to determine which one was most relevant and attention grabbing for the target population. The chosen application, *Human Anatomy Atlas 2019,* allowed users to engage in an augmented reality experience that enabled manipulation, dissection, and interaction with life-like anatomical structures of the human body (Visible Body, 2019). A unit closely related to anesthesia practice, laryngeal muscles, was chosen and a PDF worksheet was created for students to complete during their learning session. The objectives for this activity involved correct identification of key laryngeal structures and knowledge of their functions and nerve innervation. The activity’s structures, functions, and nerve innervations were chosen after thorough review of course learning objectives to be sure the experience was relevant and beneficial in student learning. The application was installed on both investigators’ mobile devices and multiple trials were employed to ensure user comfort with the technology for training purposes. Due to monetary constraints and limited availability of IOS devices that support AR, only two devices were utilized throughout the process of this project. In order to confirm relevance and increase likelihood of user satisfaction, the activity was informally introduced to other members in the investigators’ third year cohort. Positive feedback from the senior students regarding the perceived benefits of the AR application and its use throughout the second-year Anesthesia Principles II course attested to the significance of this chosen unit and PDF for this project.

Second year SRNAs currently enrolled in Anesthesia Principles II signed up in groups of two or three for one 30-minute session with the investigators. A brief introductory tutorial was provided at the beginning of each session for the purpose of familiarizing users with the technology and educating them on how to navigate through the application. Participants spent approximately 15 minutes completing the exercise while investigators were available to answer questions and assist in troubleshooting. Following the learning exercise, students were provided an anonymous survey link via email regarding their experience and asked to complete it upon exiting the lab room. Any additional questions/comments/concerns were addressed, and the session was concluded as the following group arrived. This cycle continued, uninterrupted, until all available participants completed the activity.

Barriers

The actualization of this project presented barriers which were dealt with accordingly and able to be overcome without altering the general concept. The first challenge was met in the initial phase of project design related to the lack of funding and negligible access to desired materials. To overcome this, the project design was restructured to use the researchers' personal devices with smaller groups of participants. Despite prolonging the overall time period for implementation, this design eradicated financial barriers and enabled the intended project plan to proceed.

Another roadblock arose after an unexpected alteration was made to the researchers' clinical schedules. The addition of more remote locations increased devotion of time to travel and required distant lodging outside of Indianapolis. Consequently, this limited the researchers' availability to convene on Marian's campus during the week and required remodeling of the proposed implementation plan. Fortunately, early communication and collaboration between the researchers, faculty, and clinical coordinators enabled amendments to be made in scheduling and allowed the project to ensue as planned.

Lastly, no expert in the field of AR technology was available to assist in troubleshooting or teaching the application. In preparation, the researchers partook in self-education through use of online videos and hands-on familiarization. All questions and issues were able to be readily resolved by the researchers and the need for an expert was not evident.

Instrument, Data, and Evaluation

The instrument utilized in measuring this research project's main outcome of interest was the modified Instructional Materials Motivation Survey (IMMS). Prior research suggested that the IMMS items be modified to accommodate the situational features of the project's purpose in order to remain applicable (Huang, Huang, Diefes-dux, and Imbrie, 2006). Therefore, this project ultimately utilized the modified version that has been previously been altered to evaluate the use of augmented reality. The instrument ranked 36 items on a 5-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*) to evaluate AR's ability to promote and sustain motivation among users based on the four domains that correspond with the ARCS model (Keller, 1987). Of those 36 items, 12 measured attention, 9 measured confidence, 6 measured satisfaction, and 9 measured relevance (Di Serio, Ibáñez, & Kloos, 2013). Ten of the items required a reversed ranking which the investigators adjusted for during data analysis (see Appendix C for specific items).

The mean score for each of the four domains was evaluated to determine which constructs were rated highly among the users, thereby indicating a positive learning experience. A comparison of scores among each construct was then evaluated to determine areas of strength and weakness and identify where improvements are needed. The sample population's mean global score was also calculated to evaluate the overall effect AR had on the class' motivation for learning. These results will be used to help guide and make recommendations for future use of XR as a complementary teaching modality in SRNA education.

Analysis

Of the 21 potential participants, 18 partook in the study and 16 completed the IMMS. The investigators echoed previous study evaluation methods guided by the ARCS model to define score ranges (Brits, 2016). A low score was considered ≤ 2.5 whereas a high score was ≥ 3.5. Scores that fell between these values (2.6 – 3.4) were considered inconclusive. Constructs that yielded a low score assumed the population had a negative AR experience whereas high scores were considered positive.

Qualtrics analysis was used to evaluate the response scores for each individual survey question. The researchers then re-organized the questions by grouping them into their respective category following the ARCS model: *attention, relevance, confidence,* and *satisfaction* to improve visual format for interpretation (see Appendix D). The mean score of each construct was calculated for the total sample population and deemed to be either high or low based on the numerical range it fell in. Each of the four constructs yielded a high-level score with *relevance* being the highest followed by *attention, confidence,* and *satisfaction* respectively. All individual survey questions scored highly as well as the overall mean score of the sample population.

Relevance. The highest scoring construct was *relevance* with a mean sample score of 4.25 and a standard deviation (SD) of 1.08. This category also held the highest scoring individual question (4.56) stating that participants felt the content was relevant to their interests. These results indicate a positive experience with AR as it relates to the relevancy of their learning and interests. A positive contribution to motivation can be inferred from this construct.

Attention. Trailing just behind *relevance,* the construct, *attention,* yielded a high score of 4.24 with a SD of 1.03. The two highest scoring questions in this category (4.5) strongly imply that participants found the AR activity appealing and feel it held their attention. The two lowest scoring questions (3.87) suggested that participants were not extremely surprised by what they learned nor very stimulated by the audio content associated with the application. A positive correlation exists between AR's attention-grabbing capabilities and the perception of a learning experience. Likewise, this construct may contribute to feelings of increased motivation to learn.

Confidence. The concept, *confidence*, scored next highest at 4.18 with a SD of 1.00. The highest scoring question within this construct (4.47) implies that participants were able to easily understand the content presented within the AR application. Contrarily, the lowest scoring individual question from the survey (3.56) lies within this domain and suggests hesitance exists in participants' initial impressions regarding the ease of its use. The high mean score is affirmative for positively influencing students' levels of confidence, implying a similar association with motivation exists.

Satisfaction. Though scoring lower than the other constructs, *satisfaction* was still rated highly (4.13) with a mean SD of 1.05. Numerically, this category had the fewest amount of questions and was the only one that did not include a reversed ranking question embedded within. The top scoring question within this construct stated that participants really enjoyed completing this lesson (4.33) whereas the lowest scoring question (3.87) implies there was not as strong of a sense of reward for completing it. This construct follows suit with the previous three and implies AR has a positive influence on learner satisfaction and ultimately may enhance motivation to learn.

Global. The global mean score from the sample population was high at a value of 4.21 with a SD of 1.05. This result implies that the AR activity positively influenced the students' overall airway anatomy learning experience. Therefore, it is presumable that the use of AR in nurse anesthesia education directly impacts students' motivation to learn.

Limitations

There are several limitations of this study. The inherent relationship that exists between anesthesia cohorts may have caused bias among peers and produced falsely elevated outcomes. Additionally, the small sample size limits generalizability to other SRNAs that are enrolled in different programs. Another limitation was the unintentional pressure placed onto students who were not readily eager to participate. Despite reassuring no academic penalties or consequences would ensue, feelings of forced participation may have influenced levels of engagement and consideration in IMMS responses. Furthermore, reversed IMMS questions required readers to be extra attentive in choosing their intended numerical responses. Lastly, the researchers are classified as Millennials and may have inadvertently influenced participants' perceptions.

Conclusion

Today's healthcare presents with many challenges including provider shortages, increased care complexities, and rapidly expanding medical knowledge. The current generation of healthcare students who are faced with these challenges should ideally be presented with educational strategies that are up-to-date, adhere to their alternative learning style, and motivate them to learn. The use of extended reality (XR) as an adjunct learning tool in healthcare education has proven to be advantageous, however its use in the realm of anesthesia has been much less explored compared to other medical specialties.

This study sought to evaluate whether the use of AR in nurse anesthesia education would lead to improved learner motivation. The results indicated that AR had a positive influence on all constructs of the ARCS model: *attention, relevance, confidence,* and *satisfaction* for SRNAs. The evidence validates previous literature findings and implies there may be a direct relationship between the use of AR in nurse anesthesia education and improved motivation for learning.
The concept of improving student motivation is vital for accepting and conquering the increasingly difficult challenges that present with healthcare today. Additionally, motivation increases rate of retention which also helps alleviate the imminent shortage of providers. Therefore, this study supports the use of AR as an adjunct learning tool in nurse anesthesia education. Future studies are needed to explore additional ways in which AR can be incorporated into anesthesia curricula and to determine its effectiveness on sustaining learner motivation.

Section V: References

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Section VI: Appendices

Appendix A. Evidence Evaluation Table

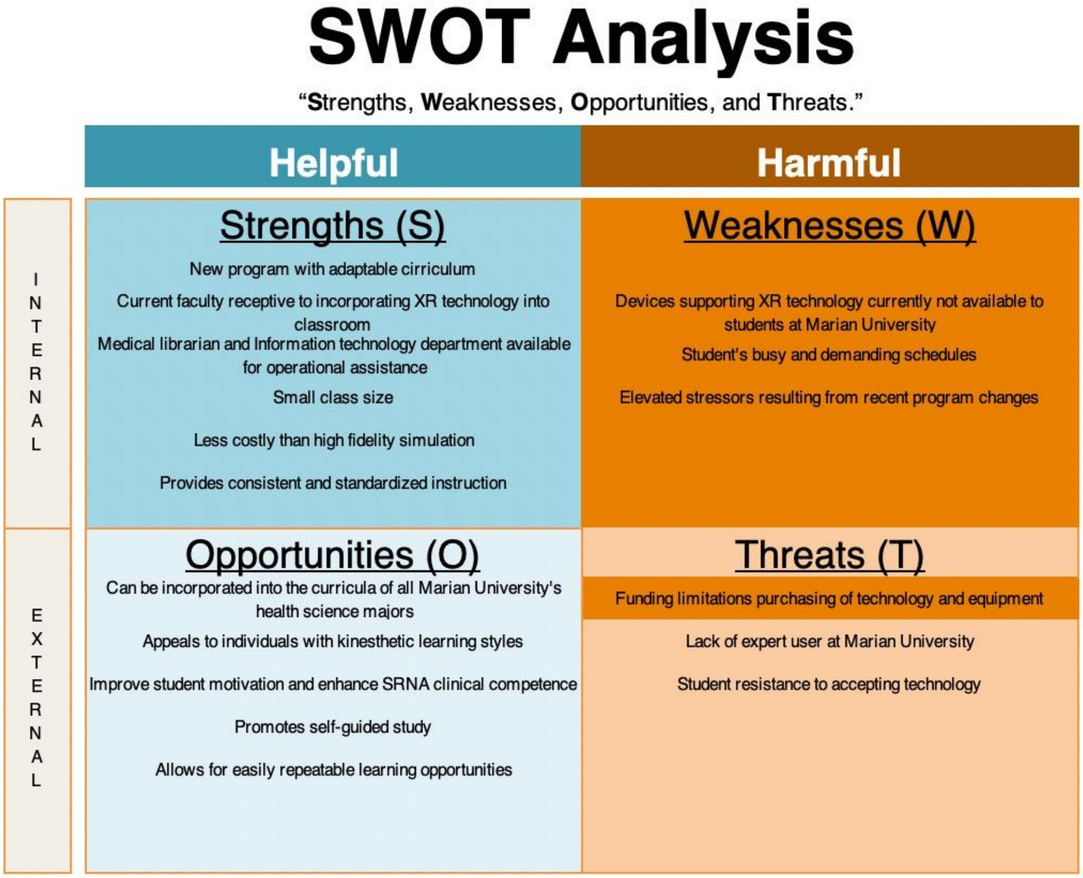
Author/ Year	Design/ Level of Evidence	Theme	Sample	Intervention	Dependent Variable	Results of XR Group
De Oliveira, 2013	RCT (II)	PP	n= 20	Fiberoptic intubation	• Task time-to-perform • Errors • Manual proficiency	• Reduced time *(p = .001)* • Fewer failed attempts *(p < .005)* • Improved dexterity *(p = .004)*
Al-Dahir, 2014	RCT (II)	C PE	n=119	Simulation	• Knowledge • Critical thinking • Self-directed learning skills • Motivation for learning	• Improved MCT scores pre- to post-simulation *(p < .001)* • Inferior to post-intervention MCT scores *(p = .001)* • Reinforcement of previous knowledge *(p = .034)* • Comprehension of new information *(p = .01)*
Smith, 2015	RCT (II)	PP PE	n=20	Urinary catheter insertion	• Task time-to-perform • Preparedness • Overall performance	• No significant difference in level of preparedness *(p > .05)* • No significant difference in time-to-perform *(p > .05)* No significant difference in performance score *(p > .05)*

Cobbett, 2016	Quasi-experimental (III)	C PE	n= 56	Simulation	• Knowledge • Self-confidence • Anxiety	• No difference in post-experience MCT scores *(p = .09)* • No difference in self-confidence *(p = .059)* • Worsened performance anxiety *(p = .002)*
Kron, 2016	RCT (II)	PP	n = 421	Simulation	• Inter-professional team skills • Multicultural team dynamics	• XR improved interprofessional communication *(p < .0001)* • XR improved intercultural communication *(p < .0001)*
Smith, 2016	Quasi-experimental (III)	PP C	n = 108	Simulation	• Knowledge • Knowledge retention • Time-to-perform	• No significant difference in MCT scores *(p = .0238)* • Improved time-to-perform skills task *(p < .001)* • Near identical retention scores *(p = .238)*
Stepan, 2017	RCT (II)	C PE	n=64	Neuro-anatomy lesson	• Knowledge • Knowledge Retention • Engagement & Motivation	• No significant difference in MCT scores *(p = .087)* • Improved engagement *(p < .001)* • Improved attention, confidence & satisfaction *(p < .01)*

Aebersold, 2018	Quasi-experimental (III)	PP PE	n= 69	NGT insertion	• Manual proficiency • Landmark Identification skill	• Improved performance skill *(p = .011)* • Improved ability to identify landmarks of structures *(p < .01)*
Haerling, 2018	Quasi-experimental (III)	PP C PE	n= 81	Simulation	• Knowledge • Satisfaction • Self-Confidence • Performance scores	• Improved MCT scores when compared to pre-intervention scores *(p < .05)* • No significant difference in satisfaction *(p = .476)* • No significant difference in self-confidence *(p = .126)* • No significant difference in performance *(p = .660)*

Note: PP = Psychomotor Performance, C = Cognition, PE = Perceived Experience, MCT = Multiple Choice Test, RCT = Randomized Control Trial, XR = Extended Reality, NGT = Nasogastric Tube,

Appendix B: SWOT Analysis

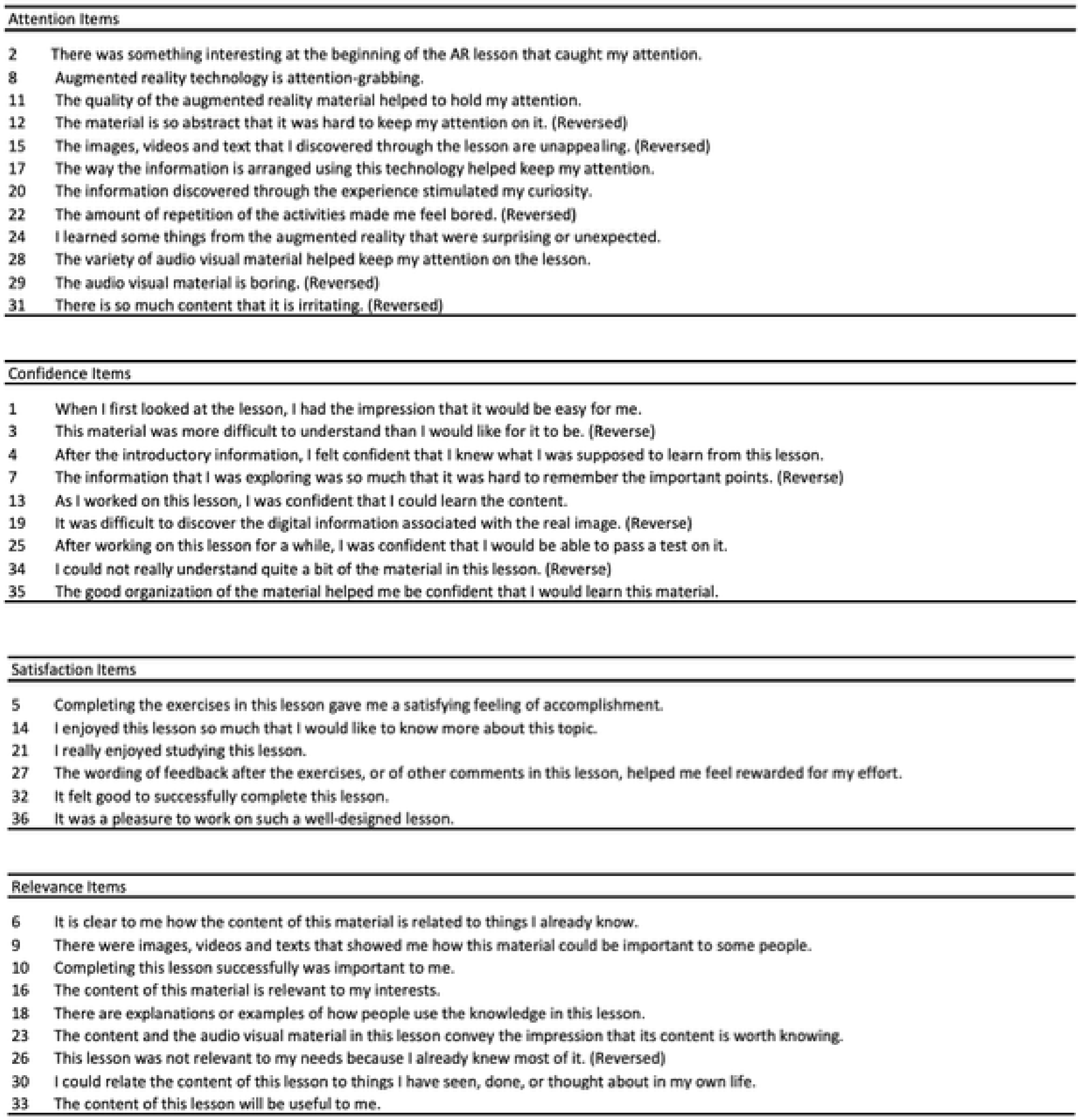


SWOT Analysis

"**S**trengths, **W**eaknesses, **O**pportunities, and **T**hreats."

	Helpful	Harmful
INTERNAL	**Strengths (S)** New program with adaptable cirriculum Current faculty receptive to incorporating XR technology into classroom Medical librarian and Information technology department available for operational assistance Small class size Less costly than high fidelity simulation Provides consistent and standardized instruction	**Weaknesses (W)** Devices supporting XR technology currently not available to students at Marian University Student's busy and demanding schedules Elevated stressors resulting from recent program changes
EXTERNAL	**Opportunities (O)** Can be incorporated into the curricula of all Marian University's health science majors Appeals to individuals with kinesthetic learning styles Improve student motivation and enhance SRNA clinical competence Promotes self-guided study Allows for easily repeatable learning opportunities	**Threats (T)** Funding limitations purchasing of technology and equipment Lack of expert user at Marian University Student resistance to accepting technology

Appendix C: Instructional Materials Motivation Survey – Modified for AR



Attention Items	
2	There was something interesting at the beginning of the AR lesson that caught my attention.
8	Augmented reality technology is attention-grabbing.
11	The quality of the augmented reality material helped to hold my attention.
12	The material is so abstract that it was hard to keep my attention on it. (Reversed)
15	The images, videos and text that I discovered through the lesson are unappealing. (Reversed)
17	The way the information is arranged using this technology helped keep my attention.
20	The information discovered through the experience stimulated my curiosity.
22	The amount of repetition of the activities made me feel bored. (Reversed)
24	I learned some things from the augmented reality that were surprising or unexpected.
28	The variety of audio visual material helped keep my attention on the lesson.
29	The audio visual material is boring. (Reversed)
31	There is so much content that it is irritating. (Reversed)

Confidence Items	
1	When I first looked at the lesson, I had the impression that it would be easy for me.
3	This material was more difficult to understand than I would like for it to be. (Reverse)
4	After the introductory information, I felt confident that I knew what I was supposed to learn from this lesson.
7	The information that I was exploring was so much that it was hard to remember the important points. (Reverse)
13	As I worked on this lesson, I was confident that I could learn the content.
19	It was difficult to discover the digital information associated with the real image. (Reverse)
25	After working on this lesson for a while, I was confident that I would be able to pass a test on it.
34	I could not really understand quite a bit of the material in this lesson. (Reverse)
35	The good organization of the material helped me be confident that I would learn this material.

Satisfaction Items	
5	Completing the exercises in this lesson gave me a satisfying feeling of accomplishment.
14	I enjoyed this lesson so much that I would like to know more about this topic.
21	I really enjoyed studying this lesson.
27	The wording of feedback after the exercises, or of other comments in this lesson, helped me feel rewarded for my effort.
32	It felt good to successfully complete this lesson.
36	It was a pleasure to work on such a well-designed lesson.

Relevance Items	
6	It is clear to me how the content of this material is related to things I already know.
9	There were images, videos and texts that showed me how this material could be important to some people.
10	Completing this lesson successfully was important to me.
16	The content of this material is relevant to my interests.
18	There are explanations or examples of how people use the knowledge in this lesson.
23	The content and the audio visual material in this lesson convey the impression that its content is worth knowing.
26	This lesson was not relevant to my needs because I already knew most of it. (Reversed)
30	I could relate the content of this lesson to things I have seen, done, or thought about in my own life.
33	The content of this lesson will be useful to me.

Appendix D: IMMS Results – Mean Sample Population

Construct	Survey Question #	Mean Score
Relevance **4.25**	6	4.19
	9	4.44
	10	4.00
	16	4.56
	18	4.19
	23	4.20
	26	4.13
	30	4.25
	33	4.27
Attention **4.24**	2	4.13
	8	4.31
	11	4.25
	12	4.06
	15	4.50
	17	4.50
	20	4.38
	22	4.20
	24	3.87
	28	3.87
	29	4.33
	31	4.47
Confidence **4.18**	1	3.56
	3	4.31
	4	4.25
	7	4.06
	13	4.25
	19	4.44
	25	4.00
	34	4.47
	35	4.33
Satisfaction **4.13**	5	4.00
	14	4.19
	21	4.33
	27	3.87
	32	4.13
	36	4.27