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# DISSECTING VIRTUAL CADAVERS: THE IMPACT OF AUGMENTED REALITY ON UNDERGRADUATE STUDENTS' MOTIVATION TO LEARN HUMAN ANATOMY

by

Annette K. Stelter

A Dissertation

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ABSTRACT

This study explores allied health undergraduate students' experiences learning human anatomy through Augmented Reality (AR) technology compared to other modalities in a private university. The research used multivariate analysis to measure and understand the impact of AR on the learning of human anatomy by undergraduate allied health students, specifically those in nursing and dental hygiene careers (N = 302). A mixed methods research design using statements on a 5-point Likert scale and open-ended questions was used to collect quantitative and qualitative data. Participants were asked to compare their educational, affective, and physical experiences in a Human Anatomy course. Although there were no statistically significant differences in the impact of AR compared to other modalities, the study demonstrated that positive and negative factors could influence students' motivation and self-efficacy.

While approximately 54% of the participants desired to use AR again, 64% stated that AR increased their knowledge of anatomy. Highlighted was a less affective experience due to unresponsive technology and physical distress. Of the findings, participants' negative physical experience with the device (e.g., eye strain, headaches, dizziness, and neck pain) was significant despite the positive feedback on AR's benefits. This study found that the physical discomfort that students experienced compared with other modalities was irremissible. Nonetheless, as AR evolves and becomes more adaptive, responsive, accessible, and cost-effective, allied health colleges will likely invest in AR as a primary learning modality.
KEYWORDS: Augmented Reality, allied health, human anatomy, HoloLens, AnatomyX

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# CHAPTER 1: INTRODUCTION

This chapter begins with the study's background, providing a review of technology using augmented reality (AR) and its potential to educate undergraduate students on human anatomy. The problem statement, the study's purpose, the study's significance, theoretical framework, and research questions follow. Also, in this section, the reader will find definitions of terms, limitations, and delimitations. Assumptions and the organization of the study are also discussed.

The idea for this dissertation topic originated during a conversation with the Dean of the General Education Department at West Coast University (WCU). In 2018, the university invested in a novel learning tool to be utilized in human anatomy courses. Our conversation revolved around the need for a foundational assemblage of data that would measure the impact this novel technology has on the learning of undergraduate students on human anatomy. The researcher aimed to support the university's leadership and future researchers by examining how students most effectively learn human anatomy in order to achieve successful learning outcomes in undergraduate general education programs. The research on augmented reality is in its infancy; therefore, it is believed that this study will act as a key resource for existing researchers, educators, and those in leadership positions within the educational setting. As more advances are made in educational technology tools, if Augmented Reality investments in undergraduate human anatomy courses are appropriate, these findings will help leaders realize if augmented reality investments are appropriate.

## Background of the Study

Traditionally, human anatomy has been taught through the dissection of cadavers. However, this practice is not as widespread as it once was. This reduction is due to various factors, including financial considerations and ethical dilemmas (Ghosh, 2015; Hamacher et al., 2018; Kaissar, 2014).  Hamacher, (2018) explains that these issues resulted in anatomy being taught in various ways, including Problem-Based Learning Scenarios (PBLs) or, more recently, through the use of technology using computer systems derived from augmented reality. Regardless of their area of expertise within healthcare, without an accurate understanding of anatomy, practitioners cannot perform examinations and procedures effectively, as they require knowledge of the precise locations of organs and tissues (Singh et al., 2015). Educational AR tools have facilitated student learning of human anatomy by improving the amount and quality of the information provided, making the educational and training environments more productive in context, and transforming the educational and training environments into more productive avenues of learning. For instance, when wearing a HoloLens device, students can observe a virtual dissection performed by an educator on a real-time model. Alternatively, an educator can flip the classroom and allow students to control the model to demonstrate what they've learned. Educational technology is changing the way students engage and interact with learning materials (Abar et al., 2019; Silva et al., 2003). AR applications allow learners to visualize and interact with three-dimensional representations of the human body, helping them build their knowledge of anatomy. Hence, they are better prepared to enter the healthcare workforce. Besides technological considerations, there is a need for pedagogies to be carefully chosen and enacted.

Educational AR tools have made it possible for students to learn human anatomy by improving the extent and quality of the information by making the education and training environment more productive in context. Using AR in place of cadavers to simulate patient and operational encounters allows students to make all of their errors within AR rather than in a dissection lab. Research shows potential positive benefits of this evolution at medical and educational institutions that have introduced AR into their curriculum (Carle et al., 2009).

Regardless of the area of healthcare, without an accurate understanding of anatomy, practitioners are unable to perform examinations effectively as they require knowledge of the precise locations of organs and tissues (Singh et al., 2015). For instance, wearing a HoloLens device, students can observe an educator performs a virtual dissection on the real-time model. Alternatively, an educator can flip the classroom and allow students to control the model to demonstrate what they have learned. With AR technology, learners can interact with 3D holograms; however, the early implementation stages of these learning opportunities leave educators, administrative leaders, and students curious about the impact this will ultimately have on students' learning outcomes.

Kivunja (2014) strongly speaks to the fact that digital natives expect to be taught using the tools that they understand and are familiar with and which are aligned with their preferences in digital technologies. Therefore, to enact pedagogy in the twenty-first-century classroom, educators need to embed digital technologies in pedagogical practices such as teaching, learning, assessment, and the curriculum. Leaders in education looking to make informed decisions on improving student learning require evidence to support those crucial decisions, which in turn would allow them to move forward and apply (or employ) more operative practices when teaching undergraduate students about human anatomy.

Educators should seek to motivate and engage learners by understanding the learning habits of the generation of digital natives and how new devices are designed to allow pedagogical principles and practices to meet their needs better. There are two main types of motivations; intrinsic and extrinsic motivation. Essentially, extrinsic motivation influences students to perform a behavior or engage in an activity solely because they want to earn a reward or avoid punishment. Saeed and Zyngier (2012) report that four types of extrinsic motivations exist: external regulation, introjection, identification, and integration, which are also exhibited in observance, passive compliance, and engagement.

It is indisputable that humans are inherently different individuals. Since areas of interest and personal passions are subjective and vary tremendously from person to person, this is where extrinsic motivation comes into play as it is achieved in the absence of intrinsic motivation (Ryan & Deci, 2017). According to Ryan and Deci, the best way to entice individuals to perform task is to reinforce the individuals' behaviors with rewards. Thus, external regulation is intentional behavior or activity controlled by external sources or factors. Introjected regulation means completing a task or acting in a particular manner out of fear of being judged or looked down on by others. However, the individual may not fully understand or accept why. On the other hand, identified regulation means that the person values a goal and believes their actions are personally significant. Lastly, integrated regulation occurs when a student has full autonomy and is not controlled by an external cause since their efforts align with their own personal values.

In comparison, intrinsic motivation is when students engage in a behavior because they find it rewarding. A student performs an activity for their own sake rather than the desire to seek some external reward. The behavior itself is the reward. Intrinsic motivation then is very closely aligned and associated with authentic student motivation. The research conducted in this dissertation will assess the efficacy and viability of these motivational frameworks concerning the study of undergraduates learning human anatomy with a novel augmented reality technology.

The ability to experience anatomical structures from the inside out can be more engaging for students and has the potential to instill a sense of excitement and motivation to dive deeper into their studies and truly grasp the material (Williams & Williams, 2011). These types of complex structures or difficult theories in higher education are typically better understood by students through the contextually enriched interaction offered by AR technology. Imagine what an exploration of human anatomy structures such as the heart from the inside out would look like. Thanks to AR, the learner can shrink in size to follow the heart's chambers from the inside. The learner can also use AR to rotate 360 degrees to visually inspect the heart cavities, meander toward the superior vena cava, pass through the tricuspid valve, enter the right ventricle, and move to the pulmonary valve before heading to the lungs. This type of learning can only be experienced with advancements in AR technology.

Today, Microsoft developers have created and developed codes to promote these types of learning engagement in medicine. Once a fictional idea, it is now a reality as learners now have many possibilities to use this technology to engage, motivate, and deeply learn human anatomy. The learner can interact intimately with the AR by using eye tracking, hand tracking, moving objects, grabbing small or large items with a finger pinch, using a baby shark movement, and other framing gestures. Baby shark motion involves bringing your thumb and index finger together, basically like a biting motion. Ideas once thought of as only science fiction have now become a reality for today's learners.

To the third-party observer, the HoloLens user will appear he is poking the air in front of user as the HoloLens detects hand gestures such as a pinch, bloom and air taps. However, the learner's engagement uses Microsoft input sources such as light cues and sounds to create an interactive experience to compensate for holograms and bring AR technology to life. The harmony of the experience uses the necessary tools to engage today's learners. The research has concluded that deep learning occurs when the participant engages fully in the learning process (Cai et al., 2014). The core idea of holograms is to instinctively use technology similar to the way one would in the physical world. For instance, a child would investigate building blocks, would reach out, grab them, stack them and possibly build towers. The basic idea is the same as the physical world of engagement with 3D objects.

## What is Learner Engagement?

Learner engagement is a measure that reflects the quantity and quality of a learner's participation in their courses and every other aspect of their educational program. Also, it reflects a learner's interaction and cooperation with co-learners and instructors. Consequently, learner engagement provides a measure of a potentially successful learning experience for everyone concerned. An engaged learner will be active in his learning, eager to participate, and expend effort as he is, motivated and inspired.

Often adult learners demonstrate higher engagement when the topic is made relevant (Al-Eraky et al., 2015). Adult learners are motivated to stay engaged on cognitive, emotional, and behavioral levels regardless of personal influences. Aebersold et al. (2018) discussed his finding that when the adult learner could participate by demonstrating a newly learned skill, that engagement improved the learner’s competence and confidence despite outside influences. An adult learner with several years of work experience and additional responsibilities outside of coursework may have different expectations for their learning. However, the learner may have many responsibilities and duties, such as working or providing for their families.

Nevertheless, their pedagogical needs and study preferences are unique based on life experiences. Social engagement is considered a pivotal construct in adult learners. Adult learners are more engaged emotionally and cognitively when they bring their work and life experiences into their learning. Their engagement grows even stronger when they share those experiences with others. All of these levels of engagement are predictors of knowledge retention. Augmented reality in education has the potential to affect the traditional learning process (Abrar et al., 2019;

Barsom et al., 2016; Dunleavy & Dede, 2014). AR can change the location and timing of studying to introduce new and additional learning methods. Capabilities of AR technology may make lessons more interactive and information more quintessential for a range of learners.

## Statement of the Problem

Students generally experience difficulties learning human body anatomy due to constraints to visualize the body anatomy from 2D into 3D images (Ferrer-Torregrosa et al., 2016; Banerjee et al., 2018). Despite these difficulties and the potential of AR to address them, there have been few studies of the use of AR in human anatomy teaching (Carle et al., 2009; Martin-Gutiérrez et al., 2015; Menon et al., 2021). According to Zhu et al. (2014), AR is still considered a novelty in the literature. Furthermore, the designed AR applications discussed in the literature lack an explicit pedagogical, theoretical framework. Whereas a considerable amount of research has centered on student motivation to learn, little attention has been devoted to providing a means for students and educators to assess how technology impacts the learner's motivation to learn human anatomy. Maintaining student engagement which would lead to high-quality outcomes within the university environment, is challenging (Carle, 2009). To address this challenge, colleges and universities can take responsibility for enhancing their curriculum delivery to ensure future health care providers are prepared with the knowledge and skills necessary to treat changing healthcare needs. Consequently, since the medical and surgical practice of AR is currently being utilized, the early implementation of AR in allied health training is paramount. The next generation of health care providers will be the future clinicians for direct patient care. This consideration includes delivering instruction with long-lasting impact and high engagement to retain and apply information newly acquired human anatomy content.

## Purpose of the Study

The purpose of this convergent parallel mixed methods study is to investigate the impact of augmented reality (AR) on undergraduate students' capacity to learn human anatomy compared to traditional methods such as 2D/3D models/3D4Medical and dissection of animal tissues. At this stage in research, augmented reality will be generally defined as an interactive experience of a real-world environment where the objects are enhanced by computer-generated perceptual information.

## Research Questions

The following research questions were designed to narrow the researcher's purpose (Creswell, 2013). There were one main and three sub research questions addressed in the study:

What impact does Augmented Reality (AR) have on learning outcomes in the undergraduate educational Human Anatomy course compared to other learning or teaching modalities? Hypothesis: Students who use Augmented Reality (AR) will increase learning outcomes, contributing to improved academic achievement in the undergraduate population (Aebersold et al., 2018).

## Sub Questions

1. How does the use of the Microsoft HoloLens technology impact the motivation for learning human anatomy in the undergraduate college for allied health training? Hypothesis: Students who use augmented reality may increase their learning motivation, which would contribute to improved academic achievement (Khan et al., 2019). This sub-question examines how the attention, relevance, confidence, and satisfaction aspects of learning motivation were affected by using AR.

2. What is the self-efficacy of students using AR in health sciences and anatomy? The term self-efficacy refers to an individual's confidence in completing a task or achieving a goal. Hypothesis: Students that use AR to learn anatomy tend to exhibit greater attention, place more relevance, display more confidence and assign more satisfaction during AR learning sessions (Moro et al., 2017; Khan et al., 2019).

3. What are the positive factors that influence student experience and attitude toward technology? Hypothesis: Students favor the visual learning environment that AR has to offer (Gerup et al., 2020).

4. What are the negative factors that influence student experience and attitude toward AR technology? A few negative factors influence students' perception of AR technology, such as postural instability, nausea, headaches, and eye strain. Hypothesis: Postural instability is not responsible for cybersickness occurring during the use of the HoloLens headset (Dennison et al., 2017).

## Theoretical Framework

The accelerated evolution of technology has changed the face of education, particularly when technology is combined with a pedagogical framework (Chai et al., 2010; Drummond & Sweeney, 2017; Foster et al., 2010; Harris et al., 2009; Koehler et al., 2013; Mundy et al., 2019). The combination between technology and education has created opportunities for improving the quality of teaching and learning experiences. Until recently, Augmented Reality (AR) is one of the latest technologies that offer a new way to educate (Chai et al., 2010; Koehler et al., 2013; Mundy et al., 2019; National Academies Press, 2011).

**Experiential Learning**

The use of technology in learning can be aligned with the experiential learning theory (ELT). AR is an experiential learning device. American educational theorist David Kolb developed his learning style inventory and published his learning styles model in 1984 (McLeod, 2017). McLeod writes that Kolb states, "Learning is the process whereby knowledge is created through the transformation of experience." Based on historical origins from theorists such as Piaget, Dewey and Lewin gave the foundation for Kolb's experiential learning theory (ELT). The six strengths of ELT include:

1- A learning outcome is not the endpoint; we continue to learn.

2- As we learn new ideas, we also modify and dispose of old ideas.

3- Effective learners are capable of balancing opposing modes of learning.

4- Learning never ends. Learning encompasses all life stages from infanthood, childhood through adulthood.

5- When learners and the environment interact, they both are changed.

6- Every field requires unique skills and a special learning process.

Kolb's experiential learning theory works on two levels: a four-stage cycle of learning and four distinct learning styles. Kolb's Model illustrates how learners absorb knowledge and then apply that knowledge, however, the learning never ends. According to McLeod (2017), Kolb's four-stage cycle of learning involves the learner moving through the four distinct phases. The four-stage cycle of learning is represented as a cycle as learning is a process. First, concrete experience is indicated when a new venture or situation is encountered. For example, a student having a background in a classroom environment. Reflective observation of the unique experience is of particular importance as the learner reflects on the experience. Due to the art of reflection, the student moves to abstract conceptualization. This is noted as abstract conceptualization because the reflection gives rise to a new idea or a modification of an existing learned experience. Finally, active experimentation reveals the learner's ability to apply their ideas to the world around them to explore what happens.

Importantly, Kolb's theory is concerned with the learner's internal cognitive processes. Experiential learning theory plays a strong emphasis on the role experiences play in the learning process (Kolb, & Kolb, 2005). The use of AR in learning human anatomy is the process whereby knowledge is indeed created through the transformation of experience.

**Motivation**

The intrinsic motivation theory was used to understand motivation in the context of learning. The ARCS model of motivational design was used to realize AR technology's impact on student motivation towards learning. The following ARCS acronym stands for Attention, Relevance, Confidence, and Satisfaction based on John Keller’s four considerations aimed to maximize student engagement (Keller, 2008). In Kivunja’s (2014) study, the impact on student learning motivation was measured by comparing students' learning motivation before and after using an AR mobile application, using a pre-and post-usage questionnaire. Kivunja further explains that students who experience active learning with technology are more motivated and retain the information as they progress into the up-level of head and neck anatomy.

Gaining new skills is rewarding and fun, but the process of learning can be challenging. Of course, what motivates one student might not motivate another (Carrera et al., 2018; Khan et al., 2019; Saeed & Zyngier, 2012). Some students are intrinsically motivated. These are students that are inspired by something within. Intrinsically motivated students might simply have a deep desire to succeed and are, therefore, motivated to do well in all that they do. Motivation is defined as the act or process of motivating; the condition of being motivated; a motivating force, stimulus, or influence; incentive; drive; something (such as a need or desire) that causes a person or student to act (Merriam-Webster, 1997)

Furthermore, intrinsic motivation comes from utilizing a topic that a student is particularly interested. When learning is centered on students' interest, the motivation is there already. If students are interested in the topic, then they are intrinsically motivated to listen and learn (Borresen et al., 2019; Carrera et al., 2018; Erbas & Demirer, 2019). Other students are extrinsically motivated. These students need some outside factor to boost motivation (Ahmadvand et al., 2018; Dodd, 2017; Khan et al., 2019). Grades are extrinsic motivators for some students. Rewards and praise can also be effective extrinsic motivators. AR has the potential to encourage students' motivation, especially in the discipline of learning human anatomy. With the student's enrollment in an anatomy course, it would be reasonable to expect that the student has interest in human anatomy and will be motivated to learn the complexity of anatomy with a tool such as augmented reality. Regardless of the motivator that students respond to, some techniques can increase intrinsic and extrinsic motivation for students.

## Significance of the Study

Research studies have shown that dynamic visualizations are better than static visuals at promoting conceptual inferences about science, consistent with the success of inquiry instruction in science (McElhaney et al., 2015). Augmented reality aims to mix real-world visual content with virtual objects. Achieving realistic results involves solving challenging computer vision tasks, such as computer vision tasks, more specifically the tasks of tracking real 3D objects and estimating the illumination conditions of a scene. Although challenging, these tasks can be solved with deep learning. When tracking real 3D objects and estimating the illumination conditions of a scene, deep convolutional neural networks are trained on large amounts of data and achieve state-of-the-art results.

The research findings will illuminate the expected and unanticipated early implementation challenges of integrating augmented reality (AR) technologies into anatomy labs, which for hundreds of years have utilized dissections to supplement text and classroom instruction. The findings can inform improvements to the technology, support, training, and implementation which will benefit the learner. This study, thus, has educational merit, but can also inform the application of HoloLens devices across and beyond the scope of medical training. Finally, the results of this study will impact future decisions to implement HoloLens technology across health and science programs throughout the US and beyond.

## Definition of Terms

The following terms are provided with definitions to aid the reader in understanding the key terms of this study.

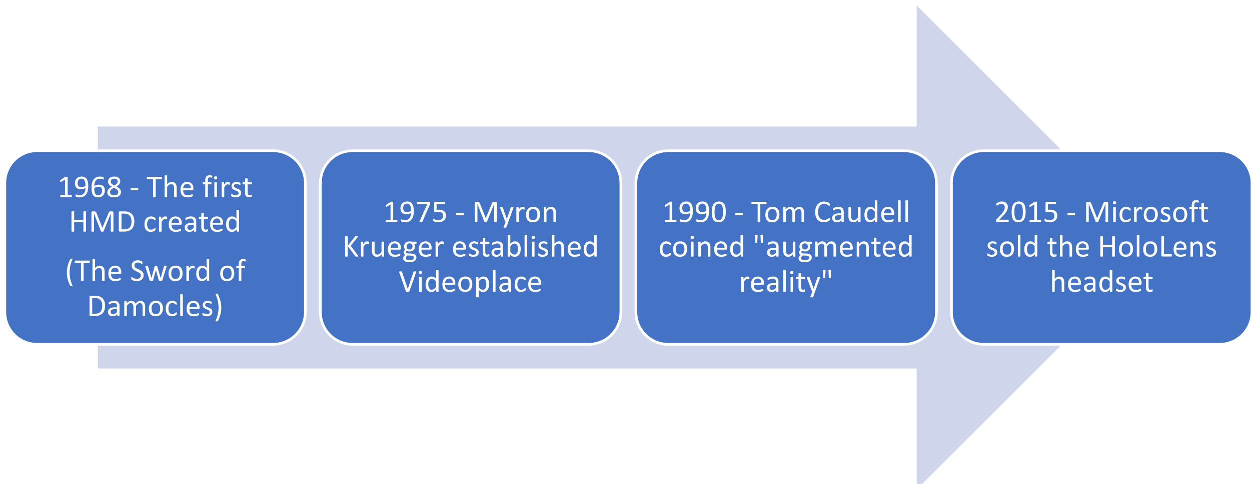
*Augmented Reality (AR):* AR is a technology that combines the real world with virtual objects and provides interaction between real and virtual objects (Azuma, 1997). In other words, predetermined target points are captured and connected with the virtual objects and interpreted through AR technology programs. Because it contains virtual objects, it is necessary to distinguish AR from the concept of virtual reality (VR). Objects are displayed in real-time and AR environments, while objects in VR are displayed in virtual environments (Dünser, et al., 2012; Goff, et al., 2018; Ibáñez et al., 2014; Kerawalla et al., 2006; Lalonde, 2018). With this feature, AR is separated from VR (Lalonde, 2018). Simultaneously, AR needs to establish a bridge between the virtual and the real world.

Three important features enable AR to distinguish itself from other technologies (Moreno et al., 2001). These are: (1) combining virtual and real objects, (2) providing real-time interaction, and (3) existing 3D objects (Azuma, 1997). According to Kimer et al., 2012, AR is an increasingly popular technology used on desktops and laptops, portable devices, and smartphones.

Applications developed with AR allow the use of virtual 3D objects, text, 2D images, video, and animation separately; they also provide the same usage. Therefore, users can naturally interact with events, objects, and information (Wojciechowski & Cellary, 2013). The history of Augmented Reality roots goes back to the 1950s. The first head mounted display (HMD) was invented in 1968. (See Figure 1.1). However, Tom Caudell first coined this concept in the 1990s. Tom Caudell used AR technology to create a digital monitoring system mounted to the head and direct employees while assembling electric cables in the planes (Caudell & Mizell, 1992; Siltanen, 2012). In 1994, Paul Milgram proposed a reality-virtuality process, as AR developed in time and had similar properties with virtual reality, which was named mixed reality and consist of reality on one end and virtuality on the other end (Cheng et al, 2012; Milgram et al, 1994). Many industries are now using AR for business and education. More will be discussed on the evolution of AR in Chapter 2. There is no doubt that AR technology is changing and maturing at a rapid interval.

**Figure 1. 1**

*Augmented Reality Timeline*




*Distance Learning:* Distance learning is described as any learning that happens without the students being physically present in the lesson. Distance education has moved the art of teaching to an online platform to include a vast range of systems and methods on practically any connected device using technology. Distance education is unconventional from regular education in terms of a student or teacher's physical presence (Ferrer et al., 2016).

*Online learning:* Online learning is where instruction and content are delivered primarily over the internet. This term is used interchangeably with virtual learning and eLearning. Students can participate in online learning through one course or a fully online school or program (U.S. Department of Education, 2010).

*Blended learning:* Author, Heikoop (2013) defines blended learning as a formal educational program in which a student learns at least in part through online learning, with some element of student control over time, place, path, and or pace; at least in part in a supervised brick and mortar location away from home. The modalities along each student's learning path in a course or subject are connected to provide an integrated learning experience. These modalities could include small group instruction, online learning, individual instruction, group projects, and pencil and paper assignments (Liu et al., 2016).

*Digital natives:* A person born or brought up during the age of digital technology and therefore familiar with computers and the Internet from an early age. Keep in mind the term digital native doesn't refer to a particular generation. Rather, it is a catch-all category for children who have grown up using technology like the Internet, computers, and mobile devices. This exposure to technology in the early years is considered to give digital natives a more sweeping familiarity with and understanding of technology than people born before it was widespread (Kivunja 2014).

*Digital learning:* Digital learning is an umbrella term that may include online learning, blended learning, and other educational technology uses (Kivunja 2014).

*Cybersickness:* Similar to motion sickness, cybersickness occurs when a person is exposed to a virtual environment. Cybersickness refers to a cluster of symptoms that occur in the absence of physical motion such as headaches, stomach awareness, nausea, vomiting, pallor, sweating, and especially disorientation. For example, Cybersickness can occur when you scroll on your smartphone or computer, use multiple screens, or attend a virtual meeting where someone else controls the screen (Dennison M. S. & D'Zmura M. (2017).

*Self-efficacy*: The term self-efficacy refers to an individual's confidence in completing a task or achieving a goal (Nischelwitzer et al., 2007)

*Mobile Application*: Also known as mobile app, most commonly referred to as an app, a mobile application is software designed to run on a mobile device, such as a smartphone or tablet computer (Turan et al., 2018). According to author Burkle (2013), "Mobile technology use is a major issue in higher education institutions, and one that is ubiquitous learning approach" (p. 14).

## Limitations

Some limitations existed in this study. Specific limitations include interviewer biases, the relationship between interviewer and interviewee, and finding and interviewing credible sources. The active incorporation of student feedback resembles a patient-centered design process commonly used in research and systems designs. Using the mixed methods approach provides a tool to systematically integrate quantitative and qualitative approaches so that arbitrations and application systems are consistent with students' experiences along the way while learning human anatomy. The research needed a quantitative analysis with an adequate sample to ensure precise measurement to mitigate the study's limitations.

Consequently, the main advantage of a convergent parallel design is that it produces insights and describes the problems for hypothesis testing in future research. Thus, convergent research is beneficial. Using the specific allied health program located in California could have been a bias against other allied health programs in states not included in this study.

Bias occurs in all research phases. To limit the bias, including study design or data collection, careful considerations were contemplated, such as a proper study design and implementation. Human perception is very comparative. However, a misperception of a sequential process can influence the outcome of important decisions in many areas of daily life, including the comparison of teaching and learning human anatomy in higher education. In an effort to limit the bias that may have been caused by the use of sample size and the lack of generalizability to the population due to the small sample size, all students enrolled at West Coast University, Anaheim, in human anatomy 260 between Spring 2019 and October 2021 were invited to participate in the study to obtain as many diverse perspectives as possible. A qualitative portion requested the allied health students to state how they experienced their learning using multiple modalities used in human anatomy courses. Students used the microscopic, developmental and gross anatomy of mammals, 2D, 3D models, 3D4Medical application, and the HoloLens with holographic software called AnatomyX included for a logical analysis of body tissues and organs and organ systems. The primary reason for understanding the students' educational experience, the effectiveness of the modalities, and the physical experiences during the learning were included for the researcher to begin establishing a base for future qualitative and quantitative research in this area.

## Delimitation

There were delimitations of this study; respondent validation and feedback and thirdly, peer review discussed in this section.

1. Respondent Validation and Feedback: The researcher would have involved detached data analysis using a software tool to analyze the data. Therefore, the researcher would have conducted a follow-up interview of those participants from the survey respondents. Providing systematic and consistent feedback would have enable the researcher to avoid misinterpretation and misunderstanding of data.
2. Peer Review: The researcher wanted support from two independent experts in education with expertise in teaching methodologies to debrief research methods, data findings, and interpretation.

## Summary

Education is disrupted by technologies such as using augmented reality. Educators no longer need to arrange for the cadaver laboratories with all the complexities of storage and the cadavers' disposal. Students will have the opportunity to engage with the 3D AR platform and practice the dissections repeatedly to dissect each body structure. This learning system cannot be achieved with the use of the traditional dissection of tissues.

AR allows the professor to walk the student through each part of the body; structure after structure can be repeatedly explored. There is an additional unique characteristic to the AR platform. Since the student and professor can use AR virtually, the possibilities are more incredible for learning. This tool changes how education works; the traditional brick and mortar buildings will no longer be necessary, freeing resources to invest in the devices that allow students to learn best.

This generation of digital natives expect to be taught what they know, and at this point, educational institutions have tools available to offer. Augmented reality was once a fictional idea but is now a reality. Today, the learner can use this AR technology to engage, motivate, and deeply learn human anatomy. Technology is a seamless approach to engaging and motivating active learning and is heavily supported in the literature. For instance, AR can contribute information by offering rich content with computer-generated 3D imagery allowing the student to discover, draw and take notes of the interactive cross-sections, microscopic models, and multiple body layers.

Mistakes are often encountered during the training period, and competency is only gained by repetition during training as the ease of cumulative fundamental knowledge and abilities become specifically instilled for the future medical practitioner. A student's core competencies are the characteristics that distinguish a university within the medical community. AR allows the student to investigate with the ability to have an infinity worth of do-overs. Educators incorporating AR technology into the curriculum will recognize that today's students will be attracted, stimulated, and excited to harness the full potential to learn the foundational skills necessary to enter the healthcare workforce.

# CHAPTER 2: REVIEW OF LITERATURE

## Introduction

Chapter 2 is a review of the literature that relates to the approach to teaching human anatomy to undergraduates in higher education in particular. This chapter includes the following sections: 1) historical perspectives of dissection; 2) an overview of essential learning necessary to provide allied health students with the knowledge of the major body systems in many health careers; 3) student engagement; 4) technology in augmented reality (AR); 5) the HoloLens. The purpose of this convergent parallel mixed methods study is to investigate the impact of augmented reality (AR) on undergraduate students' capacity to learn human anatomy compared to traditional methods such as 2D/3D models/3D4Medical and dissection of animal tissues.

## Historical Perspective of Dissection

In ancient Greece during the 3rd century BC, the inception of human dissection awakened the curiosity of learning what there is to know about the human body. Human dissection disappeared during the Middle Ages due to religious and popular beliefs until the early 14th century. According to Magee (2001), once again the practice was resurrected in Italy. As the attitudes and thirst for learning surged, people's attitude changed to accepting human dissection for teaching anatomy again. Furthermore, the bodies' acquisition for human dissection was synonymous with capital punishment as dissected bodies were from executed criminals. Anatomists had to depend on illegal means of procuring bodies to satisfy the demand. Interestingly, according to Ghosh (2015), dissection was in a public forum and seen as an event.

Anatomists depended on illegal means of procuring human bodies, which included grave-robbing which existed even in the 14th century; however, it became increasingly common during the 16th century (Moro et al., 2017: Webster et al., 1993). The processes to acquire the bodies changed over the centuries in accordance with the increasing demand due to the surge in popularity of human dissection as a tool for teaching anatomy. Webster et al. (1993) writes that the promotion of body donation programs as the source of human cadavers for anatomical study from the second half of the 20th century proved beneficial.

**Evolution of Human Dissection**

Over the last century, society has not been comfortable with death and dying. Consequently, it has not been a pleasant topic. However, there seems to be a reversal or change in attitude about dying. As the population is getting older, people are beginning to think about the possibility of body donation (Kaissar, 2014; Magee, 2001; Moro, 2017). There has been a growth in the supply of corpses which has contributed to the expansion of knowledge and research surrounding human anatomy investigation. When the economy is good, there is a reduction of body donations, similarly, the reverse is true. When the economy is weak, there is a higher rate of body donations for science. Donated corpse become the responsibility of the science community to cremate and dispose of the body after usage which relieves family funds.

Body donation for medical education and disease research impacts everyone's quality of life (Sandor et al., 2015). Donated bodies help train doctors and surgeons to save lives and enhance automobile safety measures. Innovators have used body donations to develop and improve medical devices. Body donations have been known to save lives through critical research and broaden scientists' knowledge base. The thought process behind body donation comes with a myriad of rationales. Donors come from all walks of life. Some donors are doctors or other healthcare professionals who remembered their own experience in anatomy labs at a profound level.

According to Cynthia Gordon, Ph.D., Associate Professor of Biology at the University of Oklahoma, the fees for cadaver processing have increased tremendously during an informal personal communication on March 31, 2021. Dr. Gordon affirmed 18 years ago (2003); the cadaver fee was $750.00 per body; today, the cost is $1,900.00. University administrators are looking for options to teach human anatomy at a high level, affordably and efficiently. In some settings, technology may serve as a replacement for cadaver dissection when teaching the introduction of human anatomy, such as AR, virtual reality, and mixed reality (Hacisalihoglu et al., 2018). One avenue of meriting exploration is the use of AR technology.

**Body Donation**

Respect for the body of humans is paramount, according to Moro et al., (2017). There are various schools of thought when it comes to surveying the concept of human dissection (Magee 2001). The first is that mindset that the body is a tool or vessel for learning. A pragmatic approach to examination occurs as a tool to gather the information needed to enhance the learner's knowledge level of human anatomy. The second is the mindset that this was someone's father, mother, sister, brother. The sacrifice of the donor is elevated in the learner's mind. The person's decision aids researchers, educators, and clinicians in advancing science and medicine.

The literature review reveals that bodies are donated to science to shape the knowledge and assist the next generation of learners of healthcare professionals. Others have struggled with ailments and mental disorders and have donated their bodies to be investigated and researched to enhance everyone's quality of life. Others feel that body donation makes sense to them, and it is an alternative to traditional funeral services. Body donation is the last and final way for humanity to contribute to scientific knowledge.

Educators have been striving for years to provide virtual anatomy learning interactive to enhance students' experience in living anatomy instead of struggling to see anatomical structures for the first time in an embalmed cadaver. Learning human anatomy is the foundation of a comprehensive understanding of the human body. The idea of studying the human body is expressed throughout early writings. The evidence of the concept of taking a human from skin to skeleton was revealed in ancient times.

Without studying human anatomy, the improvements seen that have advanced society's quality of life could not exist. Traditionally, the use of cadavers was the conduit through which students learned anatomy. The philosophy behind dissections holds the mindset that a learner cannot have the same experience in gaining the minute details needed to support the foundation of understanding the human body without the background. Many different electronic devices are utilized for the benefit of learning gross anatomy. Devices such as Human Anatomy Atlas 2021 and 3D4Medical are examples of APPs used for learning human anatomy content. However, leading experts in teaching gross anatomy, such as Dr. Gordon from UO have strong opinions that the student will not have the foundation to advance the art and science of medicine with the use of technology. The American Association for Anatomy supports the value of cadaveric dissection as it has been well documented regarding students’ acquisition of anatomical knowledge.

## Teaching and Learning of Human Anatomy

The undergraduate student going into the allied health science field needs to develop knowledge and skills about the human body. One of the prerequisite courses is learning human anatomy. Future practitioners are expected to understand the human body and the foundation for direct patient care. The enormous amount of knowledge required to be considered a competent health care provider is staggering. Fortunately, there are different ways for students to learn and train about human anatomy. Traditionally, cadaver dissection has been considered the gold standard for learning human anatomy (Moro, 2017: Wish-Baratz, 2020). This learning practice has often implied a patient-clinician relationship as this practice may be the learner's first patient. However, learning anatomy through dissection of cadavers has been replaced by other methods for multiple reasons, including financial limitations and ethics.

Institutions are discovering different ways to teach current anatomy courses by combining multiple pedagogical resources to complement one another. Students appear to learn more effectively when integrated multimodal and system-based approaches are used (Adams, 2013; Faerber et al., 2019; Martin et al., 2015: Wish-Baratz, 2020). The literature suggests that certain professions would have more benefits from specific educational methods or strategies than others (Bukowski, 2002; Wish-Baratz, 2020). Therefore, complete body dissection would be best reserved for medical students, especially those with surgical career intentions. Undergraduate students are well suited to learn human anatomy with AR, plastination, and prosections, especially applicable for dental, pharmacy, and allied health science students. There is a need to direct future research towards evaluating the suitability of the new teaching methodologies in new curricula and student perceptions of integrated and multimodal teaching paradigms and the knowledge to satisfy learning outcomes.

The implementation of human anatomy as a prerequisite course is not a novel occurrence in training allied health students. Educating the next generation of healthcare professionals in the art and science of health using anatomical dissection has been a foundation of pre-medical education for centuries. The physical act of dissecting a human body may seem impossible to replace, and in some senses, it is (Sue, 2007). Cadaver dissection has denoted a rite of passage in health science schools. The donated body is a student's introduction to the human aspect of medicine outside the textbook pages (Banerjee et al., 2018). Gross anatomy with the learning experience of dissection provides a uniquely emotional experience; however, there is a shortage of bodies donated to the scientific community. With the decline of donated whole bodies, storage, and cremation of the bodies after dissections were complete, new ideas evolved in learning human anatomy by AR. Additionally, with the development of technology, teaching approaches, a decrease in competent gross anatomy teachers, and a lack of structured programs, the concept of using technology in place of human cadaveric dissection has evolved.

## Student Engagement

Maintaining student engagement leading to high-quality outcomes within the university environment is challenging. Colleges and universities are responsible for improving their curriculum delivery to ensure that allied health graduates are prepared with the knowledge and skills necessary to treat changing healthcare needs. This includes delivering instruction with long-lasting impact and high engagement for the retention of and application of information.

Teaching anatomy has a long and distinguished history in the education of allied health professionals (Steinkuehler, & Duncan, 2008). The arrival of innovations such as the HoloLens (Microsoft Corporation), an example of mixed-reality (MR) technology, offers additional opportunities.

Little is known about undergraduate students' experiences of developing human anatomy knowledge using AR. However, today’s undergraduate students are “digital natives,” a term coined by Mark Prensky in 2001 regarding those who grew up in the era of technology use (Kivunja, 2014). The researcher found that "digital natives" expect to be taught via the technology with which they are familiar. This includes handheld controllers and intuitive user interfaces, like those provided by today's mobile phones and gaming devices. For this reason, technology can be a seamless approach to engage and motivate active learning for current and future generations of health care providers.

The AR anatomy learning system clearly presents visual anatomy information and provides the student with a tangible, interactive interface enhancing spatial memory (Milgram et al., 1995; Thomas et al., 2010). AR provides a visual learning component to enhance learning in anatomy and supports learning complex anatomy structures and systems better than traditional methods (Al-Elq, 2010). Today's students can work collaboratively on a holographic platform, seeing and interacting from various vantage points. The researchers, Hanna et al., (2018) claim students reported that HoloLens devices are comfortable to wear, easy to use, provide sufficient computing power, and support high-resolution imaging. Students benefit from the game-changing visualization, interaction, and integrative benefits of the technology such as the HoloLens device.

During an informal personal communication in April 2021 with Susanne Wish-Baratz, anatomy professor teaching HoloAnatomy at Case Western Reserve University, study findings about the use of holograms and smartglasses were shared with me. Susanne said she was shocked as an anatomist to find that her medical students who used the holograms and smartglasses in a health science education learned more in less time than they did in the cadaver lab. Furthermore, Kamping-Carder (2018) writes that other institutions, such as Texas Tech, University of Nebraska Medical Center, and Western University of Health Sciences, have anecdotally shown similar student experience results in simulation centers with HoloLens technology that they have built-in recent years.

**Motivational Theories of Learning**

Besides the theories on engagement, the use of AR in the anatomy classroom is further substantiated by motivation theories (Carrera et al., 2018; Khan et al., 2019; Saeed & Zyngier, 2012). Intrinsic motivation is derived from the joy, interest, and non-material benefits of learning (Law et al., 2012). Those with high intrinsic motivation approach learning with a positive investment of time and energy (Borresen et al., 2019; Carrera et al., 2018; Erbas & Demirer 2019). These contrast with externally motivated students for whom additional, outside incentives must be offered (Ahmadvand et al., 2018; Dodd, 2017; Khan et al., 2019). AR has the potential to encourage students' motivation, in our case, in the discipline of learning human anatomy. The use of technologies such as AR has positively impacted student engagement (Bond, et al., 2020; Canough, 2013). Regardless of whether they are intrinsically or extrinsically motivated, they have positive impacts on learning.

Authors Saeed and Zyngier (2012) explain that the intrinsic and extrinsic relationships between motivation and engagement are not equivalent. They argued that they are primarily parallel, so a motivated student may also be rebellious. An intrinsically motivated student may also be authentically engaged.

## Augmented Reality Technology

Augmented reality (AR), which sometimes is referred to as mixed reality, or blended reality, is a technology that allows a live real-time direct or indirect real-world environment to be augmented by computer-generated virtual imagery information (Goff et al., 2018; Ibanez et al., 2014; Kamphuis et al., 2014; Souza-Concilio & Pacheco, 2013). It is different from virtual reality that completely immerses the user in a computer-generated virtual environment. AR projects a hologram into the existing environment, but the user can still walk around and see the room without obstruction.

With a clear pop-up labeling and interactive 3D model, students can generally arrange each bone and muscle position in different angles and layers. The HoloLens uses a Windows Holographic platform and gaze input (head tracking), gestures, and voice commands to interact and direct the AR environment. Also, the AR enables the user to dissect and manipulate the body with two hands. The two gestures predominately used are a "pinching" motion to select and a "bloom" gesture, which consists of an upward-facing palm with fingertips together, followed by spreading the fingers outward to signal the application startup and shutdown.

**Demand for Augmented Reality**

The entire globe has experienced a crisis. People from all entities, such as educational institutions, businesses, and governments, have dealt with the worldwide pandemic crisis named Coronavirus disease (COVID-19). The COVID-19 pandemic had stretched to all corners of the United States. Businesses, large and small, have felt the impact of workforce shutdowns and restrictions as well as new laws passed by Congress. As a result of the COVID-19 pandemic and the social distancing required to prevent its spread, workers experienced immediate layoffs, reduced hours, and long-term displacement due to the high susceptibility of acquiring the virus due to close and intimate working conditions. Students are also caught in this dilemma for the need for social distance to reduce the risk of exposure to the Coronavirus disease. This demand jump-started the need to investigate ways to teach human anatomy online (Prunuske et al., 2012). With remote assistance software, a user wearing a headset can share their accurate time view with others using a desktop or mobile device.

AR superimposes digital content onto a user's view of the real world, became a valuable tool for educational purposes and businesses (Nuanmeesri et al., 2019). According to Castellanos (2021), her article in the Wall Street Journal (2021) references companies such as Mercedes-Benz and L'Oreal used AR technology during the social distancing requirements and lockdowns to provide employees assistance in real-time, without needing to be physically present. Educational institutions embraced the idea of AR technology more than ever before (Lin et al., 2013). When the need for distance learning arose due to the mandated lockdowns, most educational institutions scrabbled to facilitate the learning that needs to occur online. Those institutions primed for online learning and using technology such as AR continued to teach with limited interruptions from the pandemic.

Author, Castellanos (2021) writes in The Wall Street Journal estimates that AR's worldwide total market value is expected to grow to $140 billion by 2025. This is up from about $10 billion last year, according to a report from tech market advisory firm Allied Business Intelligence Inc. Those figures include hardware, software, content, AR advertising, platforms and licensing, and connectivity, to name a few line items. Furthermore, Microsoft saw a 44-fold rise in remote-assistance usage of HoloLens 2 between January and December 2020, mainly because of social distancing and lockdown requirements amid the pandemic (Castellanos, 2021). This is notable as Anatomy courses will no longer be hamstrung by a pandemic as there is immediate distance expertise that AR technology can provide.

**A New Way to Learn Human Anatomy**

The AR anatomy learning platform, AnatomyX uses the Microsoft HoloLens for the AR experience. AR is a technology that allows a live, real-time, direct, or indirect, real-world environment to be augmented and enhanced by computer-generated virtual imagery information

(Zhu et al., 2014). AR is different from virtual reality (VR), a technology that fully immerses the user in a computer-generated, virtual environment. AR projects a hologram into the existing environment, but the user can still walk around, interact with others and observe the room without obstruction. The learner can intimately interact with the AR by using eye tracking, hand tracking, moving objects, grabbing items with a finger pinch, using a baby shark motion or other framing gestures. Once only thought of as science fiction, AR is now a reality for today's learners.

A company called, Medivis Technology has a business model using technological advancements in AR and computer vision to create holographs. Medivis developers create and code software for learning engagement in healthcare disciplines. The Anatomy course moves away from traditional cadaveric dissection and integrates clinically relevant training while leveraging emerging technologies to solve problems in the learning space. Medivis has created an anatomy platform for holographic, mixed reality. Physicians and engineers created it to explore and teach human anatomy in the most engaging way possible due to the impressive 3D graphics containing several thousand structures. The intuitive interface composed by leading AR experts at Microsoft enables the software to be manipulated for learning and teaching purposes. AnatomyX allows students and professors to learn and teach individually or in shared sessions.

AR can bring revolutionary benefits to the field of medicine and education (Goff et al., 2018). Previous studies have found that students achieve the same acquired knowledge in approximately half the time using mixed-reality (MR) in both medical and nonmedical situations (Wish-Baratz, 2020). In allied health schools, the first patient is often the cavalier that is being dissected. Using AR in place of cadavers to simulate patient and operational encounters for students allows them to make all of their errors on AR rather than in a dissection lab. Research shows potential positive benefits of this evolution at medical and educational institutions that have introduced AR into their curriculum.

The pandemic that made its life-altering appearance in early 2020 has changed our world beyond measure. One of the major reformations that the pandemic has led to is the way in which students learn. Unable to communicate and learn face-to-face, it quickly became necessary to utilize technology that would allow for a similar learning experience that could still encompass the benefits of attending classes in-person, such as augmented reality and 3D4D application. Although mobile devices have had a grip on society for years, this mobile revolution facilitated change in the way students would learn from here on out.

When referring to a device, the term ‘mobile’ connotates that the instrument has universal features that can be obtained in any place and time while on the move. Common examples of mobile learning devices include cell phones, smartphones, and handheld computers; tablet PCs, laptops, and personal media players fall in this classification (Clough et al., 2009). In this section, the topic of mobile device app characteristics will be reviewed. The software, the types of AR apps, software development kit tools for mobile devices that enable the creation of augmented reality applications, cost, platforms, image recognition, 3D recognition and tracking abilities, support, and storage will be discussed

**Software**

There is a wide variety of different software packages for AR and VR visualization, those of which are not limited to Google ARCore, Apple ARKit, and Maxst. The market in all domains has been flooded with innovative AR products (Wang & Xuelei, 2021). Numerous industries widely use AR technology, such as education, healthcare, e-commerce, architecture, retail, modeling, business logistics, military training, and countless other fields.

From an AR mobile user perspective, Pokémon Go, a wildly popular entertainment technology, left most people familiar with the mobility of augmented reality (Althoff et al., 2016). However, the trend is reaching beyond the world of entertainment and starting to be seen more frequently in educational and business settings. Augmented reality does require a few components, such as computer vision, a display with sensors, and a camera. Together, the sensors and camera create a virtual environment, with the overlaying of AR content through the process. Within the technology AR applications exist to combine the virtual world with the physical world.

***Types of Augmented Reality Applications?***

There are two types of AR applications that exist. The two broad classes of AR apps are marker-based and location-based apps (Liu & Tanaka, 2021). Marker-based apps use predefined markers to activate the display of AR overlays that are cast on the image. Location-based apps use a Global Positioning System (GPS), accelerometer, or compass information to display AR objects on top of physical ones.

***Marker-Based Applications***

Marker-based applications are based on image recognition (Liu & Tanaka, 2021). The marker is seen as an image, shape, or surface with a high contrast design, which can be thought of as a unique fingerprint, just as a person's fingerprints are based on the patterns of skin ridges. Once an AR application reads and analyzes a marker, it can quickly identify the object having the given unique marker. Once the application recognizes the marker, data about its corresponding object can be displayed, augmenting the view of the subject. For a person to see the augmented content, a camera will need to point in the direction of a marker, such as a wine bottle, a QR code, or a person's face, enabling it to identify the subject and draw related information about the given object from stored data.

### *Location-Based Applications*

Location-based AR apps work without markers but rather a user's position as detected via GPS. In addition to GPS, an accelerometer, Bluetooth, Wi-Fi, or a digital compass can determine location, thus allowing for an overlay of augmented reality objects to being displayed on top of the view of an actual, physical place (Liu & Tanaka, 2021). These apps can send users notifications based on their location to provide additional AR content related to a given place. For example, an app could recommend the best restaurants nearby and direct how to get there or assist a driver in finding a car inside a parking garage using GPS. A well-known location-based app is Pokémon GO, which allows users to find virtual creatures in real-world locations.

### *Considerations for Choosing AR Mobile Learning Devices*

The advantages of mobile learning from the pedagogical perspective demonstrate that mobile learning could not be exploited if mobile devices did not have the necessary features and functions to enable mobile learning (Tan et al., 2015). According to the Business of Apps website, 1.85 million different apps are available for users to download. Built in GPS receivers on Mobile devices are becoming standard in practice. Utilizing a mobile device’s location awareness capability within mobile learning applications has become a reality (Tan et al., 2015). One of the emerging research emphases is employing mobile devices' location-awareness functionality to strengthen mobile learning further. Previous research from Liu and Tanaka (2021) has also indicated that the combination of location-awareness and a contextual learning approach can improve comprehension of concepts. Location-based e-learning delivers a personalized learning experience and assists in keeping the learners engaged in the learning activities and enhances their learning outcomes.

***Cost***

Pricing is the first distinctive AR Software Development Kit (SDK) mark (Wang & Xuelei, 2021). To nail down the exact cost for AR is challenging due to the types of work needed for a project. Building a complex app with significant, dynamic content will likely require a commercial license and a budget to accommodate the project. Demonstration packages tend to be free according to Kurniawan et. al., (2018). However, the advanced packages will be more costly based on the application scenario.

Regardless of new AR opportunities, associated costs represent a key consideration goal. For instance, maintenance and repair costs should be part of the calculations. Certainly, cost changes would depend on the particular application scenario. Their main components to consider and include when pricing AR app development costs are the scope of work, timeline, and the development team's expertise. Furthermore, the range of work and the complexity of the app logic needed to incorporate into the cost for the final product. Flexibility in timelines delivery will reduce cost. Rushing an app launch date means a rise in the price unless a prototype is considered. Labor is the highest variable in the equation which includes total cost of the expected timeline multiplied by the team(s) hourly rate.

There are dozens of SDK available and three popular SDK examples are Google ARCore, Apple ARKit, and Maxst (Wang & Xuelei, 2021). Google ARCore pricing is free. Specific features such as accurate measurements saved and restored world map, QR code detection are included in the free pricing. The limitations are that the Google ARCore is only available for Android and iOS.

In comparison, Apple ARKit, a special SDK to provide AR experience to owners of Apple devices, was introduced by Apple Inc. ARKit provides developers with improved algorithms and rendering of objects. The package is free for those with an Apple developer account. Special features such as detection of 3D objects, multiplayer AR games (they call it shared AR experiences), the drawback is that it is only available for iOS users.

Lastly, Maxst offers an all-in-one SDK. This particular kit provides the necessities to build an app efficiently. The extensive tracking and scanning options place Maxst on the radar and highly competitive. Maxst also offers cross-platform support with iOS, Android, Smart Glasses, and support of different types of content and more. Pricing is free for non-commercial use; however, packages increase with commercial use.

The cost to custom build an AR mobile device application can be expensive. An institution looking to custom build an AR mobile device application will behoove the leadership to investigate the current cost of specific human anatomy applications. Many factors contribute to the overall cost of mobile device applications. As with everything, it depends on the details of development required. Augmented Reality app development costs more when an elaborate app with custom design and complex app logic. A complex app requires considerable work and time in its development and launch. It can take three to six months of teamwork. As a result, AR app development costs soar. The price tag for projects can vary from hundreds to thousands of dollars.

***Platforms***

Platforms that use the IOS or Android will not have any problems when an augmented reality toolkit is chosen since nearly all support them (Wang & Xuelei, 2021). Meanwhile, the choice of tools compatible with Windows or macOS is relatively small. When establishing the development platform, mandatory requirements such as creating a license, creating preferred markers, and adding those to a single database will need to be followed.

***Image Recognition***

A camera on any device is an essential feature for AR apps. Cameras allow for identifying objects, places, and images. The purpose of a smartphone and other devices is to use vision and the camera, along with artificial intelligence software, to track images that can be superimposed with animations, sound, and content.

**3D Recognition and Tracking**

3D image recognition and tracking is among the most valuable features of any AR SDK. An app can identify and augment the large spaces around the user inside large buildings such as shopping centers, airports, and lecture halls due to the tracking (Frank & Kapila, 2017). Applications that support AR can recognize three-dimensional objects like books, boxes, cups, cylinders, toys, and faces. Image recognition comes down to a set of algorithms and techniques to label and classify the elements inside an image.

***OpenSceneGraph Support***

OpenSceneGraph support is an open-source 3D graphic toolkit (Wang & Xuelei, 2021). According to the OpenSceneGraph website (2021), this interface is used by application developers in visual simulation, computer games, virtual reality, and scientific visualization. The OpenSceneGraph is now well established as the world-leading scene graph technology used widely in visual simulation, games, virtual reality, scientific visualization, and modeling. Special features of OpenSceneGraph include rendering functionality and provide the following features and capabilities, such as significant, paged database support, including tools for creating geospatial terrain databases and spatial organization.

***Cloud Support vs. Local Storage***

There are two decisions on how to store user data. Data can be stored locally or in the cloud. Primarily, the number of markers created drives the consideration of storage. When an app has many markers, experts recommend storing all this data in the cloud. Otherwise, the app will use much storage on the device.

Similarly, the app's number of markers used also matters because some augmented reality SDKs support a hundred markers while others support thousands. On the other hand, storing markers locally (i.e., on-device) enables users to run your augmented reality app offline. This consideration could be convenient as users do not always have Wi-Fi or mobile data available.

### *A Mobile Application (Mobile App)*

Mobile applications have moved away from the integrated software systems generally found on PCs. Instead, each app delivers limited and isolated functionality such as a game, calculator, or mobile web browsing. Although applications may have evaded multitasking because of the minuet hardware aids found in the first-generation mobile devices, higher functionality is now part of their desirability because they allow consumers to hand-pick what their machines can do.

The mobile app, Complete Anatomy, is from the same makers of Essential Anatomy 4 (3D4Medical.com) that the Institution supported during the pandemic closure of the on-ground human anatomy course. These particular App features include 17,000 interactive structures, and, beating, dissectible 3D heart models. Learners can use the cross-sections and real-time muscle motion to visualize and deep learn the content.

## Mobile Device in Higher Education

Learning anatomy well requires the student to be constant and repeat exposure to the anatomical structures and features (Ferrer-Torregrosa et al., 2016; Erbas & Demirer, 2019; Kivunja, C. 2014). 3D4Medical app also aids students in their understanding of the material with quizzes that test their knowledge. However, it has been noted that apps don't always offer accurate or reliable information compared to decades-old anatomy textbooks such as Gray's, Netters, Thieme, and Grants (LaLonde, 2018). The 3D4Medical app gives a 3D overview of anatomical structures that allows students to isolate, rotate, and sometimes dissect, making the understanding of the anatomy's geometry clearer.

***Subscription***

Students with devices that enable the 3D4Medical app from ELSEVIER, also known as Complete Anatomy, can subscribe to an annual plan of $75.00/year. The student license allows students to master structures in 3D to prepare for labs and exams, as another cost consideration is the Institutional License. This type of plan offers access for everyone. The students and faculty can also install complete Anatomy on multiple devices such as laptops, tablets, and smartphones. All major device platforms are supported, and each user's content can be synchronized across various devices. According to a Statista forecast, the world's virtual reality (VR), augmented reality (AR), and mixed reality (MR) market is predicted to reach 30.7 billion dollars in the U.S. and surge to 300 billion U.S. dollars by 2024.

***Types of Mobile Apps***

There are two broad categories of Apps; native apps and web apps. Native apps are built for a specific mobile operating system, usually iOS or Android. Native apps enjoy enhanced performance and a more finely-tuned user interface (UI). They typically need to pass a much more rigorous development and quality assurance process before release. Web apps are used in HTML5 or CSS and require minimum device memory since they're run through a browser. The user will be redirected to a specific web page, and all information is saved on a server-based database.

The cohort of students born in 1997, known as Gen Z, entering universities for the past six years has never known a world without the internet. Similarly, they were a maximum of ten years old when the iPhone debuted, and they also never knew a world without mobile apps. Successive generations will consist only of children born into a mobile app world. According to the Center for Generational Kinetics study, author Boucher (2018) reveals 95% of Gen Z have a smartphone; 25% have had one since they were ten years old.

Savvy leaders of colleges and universities are discovering more success by meeting students where they already are instead of where some dean wants them to be. It is reasonable to consider that current educational leaderships need to invest in higher education mobile app development. The number of time students spends on their mobile phones is a significant driver of habits and behaviors. In higher education, apps are firmly installed as an institutional, cultural phenomenon. There is a growing belief in the literature that every company, organization, non-profit, or brand has tripped over itself to create a mobile simulacrum of their website, brick-and-mortar, or telephone experience. Universities and colleges have credibility as a cultural institution in their own right to the point where a mobile app may seem superfluous to administrators. AR Apps can be a fun interactive tool for learning human anatomy that helps students explain complex organ placement. These Apps can Zoom In and Out to focus on structures such as the heart, brain, and intestines. Learners can hear realistic sounds of a heartbeat and trace the circulatory system using different Apps available.

## AR Hardware

The hardware and software work in tandem to utilize the AR experience. Hardware devices for AR are complexed components that contain a processor, display, sensors and input devices. Common devices such as smartphones, tablet computers, smartglasses and headsets are examples of the types of digital hardware.

**What are the Types of AR Hardware?**

To use AR applications, devices with a complex composition of hardware modules are necessary, such as smart devices. Historically, smartphones have been the first mobile devices to use AR, especially the Apple iPhone 3GS and Samsung Galaxy Tab or Apple's iOS-based iPad are known as Tablets. Later in 2012, Google debuted its smart glass called "Google Glass." Since 2017 smart Glasses and AR headsets like HoloLens by Microsoft have taken AR to a higher level due to the devices' complex technologies and extensive sensors. A fundamental aspect of AR technologies is the operating systems (ARKIT and ARCORE) which optimize the hardware functions of smartphones, tablets, smart glasses, and HoloLens making it applicable to use in higher education.

***Smartphones and Tablets***

Smartphones and tablets are comprehensive in their featured with similar and comparable hardware components. Similarly, they have been used as platforms for AR-Apps for a long time due to the wide range of global users. Smartphone device examples include Apple (iPhone), Samsung (Galaxy S Serie), and Huawei (P-Serie). In comparison, examples of tablets are Apple (iPad), Samsung (Galaxy Tab Serie), and Huawei (Media T3-10). The advantage of tablets is they have more computing power and the display is more prominent.

***Smartglasses and Headsets***

Smartglasses exist in various kinds of applications with specific profiles and, therefore also different hardware configurations. The two options of hardware devices to consider are either tethered or standalone headsets. Tethered headsets are less expensive but the cables restrict the users' movements. Standalone headsets offer the freedom to move around without cables and do not require an external device to hand processing.

AR optimized smart glasses contain their own processor and corresponding energy supply. Also encompassing complex modules are used for hardware and software recognition and analysis of the real environment. The wearer can see the real environment and virtual additions by looking through the glasses. Examples of common AR headsets brands are Microsoft (HoloLens), Meta (Meta 2), and DAQRI (DAQRI Smart Glasses). While ODG (Osterhoutgroup) with several AR smartglasses devices such as R7, R8, and R9 Series and lastly, Atheer (Atheer AiR Glasses). A benefit of these devices is that they can favor hands-free interaction via gesture and voice recognition.

In this study, software called AnatomyX was used for student learning of human anatomy during laboratory sessions. AnatomyX is the platform for holographic, mixed reality while using the Microsoft HoloLens. The HoloLens is a headset students and faculty wear during exploration of the body systems based on the course curriculum for that session. Holographic rendering of the body is exquisitely viewed in 3D graphics containing several thousand structures. The students and faculty interface with the AR by using hand gestures as there is no mouse. The specific hand gestures used to manipulate the hologram would be a pinch of a finger or a baby shark motion of biting known as a bloom.

This technology allows the learner to locate, isolate, and dissect the 3D hologram to master the vast amount of material needed to be known for direct patient care. According to new research, students can test their knowledge by reviewing the many systems and regions of the body (Hsieh & Lee, 2018). The integrated dashboard allows the professor to record the data collected from the quiz or test modes. A significant element of this technology allows multiple users to collaborate in the same holographic session giving a deeper dive into the educational experience within the laboratory setting.

**Figure 2. 1**

*Anatomy X Visualization*

*Note*. Image credit: Medivis (Springg, 2019)

Medivis, a medical imaging and visualization company, launched AnatomyX, its (AR) platform for anatomy education, see Figure 2.1. Currently enabled on Microsoft's HoloLens AR technology, AnatomyX offers a learning platform to study human anatomy, physiology, and pathology. According to Sprigg (2019), cofounder of Medivis, Christopher Morley, MD., AnatomyX software harnesses the capability of AR and spatial computing to build software that improves learning outcomes and student engagement.

AnatomyX includes life-like details modeled from actual patient computed tomography (CT) and magnetic resonance imaging (MRI). Another feature that has been proved valuable for learning human anatomy is the interactive design components. Learners can easily navigate the controls using computer vision technology. In addition, the dashboards allow for data, including quiz and test results are stored in the Medivis cloud base. This platform is an added benefit that allows the instructor insight into student and class advancement knowledge learned each session.

Student engagement and multi-user participation allow for real-time collaboration with up to 20 users simultaneously and advanced modes including dissection, isolation, and mastery. In addition, the platform allows self-exploration or expertly guided instruction. Universities such as West Coast University are already using AnatomyX to accelerate their learning curriculums. Initial research from pilot institutions has shown that AnatomyX is bringing about positive student outcomes. These include 15% higher student performance on standardized assessments; 90% of students reporting enhanced understanding of curriculum material, and 90% of students reporting substantial value with the overall learning experience. The ability to conduct a shared AR learning experience is invaluable for students and faculty alike. The software, AnatomyX permits the immersive 3D space for multiple users to interact with one shared model in real-time.

AR technologies will also allow educators to continuously observe and give feedback to students during their training. Another advantage of implementing AR into education is that training can now be made more systematic. Through an AR training program, students in training can practice anything and everything that may come up in a real-life medical situation rather than randomly training with what's given in a dissection lab. Undergraduate students have always based medicine on theory and proven evidence, and now AR technologies allow them to visualize and practice those theories during their training. An example of this is AR apps that can overlay anatomy data on a 3D human skeleton, giving them a better understanding of how the human body works.

A strong understanding of anatomy plays a crucial role in allied health education. The AR anatomy learning system clearly presents visual anatomy information and provides the student with a tangible, interactive interface enhancing spatial memory (Cheng & Chen, 2013). AR provides a visual learning component to enhance learning in anatomy and supports learning complex anatomy structures and systems better than traditional methods. Today's students can work collaboratively on a holographic platform, seeing and interacting from various vantage points.

### *What is the Cost of the Hardware Devices?*

The price of hardware devices varies based on the functionality of the device. In research from Kastrenakes (2018) Smart phones range from $549.00 to $1,300.00 and tablets are priced at $849.00. According to author, Rakver (2021) from Smart Glasses Hub, smartglasses usually start above $1000.00 and Microsoft HoloLens are priced at $3000.00 to $5000.00 per headset.

## AR Hardware for AnatomyX

New technologies such as HoloLens AR are pushing boundaries in health care, both in the realm of professional practice as well as in training programs. Specifically in training allied health students in human anatomy laboratory courses. It is believed that the future of AR as a visualization technology looks encouraging, as shown by the interest generated in business, museums, and education. There is a high potential that AR can promote the efficiency of educating and training the next generation of health care professionals by providing information-rich content with computer-generated imagery. The role of technology in healthcare is bound to grow exponentially in the time to come. With the growing enthusiasm in this industry, and as educators look ahead to the future, the digital age will inevitably, positively impact patient care through the use of technology.

The AR anatomy learning system presents visual anatomy information clearly and provides the student a tangible, interactive interface enhancing spatial memory" (Chien, Chen & Jeng, 2010). A strong understanding of anatomy plays a crucial role in medical education. AR provides a visual learning component to enhance learning in anatomy and helps students learn complex anatomy structures and systems better than traditional methods. According to Wish-Baratz et al. (2020), Case Western Reserve University uses it to teach anatomy to their future doctors and has found that 15 minutes with the three-dimensional images have saved them from dozens of hours in their traditional anatomy labs.

Similar to the Windows PC experience that starts with the desktop, Windows Holographic starts with a mixed reality home. Students can open immersive applications and 3D content in mixed reality using the Start menu. The students were introduced to the gestures for interacting with holograms and an introduction to Windows Holographic. Users manipulate the holographic windows, menus, and buttons with their hands. A point of the index finger in the air and a hand gesture such as the "bloom" will open the menu within the hand tracking frame. The HoloLens has sensors that can see a few feet to either side of the user. Once the HoloLens is configured to meet the user's needs, the learning begins.

**Cybersickness**

Cybersickness occurs when a person is exposed to a virtual environment causing symptoms similar to motion sickness (Lee et al., 2017). According to Gallagher and Ferre (2018), cybersickness may be due to a discrepancy between the sensory signals which provide information about the body’s orientation and motion. Common symptoms parallel motion sicknesses such as headaches, stomach awareness, nausea, vomiting, pallor, sweating, and especially disorientation (Gallagher and Ferre, 2018; Keshavarz et al., 2015; Saredakis et al., 2020). For example, cybersickness can transpire when a person scrolls quickly on their smartphone or computer, uses multiple monitors, or attends a virtual meeting where someone else controls the screen.

**Physical Issues**

The virtual environment causes symptoms that are similar to symptoms people experience during motion sickness. Generally, symptoms include discomfort, headache, nausea, stomach awareness, pallor, sweating, fatigue, drowsiness, disorientation, and apathy (Saredakis et al., 2020). More severe sensations include postural instability and retching. Although these two ailments have similar symptoms, virtual reality sickness is different from motion sickness. The visually-induced perception of self-motion can cause it; real self-motion is not needed.

**Affective Issues**

Like motion sickness, cybersickness occurs when the senses send conflicting signals to the brain. Virtual reality sickness tends to be represented by disorientation and has to do with orientation. When senses report contradictory information to the brain, the result is disorientation and physical symptoms. Motion sickness is that nauseated, disorienting feeling that happens on boats, in cars, and on rides (Keshavarz et al., 2015). Cybersickness is caused by a mismatch in sensory input involving several systems. According to authors, Keshavarz et al., (2015) the following systems are involved:

- visual system (what your eyes tell your brain)
- vestibular system (what your inner ear senses regarding head movement and balance)
- proprioceptive system (what sensory receptors throughout your body feel)

While looking at a screen, the eyes signal to the brain that movement is happening. However, the vestibular and proprioceptive systems tell the brain that all is steady. This mismatching experience with the senses can lead to lightheadedness and nausea. Interestingly, studies report that user characteristics such as age are likely predictors for motion sickness (Saredakis et al., 2020). As a person ages, the susceptibility to cybersickness declines.

**Educational Issues**

Experts have suggested that the prevention of cybersickness is the key for users of technology tools. The recommended tips that may help diminish the sensations are to reduce screen time, rest the eyes and stretch or change positions (Liarokapis & Anderson, 2010; Saredakis et al., 2020). Other suggestions include avoiding using multiple screens and focusing on a stable object other than the screen (Clemes & Howarth, 2005). These factors are essential for educators to consider when utilizing technology such as the HoloLens for human anatomy class.

## Summary

With AR and allied technologies quickly becoming accepted and ubiquitous in both medical practice and medical research, the familiarization of the technology is the responsibility of colleges that are presently training health professionals and scientists. The benefits of AR technology on health professional preparation are emerging, and this research contributes to that body of evidence. With the majority of students benefitting from and preferring AR in combination with other learning technologies, health science colleges will need to continue to invest in AR technology and increasingly so to remain competitive and meet student expectations of best practices. Since the occurrence of physical symptoms was inversely related to their advocacy of AR technology usage in future courses, colleges should consider offering sections that permit sensitive users to opt-out of using the AR technology (or as some suggested, having the professor demonstrate the AR technology as students watched on personal devices such as laptops and smartphones). Finally, AR technology developers should work in partnership with health science colleges; the latter should be demanding significant improvements across the technology value proposition, but most imminently and importantly in regards to user comfort, safety, and the reduction of physical symptoms such as nausea, dizziness, eye strain and headaches which were commonly reported across all groups of the study.

# CHAPTER 3: METHODOLOGY

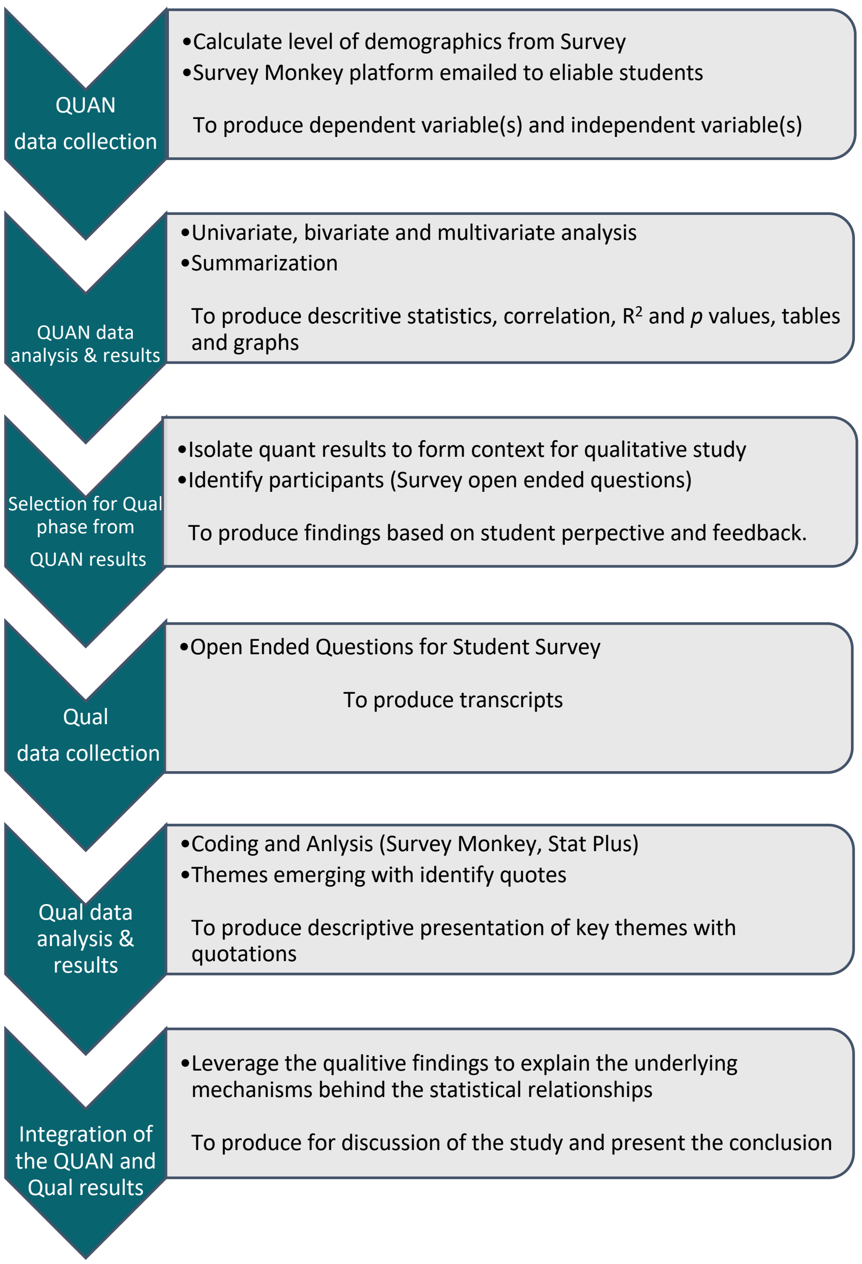
## Introduction

This study investigates the impact Augmented Reality (AR) has on learning human anatomy within undergraduate college courses by comparing different learning modalities. The researcher used three points of reference to measure the perceptions of students'- 1) Educational experience, 2) the Affectiveness experience, 3) and the physical experience students had by comparing the learning tools used in human anatomy. The learning tools include AR, 3D4Medical app, 2D/3D models, and dissection of animal tissues. A mixed methods approach was chosen to understand the impact of different teaching modalities in learning human anatomy further. Thus, both, quantitative and qualitative aspects of the survey required participants' descriptions of their learning experiences during the human anatomy course. The problem statement, the significance of the study, the purpose of the study, research questions, and a review of the literature were discussed in Chapter 1 and Chapter 2. This chapter explains the research methodology for this study, including the following subtopics: (a) setting and participants; (b) sampling procedures; (c) instrumentation and measures; (d) plan for data collection; (e) plan for data analysis; and (f) ethical issues.

Additionally, the reader should understand that in the wake of the world pandemic, face-to-face classroom teaching and learning constraints were placed on all parties due to mandated shutdowns brought about by COVID-19. All course work was delivered in a distance learning environment from March 2020 to October 2021. Therefore, rapidly evolving AR technology creates possibilities for education, teaching, and learning. AR discoveries are occurring in a multitude of disciplines. However, AR will be examined as a learning tool for undergraduate allied health students for this study. The researcher used methodological triangulation. Both qualitative and quantitative data was used simultaneously as seen in Figure 3.1. Thus, the reader will not need to ruminate on the findings as triangulation will give rise to the greater credibility and validity of the research findings.

**Figure 3. 1**

*Research Design Schematic*



## Setting and Participants

A mixed methods convergent parallel design was used to investigate the three points of reference in collecting data to compare the different learning modalities and their individual impact on the student's outcome of learning human anatomy. Participants included undergraduate students who were enrolled in a ten-week general education course titled, Human Anatomy 260 beginning in March of 2019 until October 2021. Exclusion criteria were students of non-undergraduate general educational institutions and college students who did not take Human Anatomy 260 at the Orange County allied health institution.

## Sampling Procedures

A survey was created to gather information to better understand the impact the different learning modalities have on learning human anatomy. A convenience sample of 1,011 eligible participants were asked to complete the survey, and 302 responded. Data was collected and analyzed. Exclusion criteria were students of non-undergraduate general educational institutions and college students who did not take Human Anatomy 260 at the Orange County allied health institution.

Student emails, both institutional and private email addresses, were ascertained from the participating allied health institution. With the assistance of the information technology (IT) department, batches of 50 emails were sent out to abate the potential spam alerts keeping the emails from reaching the participants. The email cover letter was sent with an embedded link to the online survey. Students' surveys included an informed consent explaining the study to the participants and included the researchers' contact information, allowing the participants to ask any questions related to the study. All participants were asked to affirmative their consent in order to continue to the survey. Those that did not accept the informed consent were taken to the end of the survey and not permitted to give feedback.

The population surveyed included undergraduate college students enrolled in human anatomy at a specific institution which included freshman through sophomore year students. The private allied health college agreed to collaborate for the research. The traditional on-ground course work includes those students using 2D/3D models, animal tissues dissection and augmented reality for building knowledge of human anatomy (*n* = 489). Also surveyed were students using non-traditional learning in a virtual class due to the COVID-19 pandemic class closure (*n* = 522) where students used 2D/3D models and 3D4Medical app.

The sampling method used voluntary response sampling. The participants are research subjects who volunteered for the study because they met the inclusion criteria for the research study objectives. One advantage of voluntary response sample survey is that data can be collected quickly and at a low cost (Creswell, 2013). The disadvantage is there could be a high level of biases contributed by the researcher. To mitigate this conflict the researcher is studying a phenomenon outside of the researcher's department. Also, survey questions were kept short and clear. The instrument avoided leading questions and centered on direct questions that followed the subset of categories across all modalities.

## Instrumentation and Measures

The instrument surveyed student evaluations of the different learning modalities ranging from exploring their perspective of educational experience, affective experience, and physical experience in order to compare across learning modalities. The modalities included 2D/3D models, 3D4Medical app, animal tissue dissections, and augmented reality (AR) technology. Each modality was assessed with three sets of Likert scale questions. For every three specific questions (Educational, Affective and Physical experience), there were six sub-questions for each point of reference. The instrument evaluated student's perceptions on clear instructions, ease of use, met learning outcomes, increased knowledge, gained marketable skills and a desire to use again for their educational experience. Participants also evaluated the level of anxiety, lack of privacy, feeling of out of control, if they had a fear of physical harm, unresponsive technology issues and unnatural affective experience. The last set of sub questions evaluated the participants physical experience across all modalities by evaluating the level of nausea, dizziness, eye strain, headache, neck pain and muscle cramps when learning across all modalities.

The specific modalities studied were (1) 2D/3D models, (2) animal dissections, (3) D4Medical mobile app, and lastly, (4) augmented reality using the AnatomyX software and HoloLens hardware. Students were asked to recall their experiences in learning undergraduate human anatomy courses. The three specifics comparison points for each modality were (1) physical experience, (2) affective experience, and (3) educational experience. The study utilized an online survey created with a decision tree questionnaire tool called Survey Monkey. Both Likert scale and open-ended questions were included in the 32-question survey. Quantitative data collection and analysis were followed up with qualitative data collection and analysis to offer the interpretation of the findings.

**Pilot Survey**

The pilot study was created and deployed on September 24, 2021. Using a pilot survey was an opportunity to get helpful feedback from members of a deliberate sample to help improve the data collection process. The pilot survey was open for ten days on Survey Monkey to a sample size of 30 subjects asked to take and give feedback on the instrument. The criteria for selecting the 30 subjects were based on expertise in healthcare, health care education, recent graduate from an allied health program and the last criteria was to not attend the allied health program where the study was taking place. The main objective of the pilot survey was to test the research tools, including the question flow, order of questions, question types, survey structure, the logic framework of advanced branching, and distribution channels such as activating the link. The online pilot survey allowed participants to review the instrument copy with a link provided by Survey Monkey. Survey Monkey's platform allowed respondents to comment and read each other's feedback. Respondents pointed out typos, spelling errors, and also grammatical errors that need to be corrected. The pilot survey participants took approximately 12 minutes to complete the 32-question survey.

Furthermore, over 60 individual feedback data points were returned regarding their perception of the questions and the ease of taking the survey. All the feedback was immediately incorporated upon receipt. Thus, it was discovered that changes needed to be made for clarity of questions, response patterns, and text that helped participants navigate the questions as challenges were discovered during this important process.

## Instrumentation and Measures

A 32-question survey (see Appendix A) derived from studies of AR technology use in the classroom, with a focus on cybersickness (Gavgani et al., 2018; Saredakis et al., 2020; Shafer et al., 2017; Yildirim, 2020) was piloted prior to deployment. The researcher administered the instrument through a Survey Monkey link for participants who were enrolled in Human Anatomy 260 from March 2019 through October 2021. The survey included questions that asked students to recall their experiences learning human anatomy with different modalities. Both quantitative and qualitative data were requested. Demographic data related to age, gender, and ethnicity were collected. Students were also asked to identify their graduation date, full-time or part-time status, and education level. Questions aimed at collecting qualitative data required the participant to describe their overall experience in Human Anatomy 260 with a focus on academic application, affective experience, and physical experience. A 5-point Likert scale using 1 for *completely disagree* and 5 for *completely agree* was employed to measure various dimensions of cybersickness (affective and physical) along with the educational experience of the diverse modalities of learning in anatomy classes. These questions were modified based on skewness and bias (accomplished through an analysis of pilot study data), with the final set of prompts validated along these lines. The Survey was initially deployed on Friday, October 8, and again on October 12 with a friendly reminder email to complete the survey. Since the response rate was lacked a desired number of respondents, a third reminder was sent to students via student affairs e-newsletter on Friday, October 22, 2021. The survey remained open until November 1, 2021.

Logic features were applied to the surveys' design to control the navigation of the specific modalities used during the anatomy course and enhance the data quality. The standard logic features used are page skip logic, question skip logic, disqualification logic, advanced branching. Participants who did not use one of the human anatomy modalities skip survey questions and are taken from certain pages to specific destination pages further ahead in the survey. The skip logic design was instrumental in sending disqualified respondents to a custom disqualification page if they selected certain answer choices. The use of the advanced branching applied logic based on multiple conditions. For example, when a respondent had answered that they used multiple variables and the criteria or conditions are met, the respondents skipped to the next location in the survey, allowing for show or hiding non-pertinent questions. This strategy was essential to limit or invalidate questions and customize the error messaging.

The instrument in which students were invited to participate in was designed to investigate the impact of learning human anatomy with different modalities such as 2D3D models, animal dissections, 3D4Medical app and augmented reality technology. There is a significant gap in evidence-based research evaluating and comparing how students can best learn the foundational anatomy curriculum, a void this study hopes to address. Participation was entirely voluntary, and survey responses were reported in aggregate form. Students were also informed that refusal to participate would involve no penalty or loss of benefits to which they are entitled at their academic institution. The average student took approximately five minutes to complete the 32 questions. To entice the participation in the study questionnaire, students were given the option to enter in a raffle to win one of several $50.00 Amazon gift cards or WCU merchandise.

## AR in the Classroom

The faculty were trained before introducing AR headsets and software into the anatomy curriculum. However, before implementation, multiple access points were placed in the new designated AR rooms. These access points extend the Wi-Fi signal range on campus to limit the number of connectivity glitches that may preclude students and educators from potential disruption in the learning exercises.

A specific and purposeful strategy for the implementation of teaching with the novel device (AR) was initiated. The first step was to introduce and train the five-faculty responsible for incorporating AR into the lesson plan. As with learning any new tool, there is a learning curve, and training on the HoloLens is no different for the educator compared to the students need to be trained effectively to use the AR software and hardware. The two-day training for the faculty was organized by the West Coast University, Director of Innovation Lab and her team with the assistance of the Head of IT. In addition to training faculty, specific room configurations were needed to support the AR tool. Lastly, the administration necessitated the security required for the protection of the expensive investment of the HoloLens.

**AR Laboratory**

A considerable amount of time and effort was used to plan the facilitation of the AR session. The inclusion of AR in the course was integrated into the anatomy curriculum as part of the laboratory requirement. The students received lab assignment credit for completing their AR assignments weekly. During the Anatomy lab session, students spent three of the four hours reviewing and examining the anatomy structures using 2D images, 3D anatomical models, and dissection of animal tissues. In the final hour, the instructor facilitated the HoloLens technology using the augmented reality tool. This approach supplemented and reinforced the anatomy that was reviewed in the lab and didactic lecture that week.

Each of the several AR anatomy labs was structured similarly to maintain consistency in the lesson plan and continuity for students' learning. The last hour was broken down into three 20-minute units of time. During the first unit, the students would obtain a HoloLens and begin their weekly pre-test. The lab instructor would guide the students through the organ system in great detail during the second unit. During this particular unit of time, the instructor pointed out the various organs and anatomical structures, demonstrate key anatomical relationships, and promote student interaction with the anatomical holograms projected in front of them.

This portion of the instruction relied on direct communication between the instructor and the students in the lab. The instructor was expected to track students by accessing that the students were on a particular structure and maintaining availability to assist those students that needed assistance to progress as a group. Additionally, to further facilitate this portion of the course, the instructor's HoloLens device is wirelessly connected to the projector within the room.

This adaptation allowed students to reference what the instructor was doing throughout the lesson. The third and final unit allowed the students to take a post-test on the anatomy reviewed during the AR session. The pre and post-test were directly downloaded and stored for evaluation and analysis. The pre-test and post-test data were compared to determine learning outcomes from the AR experience to determine the significance of the learning outcomes.

**Hardware**

Microsoft HoloLens is a wireless holographic computer that is worn on the head. The HoloLens visor permits personal computing through holographic experiences to empower the user in learning human anatomy in new ways. HoloLens blends pioneering optics and sensors to present 3D holograms pinned to the real world around the user. The headband sits at the top of the forehead, just below your hairline, with the band above the ears. The lenses are centered over the eyes in a visor. Visualization has long assisted allied health students in understanding the abstract morphology of various analyses into pictures as seen in Figure 3. 2. This allowed the student to view anatomy in three dimensions helps them understand how they appear and helps them understand various scenarios.

**Figure 3. 2**

*HoloLens and AnatomyX Technology Used for Educational Applications*

Note. Image credit: Mobilegeeks (von Carsten Drees, 2015).

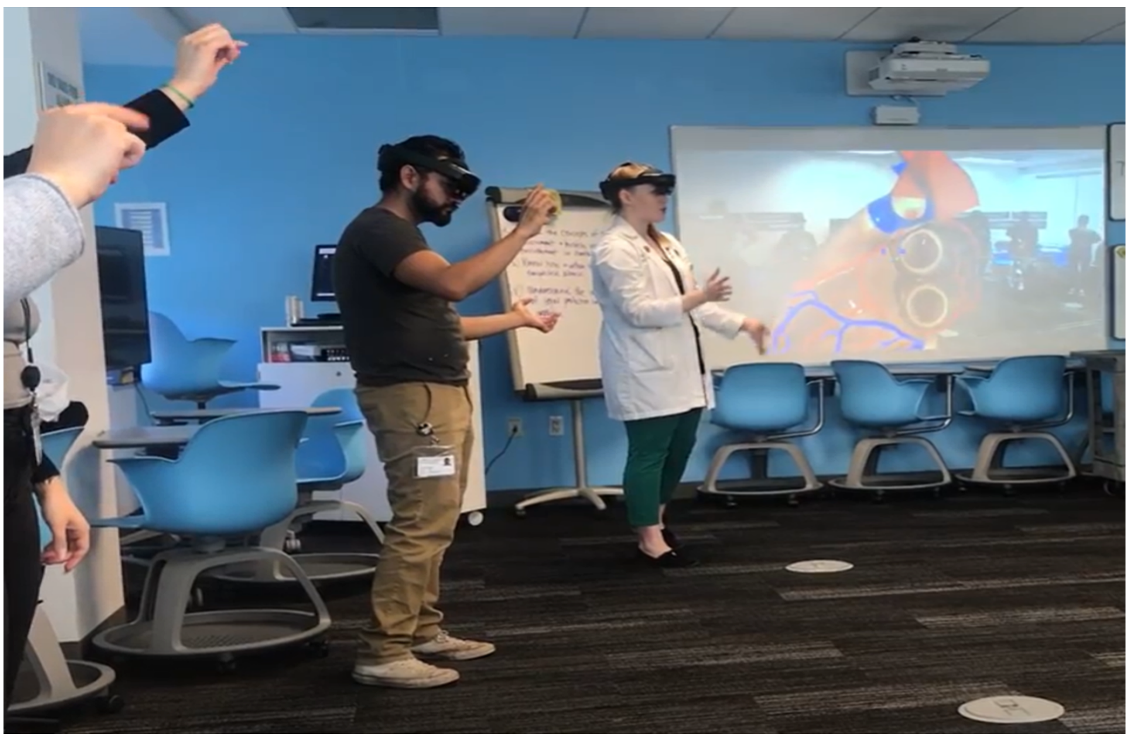
Similar to the Windows PC experience that starts with the desktop, Windows Holographic starts with a mixed reality home. Students can open immersive applications and 3D content in mixed reality using the start menu. The students were introduced to the gestures for interacting with holograms and an introduction to Windows Holographic. Users manipulate the holographic windows, menus, and buttons with their hands. A point of the index finger in the air and a hand gesture such as the "bloom" will open the menu within the hand tracking frame. The HoloLens has sensors that can see a few feet to either side of the user. Once the HoloLens is configured to meet the user's needs, the learning begins.

**Software**

Software called AnatomyX was used for student learning of human anatomy during laboratory sessions. Anatomy X is the platform for holographic, mixed reality while using the Microsoft HoloLens. The HoloLens is a headset students and faculty wear during exploration of the body systems based on the course curriculum for that session. Holographic rendering of the body is exquisitely viewed in 3D graphics containing several thousand structures. The students and faculty interface with the AR by using hand gestures as there is no mouse (Figure 3. 3). The specific hand gestures are used to manipulate the hologram would be a pinch of a finger or a baby shark motion of biting known as a bloom.

**Figure 3. 3**

*AnatomyX Software Demonstration Using HoloLens*



Note. Faculty and Students using the AR technology at West Coast University.

This technology allows the learner to locate, isolate, and dissect the 3D hologram to master the vast amount of material needed to be known for direct patient care. Students can test their knowledge by reviewing the many systems and regions of the body. The integrated dashboard allows the professor to record the data collected from the quiz or test modes. A significant element of this technology allows multiple users to collaborate in the same holographic session giving a deeper dive into the educational experience within the laboratory setting.

To begin to tell the story, as Creswell (2013) suggests must happen, the researcher will use both qualitative and quantitative research methods to provide a more complete picture. This study is a mixed methods research study employing student experiences along with comparing the grades between groups from the different modalities used for teaching and learning human anatomy with AR compared with those that have taken HA without AR.

**Reliability**

Since the adapted instruments for the present study were untested, a pilot study assisted in testing "the feasibility, reliability, and validity of the proposed study design" (Mbuagbaw et al., 2020; Thabane et al., 2010, p. 2). The pilot instrument was sent to 30 individuals requesting them to take the draft survey and report back with feedback by the Survey Monkey link. Over 60 comments were reported by 25 individuals. Reliability refers to whether the measure is consistently repeatable.

An area of complexity in this study will be the interviewing process itself. Maxwell (2013) writes, "Explaining your possible biases and how you will deal with these is a key task of your research proposal" (p. 124). In qualitative research, the concepts of reliability and validity are essential to avoid subjectivity in collecting and interpreting the data (Thomson, 2011; Xu & Storr, 2012). Creating a way to analyze data and systematic code information may be a possible limitation or area of difficulty.

The researcher's rationale for strategies to ensure reliability is to control for bias. The researcher has specifically chosen a topic outside the department. Investigating the impact of learning human anatomy via augmented reality within the general education department decreased the potential bias of the researcher. Students descend into the core after completing the pre-requisite in General Education. Choosing this direction will help the researcher with decreasing the chance of bias. It is necessary to assess one's own subjectivity. Again, it will be fundamental for the researcher's research goal to stay neutral and clearly state all possible biases.

To create a valid and reliable study, Gibbs speaks of Shipman's (1988) four key qualities of reliability, validity, generalizability, and credibility will be followed. To gain a reliable study, the investigation has to be questioned (Gibbs, 2012). It is important for a conducive environment where interviewees feel comfortable sharing their opinions and allowing less of a one-sided domination play of questions and answers.

The ultimate component of the interviewing process is to obtain credible, reliable, and willing participants. Collection and selection of data from the investigation of current published research (Maxwell, 2013) will reduce the bias of the investigator. In addition, as Gibbs (2012) states on reliability, validity, generalizability, and credibility, finding credible and typical research participants may be difficult because if they are volunteering as part of the study, they are already found atypical. Finding quality participants with valuable information can be difficult.

Finally, another area of concern for controlling the researcher's biases rests with data collection, the coding process of data, and creating a reliable system of interpreting interviewee comments, answers, and statements. It will be necessary to determine the correct length and quantity of data collected from surveys, focus groups, and interviews and implement the most valid and reliable coding process (Turner, 2019). Furthermore, Creswell and Poth (2018) mention the importance of the intercoder agreement. This method allows multiple coders to analyze the data and create a system that creates easy interpretation and reporting results.

**Respondent Validation and Feedback.**

The research involved detached data analysis using a software tool to analyze the data. Thus, the researcher conducts a follow-up interview of those participants from the survey respondents. The systematic and consistent feedback enabled the researcher to avoid misinterpretation and misunderstanding of data.

As an investigator, and to control for bias, the researcher was sensitive to the conditions, actions/interactions, and consequences of a phenomenon to arrange the appropriate theme (Turner, 2019). One author suggested looking for themes that are missing in the text (Gibbs, 2010). The most concerning is the issue of reliability and validity of the study. Validity is the strength of the study. Reliability is achieving consistency thorough out the research. At the heart of qualitative data analysis, the task was to discover the themes by word repetition, indigenous categories, and keywords in the context.

**Validity**

Validity refers to whether the study is measuring what it is supposed to measure. The pilot study also assessed the feasibility of the study process (Thabane et al., 2010). Many strategies have been suggested to test validity, including intensive, long-term involvement, rich data, respondent validation, intervention, searching for discrepant evidence and negative cases, triangulation, numbers, and comparison (Maxwell, 2013). It was important to validate the survey through a pilot study to ensure that a small group tested the instrument prior to deploying it to the entire sample.

The pilot study results were used to assess whether the instrument was a valid form of measurement. In this study, multiple methods were applied to promote validity. A mixed methods approach was included in the survey to collect both qualitative and quantitative data.

Additionally, the open-ended questions allow for rich, detailed descriptions of perceived measurements as they apply to the student's educational experience, the effectiveness of learning through the different modalities, and lastly, the physical experience with the multiple modalities, which aided the validity of this study (Maxwell, 2013). Lastly, content validity was established during pilot testing of the five-point Likert scale survey used to conduct this methodological triangulation research.

## Data Collection

To understand the mixed methods convergent parallel design of the study, a specific set of survey questions were asked for the necessary qualitative research needed to create codes. Only students enrolled in Human Anatomy 260 at a private undergraduate allied health University were surveyed. The participants surveyed had the opportunity to give feedback on the experience of using the novel AR headset device and animal tissue dissections, 2D/3D models and 3D4Medical app used during the course. Data was collected via the online survey tool (Survey Monkey) and then imported into Stat Plus to calculate quantitative statistics. General characteristics were calculated using descriptive statistics and analysis of variance (ANOVA) was used to assess differences in the perceptions of the different modalities used in human anatomy during, laboratory settings or online distance learning. Significance was set at a value of $p < 0.05$. Qualitative data were reviewed and analyzed. Participant’s data was coded and analyzed and edited for redundancy. The researcher analyzed codes for patterns and themes by conventional means of sorted and filtered in an excel spreadsheet once exported content was uploaded by Survey Monkey.

## Statistical Tests

The statistical program, Stat Plus was used to analyze all of the data in this research study. The specific statistical test used include the following: descriptive analysis and frequencies; correlation, and an Analysis of Variance (ANOVA). The nature of each statistical test used in the analysis of the data for each research question is discussed with the text in its respective section. Through data collection, data reduction, and data display, the researcher will draw a conclusion that gives meaning to the questions, confirms the hypothesis or not, verifies the research methods.

## Data Analysis

Quantitative data was collected via the online survey tool (Survey Monkey) and then imported into StatPlus to calculate quantitative statistics. General characteristics were calculated using descriptive statistics and analysis of variance (ANOVA) was used to assess differences in the perceptions across all modalities. Significance was set at a value of $p$ <0.05.

Survey Monkey was utilized to analyze the qualitative data. This tool analyzed transcripts from the survey questions. Due to the importance of collecting and coding data for the analytical process of interpretation of non-numerical data the software was invaluable. Coding with Survey Monkey allowed for interpretation, and organization of the data into meaningful theories. The software tool allowed the researcher to take the contents of the survey and effectively analyze it by exporting the transcripts into excel.

Through coding, the researcher evaluated if the analysis represented the participant base, and helped avoid overrepresenting of one person or group of people. Another advantage of Survey Monkey is the transparency aspect of coding. Lastly, coding enables other to methodically and systematically review the researcher's analysis.

With the selection, focusing, simplifying, abstracting, and transforming the collected data the researchers analyzed and verified the research methods. Throughout the reveal of the finding, the reader will see tables, graphs, and charts. An appendix will support the researcher's demonstration to quickly and easily assimilate the data collected and analyzed for the survey results.

**Ethical Issues**

To mitigate the potentially harmful effects of preconceptions that may taint the research, the researcher specifically chose a topic outside the department in which I work and my expertise. The investigation of this mixed method convergent parallel design study aims to identify the impact AR has on learning human anatomy. Currently, I work in the Dental Hygiene department, which is designated as a core program. Students arrive at the core curriculum after they have completed the pre-requisites in General Education where AR was implemented. By choosing this topic, the researcher thus decreased the chance of bias.

Creswell and Plano (2011) state, “Permission needs to be sought from multiple individuals and levels in organizations, such as individuals in charge of sites, from people providing data, and from campus based institutional review boards (IRBs) to collect data from individuals and sites” (p.175). In regard to this study, an exempt research form was completed based on the Concordia University, Irvine IRB checklist criteria. The criteria for exemption was met, for example, the collection of empirical data was made directly from humans and the research is unlikely to adversely impact students’ opportunity to learn as the research only includes survey procedures and the information is not identifiable. The approval from CUIRB was received in September, 2021 and can be found in Appendix B. The host institutions’ executive leadership granted consent to conduct this study via email to the eligible participants.

Additionally, the host IRB chair granted an exempt file number in accordance to the institution's policy.

**Summary**

This section reintroduced the purpose statement, research questions and described the mixed methods design for this research study. The research design connected the survey instrument to the study and identified the population and the sample. Lastly, the researcher highlighted the data collection and analysis processes and study limitations specific to this study. In Chapter 4, an analysis of the data collected in this mixed methods study is provided.

# CHAPTER 4: RESULTS

The purpose of this study was achieved by examining participants' quantitative and qualitative responses to a survey. There is insufficient research on the impact of using AR in education. Furthermore, there is room to discover the potential of using AR to improve student learning motivation and explore AR's contribution in improving academic achievement (Carle et al., 2009; Martin-Gutiérrez et al., 2015; Menon et al., 2021). Research studies have shown that active visualizations are better than static visuals at promoting conceptual inferences about science, consistent with the success of inquiry instruction in science (McElhaney et al., 2015) so there are benefits to studying the impact of AR as it provides active visualization.

This study intended to examine the impact that different learning modalities had on the learning of Human Anatomy in the undergraduate curriculum program. The primary research question is, what impact does Augmented Reality (AR) have on learning outcomes in the undergraduate educational Human Anatomy course compared to other learning or teaching modalities? There are three sub questions: 1) How does the use of the Microsoft HoloLens technology impact the motivation for learning human anatomy in the undergraduate college for allied health training? 2) What are the positive factors that influence student experience and attitude toward technology? 3) What are the negative factors that influence student experience and attitude toward AR technology?

Qualitative and quantitative research methods were utilized to investigate the impact that Augmented Reality (AR) has on learning human anatomy within undergraduate college courses by comparing different learning modalities. The researcher used three points of reference to measure the perceptions of students' 1) educational experience, 2) the affectiveness of the different modalities, 3) the physical experience students had by comparing the learning tools used in human anatomy. The learning tools used across the modalities included AR, 3D4Medical app, 2D/3D models, and dissection of animal tissues. This chapter discusses the results of the study, including the following subtopics: (a) quantitative data analysis, (b) findings of qualitative research, and (c) the summary.

## Quantitative Data Analysis

The survey was disseminated to the 1,011 eligible participants via an email with a link to Survey Monkey on October 7, 2021, and the link stayed open until November 1, 2021. The mass student emails were sent through the campus I.T. department in batches of 50 email addresses at a single time to reduce spam alerts. The largest response volume was on October 8, with 73 responses. On October 12, a second mass email was sent to remind those eligible students about taking the survey, with an additional 53 responses in a single day. November 1 concluded the survey with a total of 302 responses.

### Demographic Data

With 1,011 survey links distributed, 302 students responded. Three hundred and one participants agreed to the informed consent, and one participant declined and was taken to the end of the survey and removed from the study. Seventy respondents were excluded due to the lack of completion of important quantitative and qualitative data points. The research study included 232 participants; nevertheless, the yielding response rate was 77%.

The inclusion criteria were for undergraduate students who had taken Human Anatomy 260 between 2019 and 2021. Two hundred and ninety-six (82.43%) answered yes to "I was enrolled in Human Anatomy 260 at West Coast University." Excluded from the study were the 52 (17.57%) that answered no to the same question.

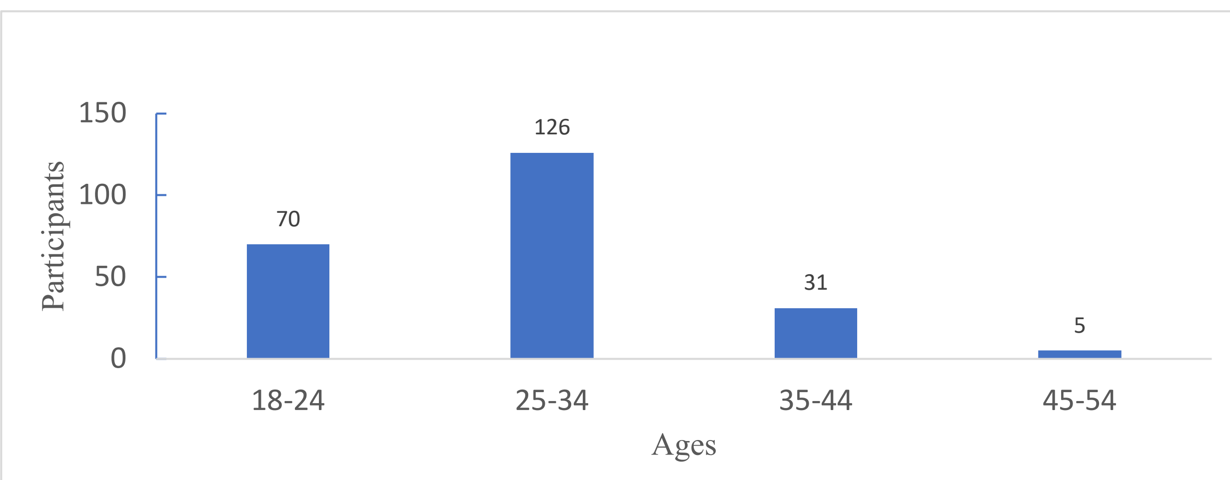
Of the 232 participants, the majority were females (77.16%), and 22.41% were males.

One person answered genderfluid/nonbinary. According to the U.S. Bureau of Labor Statistics, this statistic was not a surprise as nursing and dental hygiene comprise roughly 76% female and 24% male professionals. This is one of the most disproportionate gender compositions in any working industry. Few professions see such an inequitable composition of one gender creating an unbalanced workplace, according to the U.S. Bureau of Labor Statistics.

The following other demographic characteristics of the respondents were collected: age, ethnicity, graduation date by year, student status (full-time and part-time), the highest level of education, and degree major. Based on ages, the largest group of participants were those 25-34 years of age ($n$ = 126). See Figure 4.1 for details. This was an interesting finding as these students were considered newcomers and sophomores in college. In the USA, most people apply to college as a senior in high school at age 17 and start their freshman year at age 18 (or about to turn 18). That means that many college students turn 21 during their junior year of college and are 21 for all of the senior year, according to the Digest of Education Statistics (2018).

**Figure 4. 1**

*Age Groups of Participants (N = 232)*



A majority of the participants were nursing students (71.3%, *n* = 164), and 28.70% were dental hygiene students, as seen in Table 4.2. Two other participants responded as MRI and health administration majors. The major of the other 70 participants were undetermined and they were thus expunged from the final data analysis due to large quantities of missing data.

There were five ethnic groups represented *(N* = 232*)*. Ethnicity such as Asian; 42.67% (*n* = 99), Black or African American; 1.29% (*n* = 3), Hispanic or Latino; 30.60% (*n* = 71), White; 21.12% (*n* = 49) and other; 4.31% (*n* = 10) can be seen in Table 4.1.

**Table 4. 1**

*Ethnicity of Participants (N = 232)*

| Characteristic | Count | % |
|---|---|---|
| Ethnicity | | |
| Asian | 99 | 42.67 |
| Black or African American | 3 | 1.29 |
| Hispanic/Latino | 71 | 30.6 |
| White | 49 | 21.12 |
| Other | 10 | 4.31 |

A predominant 41.81% of participants said they expected to graduate in the year 2023 (*n* = 97), 31.9% (*n* = 74) in the 2022 graduation year, 18.53% *(n* = 43) in the 2024 graduation year, 6.9% in the 2021 graduation year *(n* = 16), and .86% (*n* = 2) students graduated in 2020. All participants were aged 18 – 54 with the majority of the students that participated aged 25 – 34 (*n* = 126). Of the participating students 86.64% stated they are full time (*n* = 201), and 13.36% were part-time students (*n* = 31). Slightly over half of the students, 50.86%, obtained a high school diploma or GED (*n* = 118), 16.81% (*n* = 39) had received an associate degree, 31.90% (*n* = 74) attained a bachelor's degree and .43% reported possessing a master's degree (*n* = 1) as their highest degree earned (See Table 4.2). The last of the demographics that the students reported on were the self-reported final grade for the 260 Human Anatomy course they completed, 37.93% said they earned an A/A+, 14.66% reported earning an A-, 13.36%, earned a B+, 15.09% earned a B, 6.90% earned a B-, 7.33% earned a C+ 3.88%, earned a C, 0% reported earning a C- or a D grade, .43% reported earning an F and finally (*n* = 1) reported that they had not completed the course yet and therefore did not have a grade assigned.

**Table 4. 2**

*Demographic Characteristics of Participants (N = 232)*

| Characteristic | Count | % |
|---|---|---|
| Graduation Year (Expected) | | |
| 2020 | 2 | 0.86 |
| 2021 | 16 | 6.9 |
| 2022 | 74 | 31.9 |
| 2023 | 97 | 41.81 |
| 2024 | 43 | 18.53 |
| Student Status | | |
| Full-time student (12 units or more) | 201 | 86.64 |
| Part-time student (less than 12 units) | 31 | 13.36 |
| Highest Level of Education | | |
| High School Diploma or GED | 118 | 50.86 |
| Associate Degree | 39 | 16.81 |
| Bachelor’s Degree | 74 | 31.9 |
| Master’s Degree | 1 | 0.43 |
| Major | | |
| Nursing | 164 | 71.3 |
| Dental Hygiene | 66 | 28.7 |

Each learning modality applied specific questions for analysis, including the students’ perception of their educational experience, affective experience, and physical experience as they recalled learning human anatomy. To summarize the sample, descriptive statistics are used for the three reference points to understand the different teaching modalities used during human anatomy class. The four modalities include students who used one or more of the following:

2D/3D models, dissections, 3D4 Medical mobile app, and/or augmented reality. Each modality was assessed with three sets of Likert scale questions. For every three specific questions, there were six sub-questions. See Table 4.3, the three points of reference that each learning modality was assessed aimed at during the study.

**Table 4. 3**

*Categories of the Three Points of Reference*

| Educational Experience | Affective Experience | Physical Experience |
|---|---|---|
| Clear Instructions | Anxiety | Nausea/Motion Sickness |
| Ease of Use | Lack of Privacy | Dizziness/Vertigo |
| Met Learning Outcomes | Out of Control | Eye Strain |
| Increased Knowledge | Fear of Physical Harm | Headache |
| Gained Marketable Skills | Unresponsive Technology | Neck Pain |
| Desire to Use Again | Unnatural | Muscle Cramp |

Using each of the three types of experience as an analytic category using a 5-point interval-level Likert scale (1 = *completely disagree*; 5 = *completely agree*), similarities were discovered in the mean and standard deviation scores of each. For example, in the educational experience category, we examined Clear Instructions, Ease of Use, Met Learning Outcomes, Increased Knowledge, Gained Marketable Skills, and Desire to Use Again. For the four different modalities (2D3D, Dissections, 3D4DMedical app, AR), the means were similar within each modality. Overall, the participants reported the highest mean scores of physical distresses when reflecting on the experience of using the Augmented Reality (AR) modality to learn anatomy (average AR mean = 3.04). While reported means for Dissections were amongst the lowest of the modalities for all physical experience (average dissection mean = 1.70) when it comes to muscle cramps, headaches, eye strain, neck pain, dizziness and nausea (See Table 4. 4).

**Table 4. 4**

*Physical Experience Across Modality (N = 244)*

| Modality | Mean | Standard Deviation | *N* |
|---|---|---|---|
| Nausea/Motion Sickness | | | |
| 2/3D | 1.76 | 1.21 | 198 |
| Dissections | 1.96 | 1.33 | 89 |
| 3D4 App | 1.67 | 1.21 | 82 |
| AR | 2.53 | 1.66 | 72 |
| Dizziness | | | |
| 2/3D | 1.70 | 1.17 | 198 |
| Dissections | 1.63 | 1.11 | 89 |
| 3D4 App | 1.63 | 1.15 | 82 |
| AR | 2.58 | 1.62 | 72 |
| Neck Pain | | | |
| 2/3D | 2.02 | 1.32 | 198 |
| Dissections | 1.60 | 1.08 | 89 |
| 3D4 App | 1.85 | 1.32 | 82 |
| AR | 2.51 | 1.64 | 72 |
| Eye Strain | | | |
| 2/3D | 2.24 | 1.36 | 198 |
| Dissections | 1.64 | 1.17 | 89 |
| 3D4 App | 2.01 | 1.37 | 82 |
| AR | 3.00 | 1.57 | 72 |
| Headache | | | |
| 2/3D | 2.18 | 1.41 | 198 |
| Dissections | 1.78 | 1.25 | 89 |
| 3D4 App | 2.06 | 1.41 | 82 |
| AR | 3.08 | 1.60 | 72 |
| Muscle Cramp | | | |
| 2/3D | 1.71 | 1.15 | 198 |
| Dissections | 1.61 | 1.13 | 89 |
| 3D4 App | 1.55 | 1.12 | 82 |
| AR | 2.24 | 1.61 | 72 |

Note. The shaded color blue represents a low mean, pink a medium, and a green high mean.

As seen in Table 4. 4, the blue shading represents the low mean for physical experiences by modality. The pink shading represents the medium values and the green shade represents the highest values from the 5-point Likert scale. Overall, the participants reported a high mean score of physical distress when reporting the experience of using the augmented reality modality. The green shade represents the highest value rating eye strain and headache across modality in AR. Participants *(n* = 72*)* reported eye strain a mean (3), closely scored headache mean (3.08), with dizziness/vertigo with a mean (2.58), nausea/motion sickness mean (2.52), neck pain mean (2.51) all similarly reported, and lastly, mean (2.2) for muscle cramping. In contrast, participants *(n* = 82*)* identified the 3D4 Medical mobile app as having a low physical experience with nausea/motion sickness by modality with a mean of (1.67) and for muscle cramp (1.5). This was a surprise as both modalities used a computer screen as a learning tool.

The overall lowest physical experience shaded in blue with the mean was reported by participants *(n* = 89*)* that used animal tissue dissections as a learning modality. Survey results demonstrated a low average mean (1.5) for neck pain, and a lack of dizziness rating with a mean (1.6)*,* eye strain mean (1.64), and headache mean (1.77) was reported by participants that used dissection as a modality.

As seen in Table 4. 5, the mean and standard deviation characteristics for affective experience across all modalities demonstrated more variation compared with physical experience. The blue shaded means represent a low mean whereas the pink represent a value in the mid-range of the 5-point Likert scale. For AR, anxiety was reported to be a low value, anxiety mean (1.74), lack of privacy mean (1.67), out of control mean (1.66), and unnatural mean (1.72). However, AR was rated highest mean (2.14) for unresponsive technology. The unresponsive technology was so problematic that the I.T. department was on standby to assist the students and faculty during the learning exercises. Lastly, for affective experience, AR had the most negative mean value given for fear of physical harm (1.5).

**Table 4. 5**

*Affective Experience Across Modality (N = 244)*

| Modality | Mean | Standard Deviation | *N* |
|---|---|---|---|
| Anxiety | | | |
| 2/3D | 2.32 | 1.35 | 198 |
| Dissections | 2.20 | 1.37 | 89 |
| 3D4 App | 1.76 | 1.11 | 82 |
| AR | 1.74 | 1.01 | 72 |
| Lack of Privacy | | | |
| 2/3D | 2.01 | 1.23 | 198 |
| Dissections | 1.91 | 1.31 | 89 |
| 3D4 App | 1.57 | 1.02 | 82 |
| AR | 1.67 | 0.95 | 72 |
| Out of Control | | | |
| 2/3D | 1.80 | 1.18 | 198 |
| Dissections | 1.81 | 1.29 | 89 |
| 3D4 App | 1.51 | 0.96 | 82 |
| AR | 1.66 | 0.94 | 72 |
| Fear of Physical Harm | | | |
| 2/3D | 1.60 | 1.11 | 198 |
| Dissections | 1.85 | 1.28 | 89 |
| 3D4 App | 1.46 | 0.92 | 82 |
| AR | 1.53 | 0.85 | 72 |
| Unresponsive Technology | | | |
| 2/3D | 1.94 | 1.23 | 198 |
| Dissections | 1.79 | 1.30 | 89 |
| 3D4 App | 1.93 | 1.19 | 82 |
| AR | 2.14 | 1.08 | 72 |
| Unnatural | | | |
| 2/3D | 1.87 | 1.23 | 198 |
| Dissections | 1.87 | 1.36 | 89 |
| 3D4 App | 1.66 | 1.14 | 82 |
| AR | 1.73 | 0.99 | 72 |

Note. The color blue represents a low mean and pink represents a medium mean.

The responses related to the educational experience across all modalities revealed that instructions were clear for students and this was found to be in agreement across the modalities. In general, there was strong agreement among the candidates about all categories associated with educational experience. However, as seen in Table 4. 1, across all educational experience, AR had the lowest mean scores. Participants (*n* = 72) reported ease of use as the lowest of the means (3.8). With the desire to use again, AR specifically was the second lowest mean (3.9). AR modality represents three other lowest means in the educational merit experience. For example, clear instructions with a mean of (4.2), met learning outcomes (4.3), and lastly, knowledge gained (4.3). A notable sub-category of marketable skill was discovered to have a value with a mean (4.2). This reflection has weight as the medical profession is moving toward using AR in practice.

**Table 4. 6**

*Educational Experience Across Modality (N = 244)*

| Modality | Mean | Standard Deviation | *N* |
|---|---|---|---|
| Clear Instructions | | | |
| 2/3D | 4.29 | 0.98 | 198 |
| Dissections | 4.46 | 0.91 | 89 |
| 3D4 App | 4.32 | 0.98 | 82 |
| AR | 4.28 | 1.06 | 72 |
| Ease of Use | | | |
| 2/3D | 4.24 | 1.00 | 198 |
| Dissections | 4.37 | 1.02 | 89 |
| 3D4 App | 4.18 | 1.11 | 82 |
| AR | 3.88 | 1.24 | 72 |
| Met Learning Outcomes | | | |
| 2/3D | 4.34 | 0.97 | 198 |
| Dissections | 4.44 | 0.93 | 89 |
| 3D4 App | 4.35 | 0.93 | 82 |
| AR | 4.32 | 1.00 | 72 |
| Increased Knowledge | | | |
| 2/3D | 4.39 | 0.99 | 198 |
| Dissections | 4.38 | 1.02 | 89 |
| 3D4 App | 4.37 | 0.95 | 82 |
| AR | 4.33 | 1.06 | 72 |
| Gained Marketable Skills | | | |
| 2/3D | 4.15 | 1.10 | 198 |
| Dissections | 4.24 | 1.11 | 89 |
| 3D4 App | 4.27 | 1.03 | 82 |
| AR | 4.22 | 1.13 | 72 |
| Desire to Use Again | | | |
| 2/3D | 4.13 | 1.21 | 198 |
| Dissections | 4.18 | 1.16 | 89 |
| 3D4 App | 4.27 | 1.10 | 82 |
| AR | 3.94 | 1.37 | 72 |

Note. The color green representing lower mean values compared to yellow representing a low mean.

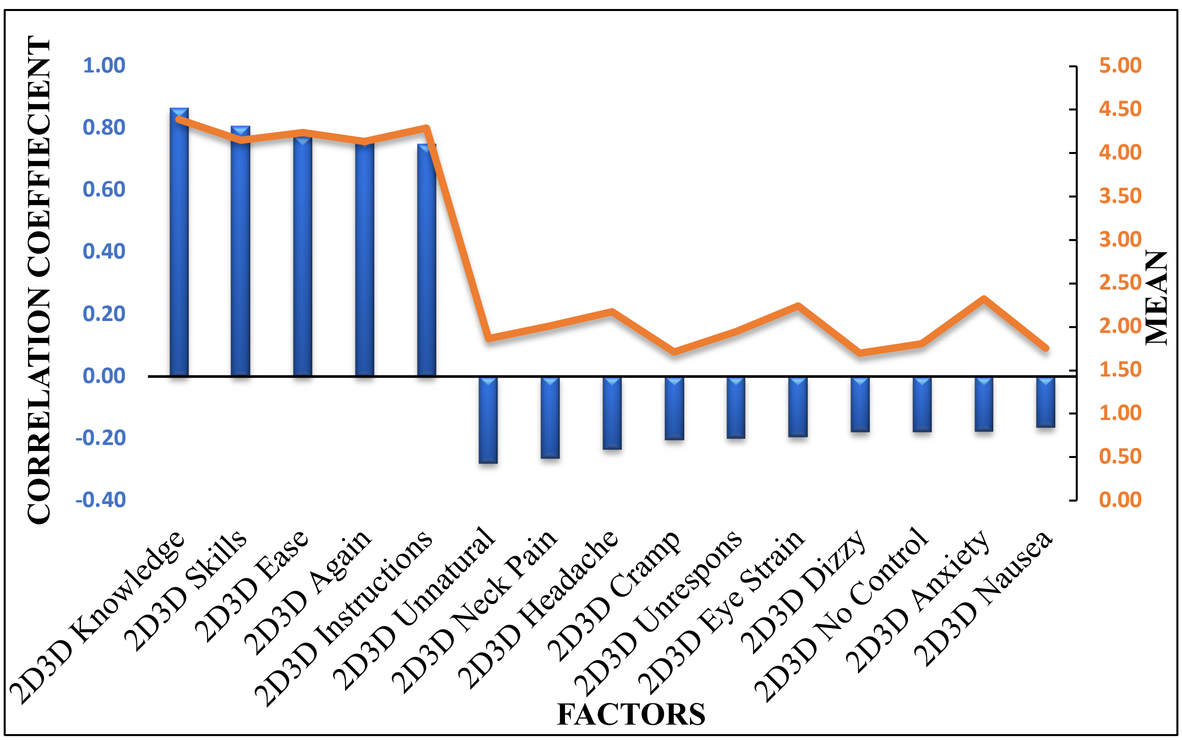
## Inferential Statistics (Multivariate Statistics)

Experiences (e.g., Educational, Affective, Physical) with dissections, 3D4D, and AR showed no significant correlations with GPA. As seen in Figure 4. 2, the only modality with statistically significant results was 2D3D across most experience factors. The highest correlations were found between educational factors such as Knowledge, Skills, Ease, the likelihood of Using again, and Clear Instructions and GPA. The educational experience correlated most strongly with GPA was Knowledge ($r(198) = .86, p < .05$). Physical and Affective factors such as Headaches, Neck pain, Cramps, Dizziness, Anxiety, and Nausea are correlated with GPA, but at much weaker values. For example, there was a weak correlation between nausea and GPA, $r =(198) = -.16, p <.05$.

The factors with the highest correlations also tended to have high mean scores. There were, however, several exceptions to this. For example, Clear Instructions were rated higher on average than all but Knowledge within the educational factors. Also, Anxiety with a mean of 2.32 was rated higher on average than all Physical and Affective factors, even though its correlation to GPA was second to last, $r(198) = 0.18, p < 0.05$.

**Figure 4. 2**

*Correlations Between 2D3D Modality and Mean (n = 198)*



A one-way analysis of variance (ANOVA) was computed on data from the participant sample ($N = 302$) to uncover a statistically significant difference in the identified significant factors that influence the use of the modalities. A significance level of .05 was used; therefore, p values less than 0.05 were considered significant while p values greater than .05 were considered insignificant. A limited amount of statistically significant differences influenced the factors based on all categories of demographics, as seen in Table 4. 7. Six factors out of the 84 factors were found to be significant, $p < .05$, when computing by the average in all three points of reference: Educational, Affective, and Physical experiences in each modality used in human anatomy.

An ANOVA was computed on the data set to examine the difference between average mean factors by Physical Experience using the 3D4DMedical mobile app based on gender. There was an effect for gender on physical experience using 3D4DMedical mobile app, $F(1, 82) = 5.44$, $p = .038$. A graph summarizes the results see Figure 4. 3.

**Figure 4. 3**

*Influence of 3D4Medical App on Physical Experience by Gender (n = 82)*

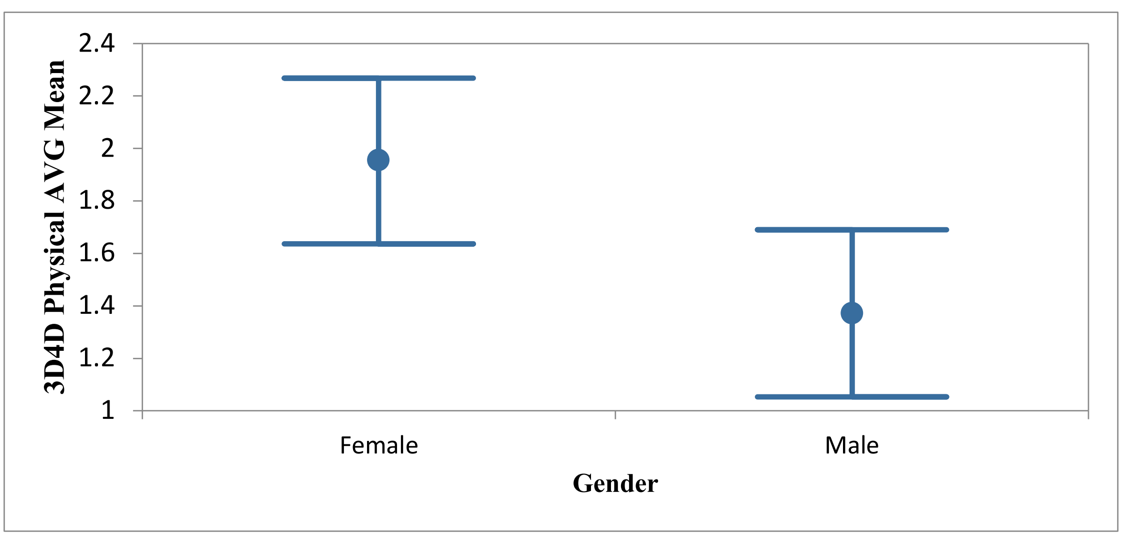


**Table 4. 7**

*ANOVA p value for Impact of Demographics on Educational, Affective and Physical Experience across Modalities using the Average Means for Educational, Affective, and Physical Experience. (N = 232)*

| | 2D/3D Models | | | Dissections | | | 3D4 Medical APP | | | AR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Phy Avg | Aff Avg | Ed Avg | Phy Avg | Aff Avg | Ed Avg | Phy Avg | Aff Avg | Ed Avg | Phy Avg | Aff Avg | Ed Avg |
| Gender | 0.58 | 0.75 | 0.67 | 0.52 | 0.57 | 0.09 | 0.04* | 0.60 | 0.82 | 0.13 | 0.57 | 0.48 |
| Ethnicity | 0.35 | 0.88 | 0.70 | 0.60 | 0.51 | 0.30 | 0.88 | 0.23 | 0.61 | 0.25 | 0.24 | 0.29 |
| Level Ed | 0.59 | 0.98 | 0.68 | 0.30 | 0.43 | ** | 0.29 | 0.26 | 0.48 | 0.40 | 0.58 | 0.96 |
| Status | 0.62 | 0.13 | 0.39 | 0.26 | 0.01* | 0.37 | 0.37 | 0.55 | 0.80 | 0.51 | 0.76 | 0.33 |
| Grad yr | ** | 0.10 | 0.20 | 0.10 | 0.06 | 0.77 | 0.08 | 0.74 | 0.86 | ** | 0.03* | 0.09 |
| Age | 0.44 | 0.80 | 0.81 | 0.48 | 0.60 | 0.68 | 0.41 | 0.97 | 0.51 | 0.32 | 0.43 | 0.52 |
| Major | 0.71 | 0.13 | 0.50 | 0.63 | 0.26 | 0.91 | 0.54 | 0.46 | 0.34 | 0.72 | 0.93 | 0.89 |

Note. * Statistically significant *p*- value of $p < .05$, **$p < .001$

### Impact of Gender

After testing Gender as an Independent Variable, the researcher revealed only one statistically significant relationship was found with the Physical Experiences (e.g., nausea, headache, etc.) with the 3D4D Medical App, $F(1, 82) = 4.41$, $p = .04$.

### Impact of Level of Education

When the researcher tested Level of Education as an Independent Variable, only one statistically significant relationship with the Educational Experiences (e.g., knowledge, instructions, etc.) with Dissections, $F(2, 89) = 6.29$, $p = .002$.

### Impact on Graduation Year

After testing Graduation Year as an Independent Variable, the researcher found only one statistically significant relationship with the Educational Experiences (e.g., knowledge, instructions, etc.) with the 2D3D modality, $F(4, 198) = 4.98$, $p = .0030$. This was also seen as a statistically significant difference by graduation year in the factors of AR. Physical Experience (e.g., headache, nausea), $F(4, 72) = 8.7$, $p = 0.001$. There was a significant effect for AR within the Affective Experience area (e.g., anxiety, unnatural, etc.) between graduation years, $F(4, 72) = 1.8$, $p = .03$.

**Factors that Lacked Statistical Significance**

Factors that are not statistically significant included ethnicity, age, full-time/part-time student status, and major.

## Findings of Qualitative Research

Questions within the survey aimed at collecting qualitative data required the participants to disclose their overall experience with each of the learning modalities they experienced in their anatomy course. The survey included four open ended questions in total which were analyzed through thematic analysis. The following two research questions were used to guide qualitative data analysis:

1. What are the positive factors that influence student experience and attitude toward technology?
2. What are the negative factors that influence student experience and attitude toward AR technology?

Many responses were provided as examples of the positive and negative experiences subjects encountered with educational, affective, and physical experience across all modalities. Upon data analysis of participant responses related to the three points of reference (educational, affective, and physical experiences) across all modalities, hundreds of words were analyzed, and 26 codes were assigned to the data points. From the 26 codes, 10 themes emerged which included guidance from professors, online learning, negative attitudes, motivation, learning styles, ease of use, and heavy headset. The emerging themes and their corresponding codes related to the research questions based on the three points of reference discovered from the analysis of the impact that AR has on learning in undergraduate educational human anatomy course compared to other learning modalities are available in Table 4.8.

**Table 4. 8**

*Codebook of Question and Themes*

| Research Question | Theme | Codes |
|---|---|---|
| RQ1<br>What impact does Augmented Reality (AR) have on learning outcomes in the undergraduate educational Human Anatomy course compared to other learning or teaching modalities? | Guidance from professor | Competency of Instructor, Delivery of clear instructions |
| | Online learning | Poor learning environment, Covid, Mandated closures |
| RQ2<br>How does the use of the Microsoft HoloLens technology impact the motivation for learning human anatomy in the undergraduate college for allied health training? | Negative Attitudes | Frustration, Low confidence, Distress |
| | Motivation | Intrinsic |
| | Learning Styles | Interactive, Visualization, Kinesthetic |
| RQ3<br>What is the self-efficacy of students using AR in health sciences and anatomy? The term self-efficacy refers to an individual's confidence in completing a task or achieving a goal. | Relevance | Extrinsic |
| | Confidence | Confusion, Out of Control, Fear of harm |
| | Satisfaction | Frustration, Unresponsive technology, Steep learning curve |
| RQ4<br>What are the positive factors that influence student experience and attitude toward AR technology? | Ease of Use | Digital native, Enjoyment, Cool, Helpful |
| RQ5<br>What are the negative factors that influence student experience and attitude toward AR technology? | Heavy Headset | Eye strain, Headache, Dizziness, Neck pain |

**Modality of Learning**

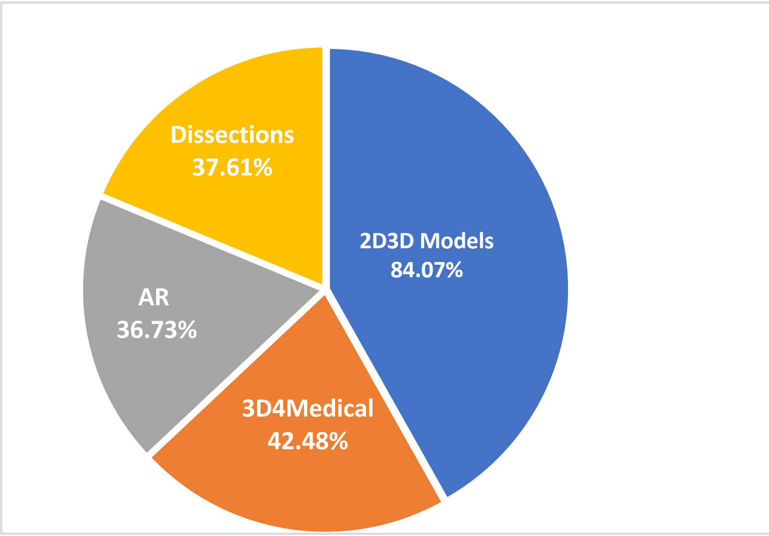
Responses to four open-ended questions addressed the participants' perception of each learning modality. The participants expressed their experience with AR technology and suggestions for improving the implementation of AR in the Human Anatomy course.

As shown in Figure 4. 4, the surveyed respondents were asked to indicate the learning modality used during the 260 Human Anatomy course or a combination of the learning modalities *(n* = 226). The participants *(n* = 190) overwhelmingly used the learning modality of textbooks with the 2D models' textbooks encompassing 84.07%, indicating this learning method was used in combination with 3D Models such as skulls, skeleton, brain, heart plastic models, 42.48% indicated using the 3D4 Medical app, also known as Complete Anatomy, which features a video of core anatomy structures. The use of animal tissues dissections, 37.61%, and A.R. (AnatomyX software with HoloLens headset) was closely equivalent with 36.73%.

Visualization was the most common reason (23 separate cases) offered by Human Anatomy students as they recalled their positive experience using each modality or the combinations of modalities presented to them in their course. Kinesthetic was the second most mentioned rationale in students' expressions of a positive experience using the different modalities in learning human anatomy (10 separate cases). The majority expressed this paradigm with the modality of animal tissue dissections.

**Figure 4. 4**

*The Modality Used to Learn Human Anatomy (N = 302)*




**2D3D Modality**

This research found that 84% of the subjects indicated that they used 2D3D as a modality. When surveyed, these participants commented on the physical, affective and educational experiences in addition to the preferred learning style of visualization regardless of whether it was 2D/3D, 3D4Medical app, dissection or AR or a combination of those, sharing both positive and negative reflections. Participants physical concern was nonexistent when reflecting on 2D3D modality. However, the participants demonstrated a high affinity to the educational virtues of using 2D3D modalities to learn human anatomy.

***Physical:*** Participant's agree as 100% of the subjects that gave feedback on the use of 2D3D modality reported no physical discomfort.

***Affective:*** Subjects reported that using the 2D3D textbooks and models had no negative affect on their perceived learning. To the contrary, most simply stated it was a "good experience with no issue" (Subject 174). Another subject responded that 2D3D was "adequate for undergrad anatomy and the 3D model experience was great!" (Subject 190).

***Educational:*** Most subjects found the 2D3D modality to be a positive learning aid. “It was a good experience. I liked the 3D models because that helped me learn the most” (Subject 67). “The book was a great resource as well" (Subject 5). Similarly reported, “I used a electronic textbook... It is really easy to use and I never had a problem with it (Subject 146). Many subjects discussed how they viewed themselves with the preferred learning style, “I am a visual learner so models and photos are helpful." (Subject 54). “Very useful, especially the 3D models. Great asset to my success in the course” (Subject 47). A general theme that emerged in the feedback of 2D3D modality was how the subjects learned during the transition from classroom laboratory sections to online coursework due to the Covid pandemic. “it was an okay tool to use, especially being taught online, the more interactive resources" (Subject 97). Other subjects reflected, “I personally liked it because since we were not able to be hands on, using that still kinda gave me the hands-on experience that I needed" (Subject 211). “They were really helpful especially since we were in class virtually and couldn’t see models in person” (Subject 18) and “I used my supplies at home and the textbook. Both worked super well!” (Subject 204). Subject 206 shared, “never experienced any of these aside from textbook images. was taking this class during covid and everything was online. Experience was not as beneficial and did not learn as much as i wouldve liked.” Not all subjects were content with online learning, “not an effective way to learn anatomy. Should be done in a classroom experience" (Subject 199). Another subject reflected, “It’s a good tool for students who have taken anatomy prior to WCU, but perhaps for students who have never done that, they need real cadaver experience to enhance learning" (Subject 159). The vast majority of subjects had a positive experience with 2D3D modality to all three points of reference compared to other modalities as 54 gave positive feedback and 12 gave a neutral response.

**Dissections Modality**

In this study 37.61% of the subjects indicated that they used dissections as a modality. When surveyed, these participants commented on the physical, affective, and educational experiences in addition to the preferred learning style of visualization regardless of whether it was 2D/3D, 3D4Medical app, dissection or A.R. or a combination of those as they shared positive and negative feedback.

***Physical:*** Subjects using dissection modality indicated that they had very little physical discomfort outside of nausea. For example, "The smell of formaldehyde makes me sick" (Subject 57). A few subjects were unimpressed with the dissection's modality, "I never want to dissect animals again, they were extremely foul smelling, not relatable to nursing and what we needed to know for the class. I am highly opposed to this portion of the class" (Subject 234).

***Affective:*** Subjects also reflected on their dissection experience in a unenthusiastic manner, "It was okay… kinda unnecessary" (Subject 111), which displayed feedback from category unnatural, exhibiting an affective experience. "Sometime the material is hard to use such as scalpel to cut the heart dissection" (Subject 89). However, the majority of the subjects reported with positive remarks such as, "It was a lot of fun. Definitely learn so much from dissections"! (Subject 9), which displayed no negative affective experiences for most subjects.

***Educational:*** Overwhelmingly, subjects indicated positive statements on the overall educational experience of using the dissection modality. Several subjects reported positive comments in their feedback such as, "I enjoy looking at other mammals' anatomical figures which allowed me to see it in a more realistic view" (Subject 197). "Dissections were helpful to visualized the body parts and get better understanding of their functions" (Subject198). "Dissecting enhanced my knowledge by being able to compare and contrast it to the human body. For example, seeing where the heart, liver, and pancreas was placed helped me visual it in the human body" (Subject 210). Visualization was a strong theme on the dissection reflections, "By being able to dissect I could see every area piece by piece" (Subject 81). Subjects also discussed the kinesthetic advantages they considered positive as most subjects that used the dissection modality were in strong agreement, "Loved learning hands on" (Subject 192). "Good learning experience especially for students who are hands on learners" (Subject 226) and "Good way to apply our skills" (Subject 228). One subject equivalently reported that dissection was "Fun/active learning style, but could have been done more effectively" (Subject 163). The analysis from the survey revealed that the subject's feedback strongly supported the use of the dissection modality as an intercuts part of learning human anatomy.

**3D4DMedical App Modality**

The research discovered that 42.48% of the subjects indicated that they used 3D4DMedical app as a modality. When surveyed, 31 participants commented on the physical, affective and educational experiences in addition to the preferred learning style of visualization regardless of whether it was 2D/3D, 3D4Medical app, dissection or AR or a combination of those as they shared positive and negative reflections.

***Physical:*** The majority of the subjects found that using the mobile app did not cause physical discomfort. However, one subject reported a negative statement toward the modality, stating, "It was cool but got dizzy" (Subject 232). Those subjects that discussed the need to acquire hands-on experience for deeper learning stated, "The app is great if it is accompanying an in-person class but by itself it is a bit difficult to remember the body. I am not a kinesthetic learner but for anatomy I think it is necessary to see and feel the human skeleton and parts" (Subject 93).

***Affective:*** A few subjects did not enjoy using the 3D4DMedical mobile app because of unresponsive technology, "Successful but at times frustrating when having to touch the screen and the video not respond" (Subject 88). "Didn't care for this technology" (Subject 145). "It can be slow to render but perhaps I need better computer" (Subject 159). The 3D4DMedical app displays useful human anatomy images that were useful but learners desired to be in the classroom, "images useful but still hard to visualize... computer modality should not be an option for this course" (Subject 199). A handful of the comments were neutral regarding the app such as "It was okay" (Subject 111), and "nothing special" (Subject 158), and "Instructor used this app through Zoom for demonstration" (Subject 51). One participant shared, "Since we were not in person, I felt this was a better tool than I originally anticipated" (Subject 166).

***Educational:*** Again, the theme of online learning emerged through the survey feedback with those subjects that used 3D4DMedical app during online course work such as "I took anatomy online during Covid so I was unable to experience the 3D models but did receive the complete anatomy app that was provided throughout my course and it helped me tremendously” (Subject 162). "It’s very helpful, especially since we have labs via Zoom"! (Subject 185). A positive experience was the general consensus by the subjects using the 3D4D mobile app. Examples of their positive feedback were, "The app was very cool! I had never used anything like it before, I would have loved to experience on ground lab. However, I took anatomy while Covid was in full effect. I personally enjoyed the app” (Subject 4). "Fascinating technology. Good to know our tuition payments are going to a unique learning experience,” (Subject 13), “helpful” (Subject 43). "Used the software for 7+ years. Really great software” (Subject 53). "I found the APP useful and accessible" (Subject 54). “I really liked the complete anatomy app that I still use it in core” (Subject 67). "Having one main view and shared screen of it made it easy to know what was being discussed” (Subject 83). "I enjoyed it” (Subject 120). "It’s cool” (Subject 128). "We used it on our lab days and it helped prepare me for what to expect for our homework” (Subject 129). "I highly enjoyed having this feature/app on our phones as it was a smaller version of the VR simulation in class. When I was struggling on a body system, it was very easy to manage the app and help me gain a better understanding” (Subject 136). Overall, the subjects had positive feedback for the 3D4Medical modality and continue to use it in other courses.

**Augmented Reality Modality**

Of the subject, 36.73% indicated that they used AR as a modality. The tremendous amount of qualitative feedback came from asking participants *(n* = 72) to describe their overall experience with AR Technology in their Anatomy course(s). The survey provided 62 separate data points for analysis. When surveyed, these participants commented on their physical, affective and educational experiences. Additionally, many subjects indicated a preferred learning style of visualization regardless of whether it was 2D/3D, 3D4Medical app, dissection or AR or a combination of the used modalities.

The most varied feedback came from AR's open-ended survey question. Participants were asked to "Please describe your overall experience with AR Technology in your Anatomy course". There were 23 positive remarks, 16 negative remarks, and 2 neutral. Interestingly, 18 subjects, unlike the other modalities reflected upon, subjects that used AR had by far the most positive and negative commentary in the same breath. A majority of AR modality users were motivated to learn with a novel learning modality and responded with positive feedback even if they had a negative experience with the technology device. Participants of AR technology experienced usability issues and technical problems, and some participants found this technology complicated to use due to the unresponsiveness of the technology.

***Physical:*** AR users, unlike the users of the other modalities reflected upon in this study had by far the most positive and negative commentaries. Furthermore, those subjects that used the AR modality shared both positive and negative reflections. For example, "I thought it was very cool and interactive, at times some of the headpieces would not work and the hand motions would not be read properly. After the third or fourth time using them, I felt as though I had the hang of it. I did get headaches and eye strain from using them for long periods of time and I did take it off for a few minutes at a time. It really helped prepare me for quizzes, and I liked the exams we took with the headset, overall, I would like to use it again as I found it beneficial" (Subject 54). **"**Over all good educational experience, helped visualize anatomical structures. Long periods of time may strain the eye, good instructor is vital to good experience with equipment/education The headset is not very comfortable for students wearing glasses."

(Subject 163). “Loved it despite the heaviness of the headset. One of my favorite non clinical experiences at West Coast University.” (Subject 13). “It was the best thing I did in GE but if gives you headache and Hurts your eyes if you wear contacts or glasses.” (Subject 112). “It caused pain and headache after more than 15 minutes but was worth it for the learning experience.” (Subject 84).

A fraction of the feedback was negative toward the AR technology reducing the motivation to use the learning modality “I hated this… every time we used it, I felt ill.” (Subject 15). “Difficult to use and caused headaches.” (Subject 57). “Nauseating, and anxiety sickening esp when unreliable tech contributed to a portion of grade via assessments.” (Subject 64). The negative physical experiences leaned heavily into the sensation of dizziness, “I always had headache and dizziness after” (Subject 113). “I only got dizzy using AR when I was standing up while using it” (Subject 152). “I dreaded using the AR, It was a lot of strain on my body, and we weren't allowed to seat down while using the technology. The heavy equipment on my face resulting in neck, and back pain that lasted hours after the class had ended. I was relieved when the class was over. Due to the physical impact, it had on my body, It was challenging to stay focused in class.” (Subject 124). “I hated it. It made me feel so sick every time we used it.” (Subject 15). The negative physical experience impacted the subject’s ability to stay focused, reduced motivation for a select few who were adversely affected to the point that they dreaded going to class.

***Affective:*** Subjects did not enjoy using AR due to the unresponsiveness of the technology. For example, “Hard to use for those who wear eyeglasses. Technology malfunction made difficult for use. Did not increase my learning by experience and does not make a big impact on learning" (Subject 133). The experience for some was unnatural for a few subjects as they reported, "It's a little bit heavy which causes headache towards the end. It also hurts my eyes due to the light and also the 3D image." (Subject 176). Feedback from subjects reported that they did enjoy the novel device as a learning modality, however, explained it was beneficial for a short period of time, "I enjoyed the use of the hololens, but I could not use them for extended periods of time." (Subject 227). Students who had negative experiences with affectiveness such as unresponsive technology lost interest and motivation for learning, "Using AR… difficulty because moving and zooming into parts of the model were sensitive. I would often give up because I couldn't control the movement to where I wanted to look." (Subject 82). On a positive note, many students highlighted the instructor as a poignant part of the experience "Was a little difficult to get the commands right but once I learned the hand gestures to be able to navigate operate the lens, I was able to get appreciate the app way more but overall, all I can say is that I looked forward to this class every week! Professor B made my experience even better! Thank YOU!" (Subject 76). A theme was identified in that subjects credited the professors for the positive experiences and the unresponsive technology was the critical aspect of affective experience when using AR modality.

***Educational:*** Once more subjects had a great number of comments both positive and negative feedback on the educational experiences of the AR technology, "Halo lenses were a great experience, especially when referring to Anatomy. Pros: it helped retain information as it's both interactive and visual, Cons: may strain eyes over long period of time, good instructor is crucial." (Subject 163). "Didn't feel like it helpful at all compare to the actual model that we can touch." (Subject 145). "Different but effective. A memorable experience in anatomy." (Subject 122). Those subjects that had positive comments generally started off with the word enjoyed "Enjoyed such a unique facet of our learning." (Subject 13). "I enjoyed Having this new experience of not only physically dissecting an animal but also getting to look at virtual technology in the healthcare setting." (Subject 230). "Wow! Best experience EVER! Couldn't believe this was possible. FANTASTIC!" (Subject 76). "I enjoyed it, It was brief though… but did give more insight." (Subject 142). In direct opposition to many subjects' comments, one indicated "Fairly easy to use. Great learning experience." (Subject 53). One subject expressed a desire to use gain in future course work, "overall I would love to be able to use technology like this for dental anatomy. It definitely made it very easy to understand what bones and muscles laid on top of each other. Also, it made the lymphatic system easier to understand. Since the lymph nodes were able to be separated. Definitely, a great experience and after learning how to use it, the routine became very easy to do. Also, the gestures were all very natural." (Subject 60). In analyzing the feedback, it was notable that those subjects that had the on-ground experience in lab supplementing AR with animal dissections, the textbook and with plastic models where enthusiastic about the AR modality experience.

## Summary

In this chapter, quantitative and qualitative data analysis was presented to evaluate AR's impact on educational merit, affective capability, and physical consequences. Descriptive statistics were used to discuss participant demographics and frequency data. Analysis of variance was used to analyze differences in the positive and negative perceptions of the subjects for the modalities used as learning aids during Human Anatomy courses. Qualitative data was analyzed for themes related to the student's perceptions as they recalled their lab experiences.

# CHAPTER 5: DISCUSSION

Human anatomy is a foundational course for all allied health students desiring to enter the workforce in health care. Human anatomy has been taught through many different modalities. Those modalities include dissections (human and animal), textbooks, plastic models, and 3D computer apps. More recently, a novel modality became available that uses augmented reality technology. Since AR is one of the newest modalities used for educational purposes in health care training, it was necessary to investigate its educational merits. Augmented Reality aims to mix real-world visual content with virtual objects in a hologram. The AR's software and hardware are in an early implementation phase, and little is known about how this novel device would impact the undergraduate allied health student. This study compared the learning modalities of AR to the 3D4Medical app, 2D/3D models, and dissection of animal tissues.

Researchers' studies have shown that dynamic visualizations are more promising than static visual modalities at promoting conceptual inferences about science, consistent with the success of inquiry instruction in science (Ferrer-Torregrosa et al., 2016: McElhaney et al., 2015). AR headsets and software for learning human anatomy have very little data to support the investment required to facilitate the objectives and meet the learning outcomes. According to Ferrer-Torregrosa et al. (2016), many questions still linger about its use in education and training. There are relatively few studies assessing the adoption and usability of AR in the classroom. Specifically, how does AR impact the learner? What is the self-efficacy of students using AR in health sciences and anatomy? How does the Hardware impact the motivation for learning human anatomy? Lastly, what are the positive and negative factors influencing student experience and attitude toward AR technology?

This mixed methods convergent parallel study investigates the impact Augmented Reality

(AR) has on learning human anatomy within undergraduate college courses by comparing different learning modalities. Through research within this study, I have identified AR's impact on learning outcomes in undergraduate human anatomy courses compared to other learning modalities. I have also identified how the use of the hardware impacts the motivation and self-efficacy for learning human anatomy by investigating the positive and negative factors that influence student experience and attitude toward technology. The factors have been identified, which can help leaders in higher education make informed decisions on the future implementation of AR technology. By analyzing the three points of reference to measure the perceptions of students' (a) educational experience, (b) the affective experience, and (c) physical experience, conclusions were made.

## Summary of the Study

### Primary Research Questions #1

What impact does Augmented Reality (AR) have on learning outcomes in the undergraduate educational Human Anatomy course compared to other learning or teaching modalities?

#### *Sub-Questions:*

How does the use of the Microsoft HoloLens technology impact the motivation for learning human anatomy in the undergraduate college for allied health training?

What is the self-efficacy of students using AR in health sciences and anatomy?

What are the positive factors that influence student experience and attitude toward technology?

What are the negative factors that influence student experience and attitude toward AR technology?

The following section of this chapter utilizes analysis and findings to answer the study's primary research question #1: What impact does Augmented Reality have on learning outcomes in the undergraduate educational Human Anatomy course compared to other learning or teaching modalities? The hypothesis: Students who use Augmented Reality will increase learning outcomes, contributing to improved academic achievement in the undergraduate population (Aebersold et al., 2018). According to the quantitative data collected and analyzed, AR impacts the learning outcome with the lowest mean scores than all other modalities when compared to the student's educational experience. Students reported that they met learning outcomes using AR technology by 59.72% ($n$ = 43) with an average mean of 4.32. The null hypothesis was found: Students who use AR do not increase learning outcomes, nor does AR contribute to improved academic achievement in the undergraduate population. The novel device was rated lowest in ease of use and the desire to use again. Although students indicated that the instructions were clear, outcomes were met, and knowledge was gained, AR was too complex for the users as a whole.

Students indicated that AR was a slightly more marketable skill with a mean value (4.2) compared to the lowest mean (4.1) of the 2D3D modality. According to the literature review, AR is being utilized in medical practice today and in other health care institutions (Kamping-Carder, 2018; Wish-Baratz, 2020). Medical doctors and surgeons are utilizing the AR technology for indirect patient care today. The students' perception that AR technology is not that much of a marketable skill may be sabotaging and concerning for these early implementers of AR.

The four sub-questions further addressed the impact that AR has on (a) motivation for learning human anatomy, (b) factors that inspire students' self-efficacy using AR, and lastly, the (c) positive and (d) negative factors that influence student experience toward using augmented reality technology.

The first sub-questions: How does the use of the Microsoft HoloLens technology impact the motivation for learning human anatomy in the undergraduate college for allied health training? Hypothesis: Students who use augmented Reality may increase learning motivation, contributing to improved academic achievement (Khan et al., 2019).

This sub-question examines how the attention, relevance, confidence, and satisfaction aspects of learning motivation was affected by using AR (Keller, 2008). Quantitative and qualitative data discovered that students lacked attention, relevance, confidence, and satisfaction, which reduced the motivation to use the AR technology for the future. When analyzing the descriptive analytics from the data, it was revealed that the physical experience when using AR demotivated the student. The highest average mean was aligned with the unresponsive technology when using AR with a mean of 2.1 when compared to other modalities. This was a factor for demotivation when learning human anatomy with AR technology. Through statistical methods, the data revealed that students encountered eye strain, headaches, dizziness, nausea, neck pain, and muscle cramps which impacted the learners motivation to use the technology of AR again.

The second sub-question: What is the self-efficacy of students using AR in health sciences and anatomy? Hypothesis: Students that use AR to learn anatomy tend to exhibit greater attention, place more relevance, display more confidence and demonstrate more satisfaction during AR learning sessions (Moro et al., 2017; Khan et al., 2019). Self-efficacy refers to an individual's confidence in completing a task or achieving a goal. The outcomes of this research demonstrated that AR technology did not increase the self-efficacy of undergraduate health science students at WCU. The complexity of seeing the hologram over the real world may be of concern and cause confusion. Confusion is unproductive in a learning situation as students may lose track of the real environment as participants reported a mean score of (1.66) when asked to recall out of control and a mean of (1.53) for fear of harm. A source of frustration for participants was established with a high mean (2.1) of the unresponsiveness of the AR technology. Another challenge may be that the stability of AR technology is not certain, and difficulties may be encountered if the technology includes interfaces that are not well-designed, as this may result in the technology being too complicated for a novice to use. Further, there is a steep learning curve with using AR technology, and users may also need additional training and time to become familiar and comfortable with AR technology.

The third sub-question: What are the positive factors that influence student experience and attitude toward technology? Hypothesis: Students favor the visual learning environment that AR has to offer (Gerup et al., 2020). The hypothesis was proven through the qualitative data points. The positive comments on AR technology were overwhelming. Those learners who prefer visualization expressed positive feedback with statements about enjoying the experience. Others thought it was cool, and many stated that it was helpful to see the anatomy structures in holograms. For example, one subject enthusiastically announced, "Loved the experience! Way better than just seeing in a book! Holograms where amazing! Best experience ever!" (subject 76).

Finally, the fourth sub-question: What are the negative factors that influence student experience and attitude toward AR technology? Hypothesis: Postural instability is not responsible for cybersickness occurring during the use of the HoloLens headset (Dennison & D'Zmura 2017). The hypothesis was proven as students did not perceive the affective experience with high mean scores when evaluating the feeling out being out of control, lack of privacy, unnatural feeling, fear of physical harm when using the AR technology. The students also revealed that using AR gave them a low mean score of 1.74 for anxiety. Several negative factors influence students' perception of AR technology as it was reported that students experienced nausea, headaches, and eye strain. The AR technology did not concern the student when asked about lack of privacy, out of control or fear of physical harm, and an unnatural feeling when using the AR modality.

Student perceptions were not statistically different across modalities and demographics. According to the demographic characteristics, the graduation year or a specific cohort reported a statistically significant value in 2D/3D models and the use of augmented reality technology. Gender has a significant $p$-value associated with the 3D4Medical mobile app to learn human anatomy. Additionally, most of the students reported their highest degree as a high school diploma or GED. This level of academic knowledge might attribute to a difference in what they perceive as a value to learning human anatomy.

While the quantitative data did not reveal statistically significant differences in student perceptions, the qualitative data highlighted a primary reason for a negative perception of the human anatomy course. The stress of taking human anatomy online was identified as one of the primary reasons for the students' negative perceptions toward learning human anatomy when analyzing the feedback. At West Coast University (WCU), the General Education curriculum is an accelerated curriculum condensed into six ten-week courses. The open-ended questions capturing the qualitative data demonstrated that moving to an online curriculum due to the pandemic was stressful for students enrolled in a "brick and mortar" curriculum. Students expressed frustration and discontent learning human anatomy online. Students were worried since it meant establishing new relationships, developing new studying habits related to the chosen program, managing time effectively, coping with overwork, and often changing one's residence, not to mention doing all this within the whirlwind shift due to the pandemic. The COVID-19 pandemic has changed the operational systems of universities worldwide. At WCU, the transfer to online teaching was announced without prior warning, which radically changed students' daily functioning. Many of the participants who answered the open-ended questions when surveyed indicated this was a stressful situation for them.

## Implications for Practice

The current study results lead to the formulation of several recommendations for universities that teach allied health programs. Allied health educational institutions strive to prepare competent allied health professionals and leaders for direct patient care. Leaders at the executive level know little about the learning outcomes when AR is used to train undergraduates in human anatomy. University administrators are looking for options to teach human anatomy at a high level, affordably and efficiently. Improvements to the technology, support, training, and implementation will benefit the use, educational merit and application of HoloLens devices across and beyond the scope of medical training. Finally, the results of this study will impact future decisions to implement HoloLens technology across health and science programs throughout the US and beyond. The lack of qualified healthcare providers in the workforce has huge implications for patient care across America.

This study evaluates the impact of different teaching modalities found in the curriculum by considering the students' experience in matters of educational merit, affectiveness, and the physical experience functioning to a greater extent. These suggestions include: Continued training and calibration of the faculty teaching human anatomy. The need for the teaching faculty to emphasize the importance of learning AR technology and how their future practice of healthcare will be determined by their ability to acquire skills depends on learning the fundamentals of AR technology in the classroom. Also, by relaying the results of the student's feedback and inform the University leadership of possible improvements to support and train with the AR technology. AR is currently used in healthcare practice, such as in surgical rooms. If the student is unaware of how AR will shape their future practice in healthcare, they might not be as motivated to learn effectively with AR.

Another recommendation is to establish partnerships with hospitals and doctors using AR technology, so that the concept of field trips can be applied. The benefit of these trips for the learner is that they that can see how AR is used in the private sector and be motivated to concur the learning curve to gain competency for the future career. For allied health institutions that are training future health care providers, it is highly probable that AR technology will be increasingly incorporated into the curriculum. The leadership of hospitals are now viewing AR platforms as transformational in the operating room because they know AR is poised to meet the real need for greater surgical accuracy, however, teaching institutions will lag behind if they do not embrace AR technology as a learning modality. Teaching institutions are poised to build curriculum of immersive health education and take advantage of innovative AR technology.

University leadership may have an inclination to implement assessments of students' physical function to determine the potential need for support and minimize the negative physical experience while learning human anatomy with technology such as AR. This study is considered a pilot study. There is a minimal amount of information on how augmented Reality impacts the learner. More research could benefit those seeking to use technology in the educational curriculum.

Despite the negative physical experiences reported, when it comes to remote learning, AR can be utilized as an inter-active learning tool, for instance, when the next worldwide pandemic arrives. When students and faculty cannot meet in a physical environment, it would be advantageous for students and faculty to be synced with AR on zoom. AR would need to catch up to the worlds need of high-speed broadband or 5G so that any given student has access to the volume of data that AR requires. AR has not shown itself as a better learning modality, nevertheless, it can-not be called inferior either because we don't have data to compare to any other modalities. There needs to be more research.

## Recommendations for Further Research

Although this study within its context, provides some evidence that using AR technology impacted learning human anatomy, research on this topic is still early. Further research should be conducted to determine which learning activities would benefit from AR technology. Further research should be conducted to assess the impact of AR on academic performance. I consider this study to be a pilot as it provides a minimal amount of information on how augmented Reality impacts the learner when using AR as a learning modality. However, future research focusing on AR's impact on the learning outcomes for a larger population will benefit the academic community and help clarify how we view knowledge accumulation by linking the fundamental concepts of theory and offering explanations. It will also be important to narrow the scope as the essential purpose of academic research is to prove a theory and development of knowledge for those seeking to use technology in the educational curriculum. This study was sufficient in positive findings to warrant a second large-scale investigation of integrating AR applications among the undergraduate colleges, specifically to expand the data collection to more allied health students., and obtain more findings. Additionally, more data could be collected through more data collection methods. For example, a focus group could be carried out with a subsample of participants in conjunction with conducting observations of the integration process.

A second focus group discussion could be conducted to identify success and participants' attitudes after the integration. AR is new to the education field in allied health and needs more in-depth studies to provide solid standards for AR technology integrations into human anatomy courses.

**Limitations**

This study was limited to one allied health institution; therefore, participant responses may not represent all healthcare institutions. Data were gathered from undergraduate students taking a Human Anatomy course in a California private college and may not represent all allied health students in the nation or even statewide. Using a volunteer sample may generate bias and limit the generalizability of the results to the population of interest. Future research inclusive of a larger sample size will limit bias and increase the generalizability of the results to the larger population.

Many variables outside the researcher's control could potentially impact the study, such as the participants' full participation. This qualitative study relied on participants' recollection of learning human anatomy and did not examine the transition as it was occurring; as a result, participants may have encountered difficulties reflecting on their learning experiences in the course. Using an online survey for students could be considered a limitation of this study. It may have generated a lower response rate than the student participants who completed paper surveys. The use of paper surveys in future research might help to increase the response rate for essential data points.

Learning styles preferences were related to traditional human anatomy curriculum and computer-based healthcare training, which may change depending on the professional occupation. Participants self-reported their preferences in learning modalities (traditional 2D (textbooks), 3D models, animal dissections, and technology computer-based) in healthcare education. Furthermore, demographic and questionnaire survey instrument responses could result in bias if students misunderstood specific questions.

Participants might have been motivated by the raffle drawing and completed the self-reported questionnaire survey too quickly. This may contribute to erroneous data, resulting in inaccurate interpretations of the results.

Another limitation of the study is the high proportion of female students in general education seeking a degree in the medical or dental field. Women (76%) choose these programs more often than men (24%). This explains why this resulted in a high gender imbalance in the sample.

**Delimitations**

Initially, two focus groups were included in the method and materials but due to the complexity of COVID-19, the study was delimited to specific data collection methods which were possible under the circumstances, which included an online survey to collect the recall in memory of the students' experiences during anatomy class. Other delimitations included the elimination of previously collected pre-test and post-test results from the AR modalities as the other modalities did not ascertain the pre-test and post-test for comparisons, as a comparison across all modalities would have been needed to analyzed equably across all modalities. The literature review examined the evolution of teaching and learning human anatomy with traditional and novel AR modalities. Although the use of AR in education is innovative, the literature review explored an overview of previous studies that used AR applications in other businesses and medical sectors, such as in the operating room.

## Conclusions

Technology has developed rapidly, especially in information and computer technology. The development encompasses almost all aspects of life, including the medical learning process. Currently, students who learn human anatomy use textbooks, text and picture media (2D), and statue models (3D). According to the literature, classical tutorials using didactic lectures and textbooks do not meet the necessities of "digital learners" who seek to use what they know. Researchers and educators are now discussing the need to reform the current education system by enhancing the overall learning experience for the undergraduate. Educators and leaders pay attention to the fact that without modern technologies, it may be unattainable to make a significant breakthrough in solving the problems of reforming education and improving the qualitative parameters of training of future health care professionals. In this case, informatization is a critical condition determining the further development of education curriculum, economy, science, and culture.

The relevance and effectiveness of using AR technologies for pedagogical purposes need to be considered by those that create the curriculum with the addition of AR technology. With AR technologies becoming accepted in both medical practice and medical research, the responsibility lay with colleges that are presently training health professionals and scientists to introduce advancements in technologies. Even though AR technology is relevant and has several advantages over traditional learning, there are some inherent problems in its implementation in education. This study found that the physical discomfort that students experienced compared with other modalities was too blatant to ignore. Although current Augmented Reality devices such as Microsoft HoloLens, are yet to provide the perfect experience, there is no reason to believe that manufacturers of AR technology will not get there soon. Educators need to be ready for future developments and the most effective way to be ready for this future trend is to start educating ourselves and our students with the latest technology.

Students do not generally experience difficulties learning human anatomy across 2D/3D, dissections, or 3D4Medical apps modalities according to the three points of reference are evaluated. When AR technology was used, participants rated their educational experience the lowest. Students had low anxiety and provided positive feedback on their educational, affective, and physical experiences. Based on the analysis of AR modality to learn human anatomy survey data, anatomy learning applications using augmented reality technology received both positive and negative feedback. AR helped learners visualize student learning. When AR technology was used in conjunction with other modalities, participants gave more positive feedback. Some improvements in the headset design are needed. The learners are demanding smaller, lighter headsets for comfort. If heeded by the manufacturers, the negative feedback can lead to better learning experiences for users of AR technology.

Based on the results of this study, it can be concluded that augmented Reality can help undergraduate allied health students learn the anatomy of the human body with interactive learning. However, until the physical limitations are addressed, the students are content with other modalities to learn human anatomy. Future use requires the headset to be lighter, cheaper and the software needs to provide content similar to a textbook modality. The maturation and infrastructure of the technology is required so that learners using AR do not get frustrated by the lack of unresponsiveness of the technology. There is an expectation that AR needs to function with the same speed and responsiveness of today's commonly used technologies, such as current smart phones.

An expectation of today's learners, known as digital natives, is to work with technology with ease. When they experienced unresponsive technology, this warranted their negative feedback and confirmed their rationale for not using it again. Digital natives are comfortable with technology and computers early and regard technology as an integral and necessary part of their lives. This was established during the feedback on affective experience with when the rating for anxiety factor was the lowest mean score for AR and 3D4Medical app modality. The expectation is high that AR would promote the efficiency of education and human anatomy training in academic environments. The results of this study did not support the idea that technology would be a seamless approach to engage and motivate active learning due to the many negative physical experience's that student discussed. However, the innovative approach to expose students to AR technology is a selling attribute to a career in healthcare. Hospitals and physicians are employing AR technology in real-life settings.

Surgeons are using AR as a pre-surgical preparation, and for interactive remote surgeries, which are both gaining ground in practice. The next generation of healthcare providers need to be introduced to how technology is utilized in the health care world. With the potential to use AR to enhance learning, educators need to dedicate the necessary time to learn the program, create meaningful lessons, measure learning outcomes, correlate supplement material, and deliver clear curriculum connections as implementation occurs.

## Summary

Educational leaders in allied health colleges know little about the learning outcomes when AR is used to train undergraduates in human anatomy. The leader's ability to make decisions that create deep learning for the next generation of health care providers is narrowed due to the lack of evidence decision-making process. Minimal studies have been published that focus strictly on the educational uses of AR technology at the undergraduate level and, more specifically, in health training programs in the literature review. Few allied health programs have implemented AR for several reasons, such as the cost of equipment, lack of evidence for improved academic outcomes, and AR is still early in its development stage. Even those published studies that have shared positive implementations results, continued investigation is warranted before educational leaders can have the confidence to invest in the costly approach of supporting learning with AR technology.

According to Bölek et al. (2021), AR impacts learning human anatomy and promotes a high level of knowledge. Identifying the direct impact AR has on the motivation and engagement of learning human anatomy can assist those in the discussion making process. Ultimately, this research study can help inform leadership that evidence-based decision-making can be at the forefront of the stakeholders when data supports the evidence. Leaders reduce the risk of costly mistakes. Training competent healthcare providers and closing the gap on qualified healthcare providers in the workforce will have enormous implications for patient care across America, especially as life expectancy goes up and people live longer.

Educators, with the assistance of the hardware manufacturers, if implemented with a strategic and systematic plan, AR can contribute information by offering rich content with computer-generated 3D imagery. Also, mistakes are often experienced during the training period, and competency is only gained by repetition during training. This education model allows the student to learn without determinantal consequences. AR allows for continuous repetition until the student understands the information needed to be deemed competent during assessments. The literature is clear that AR and VR are in high demand for teaching/learning in various disciplines, from architecture to language. As technology is enhanced, it is theorized that technologies will also increase.

Augmented reality technology has gained attention in many fields, especially in educating allied health students going into health care. The modality of dissections which were once the norm for learning human anatomy, traditional modalities such as human dissections may be replaced with AR technology. However, there are fundamental issues yet to be overcome for greater efficacy, such as the comfort level of the headsets, the integration of the software, and the learning curve for the student. As AR technology evolves and becomes more effective, accessible, and cost-friendly, more institutions may implement AR technology as a stand-alone training modality as an alternative to dissections for learning human anatomy. Augmented Reality has the potential to usher in this century's first paradigm shift, benefiting both students learning their trade and countless patients whose lives will be saved and improved through their care.

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# APPENDICES

## Appendix A: Informed Consent and Instrument

Learning Human Anatomy

### Informed Consent

**WHAT IS THE IMPACT OF LEARNING HUMAN ANATOMY WITH AUGMENTED REALITY COMPARED TO OTHER MODALITIES?**

**The study in which you are being asked to participate is designed to investigate the impact of learning human anatomy with the different modalities such as 2D models, 3D models, dissections, and compared to augmented reality technology. Annette K. Stelter is conducting this study under the supervision of Eugene Kim, Ph.D., Chair, Institutional Review Board Professor, Educational Leadership, Concordia University, Irvine (CUI). This study has been approved by the Institutional Review Board, CUI, in Irvine, CA.**
**Purpose: This research is a way of gaining new knowledge. This quantitative and qualitative study aims to evaluate different learning modalities' impact on a student learning human anatomy. There is a significant gap in evidence-based research evaluating and comparing how students can best learn the foundational anatomy curriculum, a void this study hopes to address.**
**Description: The online survey is designed to record the responses to the survey questions for data analysis. The survey results will be viewed by the primary investigator with no identifiable information related to the participants. Participation: Participation is entirely voluntary, and survey responses will be reported in aggregate form. Refusal to participate will involve no penalty or loss of benefits to which you are entitled at your academic institution. You may discontinue your participation at any time without penalty or loss of benefits.**
**Confidentiality or anonymity: Your responses to the survey will be anonymous. Your name will not be collected or appear anywhere on the survey, and complete privacy will be guaranteed. The data will be encrypted for this online survey as it travels from your computer to the survey servers, and IP address tracking will be disabled to ensure the responses are anonymous. A secured computer using password protection will be used to store the data. Duration: The survey can be filled out in approximately 10 minutes. By completing the survey, you consent to participate in the study.**
**Risks: There are no foreseeable risks to your participation in this research.**

**Benefits: There are no benefits to your participation in this research.**

**CONTACT: If any questions arise about the research or your rights as a participant in this study, you may contact Eugene Kim, Ph.D., Chair, Institutional Review Board Professor, Educational Leadership, CUI by email at eugene.kim@cui.edu or by phone: 949-333-9188.**
**Results: The results of this study will be available on ProQuest after completion of the dissertation document. CONFIRMATION STATEMENT: I have read the information above and understand that I have agreed to participate in your study by completing the**

**survey.**

**If you want to be entered into a raffle to win one of several $50.00 Amazon gift cards or WCU merchandise, leave your name and email at the end of the survey!**

* 1. I have read the informed consent and agree to the terms.

- I agree and give my consent
- I do not agree and do not give my consent

## Learning Human Anatomy

### Human Anatomy 260

**Please recall your experience taking Human Anatomy 260 in GE at West Coast University.**

* 2. I was enrolled in Human Anatomy 260 at WCU

- Yes
- No

## Learning Human Anatomy

### Welcome to the Survey

* 3. Gender

Female

Male

Other (please specify)

* 4. Age (years)

Under 18

18-24

25-34

35-44

45-54

55+

* 5. Graduation Year (Expected)

2020

2021

2022

2023

2024

Other (please specify)

* 6. Student Status

Full-time student (12 units or more)

Part-time student (less than 12 units)

Other (please specify)

* 7. Highest Level of Education

High School Diploma or GED

Associate Degree

Bachelor's degree

Master's degree

Doctoral degree

* 8. Ethnicity

- Asian
- Black or African American
- Hispanic/Latino
- White
- Other (please specify)

9. What is your major?

- Nursing
- Dental Hygiene

Other (please specify)

10. Recall the learning aids you used in Human Anatomy 260 General Education (GE) course: Models/Tools/Technologies, please check all that apply.

- 2D Models (textbook images)AnatomyX software with the
- 3D Models (models of skull, skeleton, brain, heart, etc.)
- HoloLens (technology headset for augmented reality/virtual dissection)
- Animal Tissue Dissections (frog, cat, pig, etc.)
- 3D4Medical App (a.k.a., Complete Anatomy - video of core atlas features)

* 11. Letter grade I received in my Anatomy Course 260 in GE

- A/A+
- A-
- B+
- B
- B-
- C+
- C
- C-
- D
- F
- Withdrew/Dropped
- Other (please specify)

* 12. Did you use 2D/3D Models in your Anatomy course (textbook images, models of skull, skeleton, brain, heart, etc.)?

- ◯ Yes
- ◯ No

## Learning Human Anatomy

### 2D/3D Models

* 13. **EDUCATIONAL EXPERIENCE WITH 2D/3D MODELS:** Please indicate your level of agreement with these educational outcomes regarding the 2D/3D models (1=completely disagree; 5=completely agree)

| | Completely Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Completely Agree **(5)** |
|---|---|---|---|---|---|
| Clear Instructions | ◯ | ◯ | ◯ | ◯ | ◯ |
| Ease of Use | ◯ | ◯ | ◯ | ◯ | ◯ |
| Met Learning Outcomes | ◯ | ◯ | ◯ | ◯ | ◯ |
| Increased Knowledge | ◯ | ◯ | ◯ | ◯ | ◯ |
| Gained Marketable Skills | ◯ | ◯ | ◯ | ◯ | ◯ |
| Desire to Use Again | ◯ | ◯ | ◯ | ◯ | ◯ |

* 14. **AFFECTIVE EXPERIENCE WITH 2D/3D MODELS:** Please indicate your level of agreement with these psychological states while using the 2D/3D models (1=completely disagree; 5=completely agree)

Completely Completely Agree

| | Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | **(5)** |
|---|---|---|---|---|---|
| Anxiety | | | | | |
| Lack of Privacy | | | | | |
| Out of Control | | | | | |
| Fear of Physical Harm | | | | | |
| Unresponsive Technology | | | | | |
| Unnatural | | | | | |

* 15. **PHYSICAL EXPERIENCE WITH 2D/3D MODELS:** Please indicate your level of agreement with these physiological conditions while using the 2D/3D models (1=completely disagree; 5=completely agree)

| | Completely Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Completely Agree **(5)** |
|---|---|---|---|---|---|
| Nausea/Motion Sickness(N) | | | | | |
| Dizziness/Vertigo(D) | | | | | |
| Eye Strain(O) | | | | | |
| Headache(O) | | | | | |
| Neck Pain(P) | | | | | |
| Muscle Cramp(P) | | | | | |

16. Please describe your overall experience with 2D/3D Models in your Anatomy course(s).

## Learning Human Anatomy

### Decision Tree - Dissection

* 17. Did you use animal DISSECTIONS in your Anatomy course(s)?

- Yes
- No

## Learning Human Anatomy

### Dissections

* 18. **EDUCATIONAL EXPERIENCE WITH DISSECTIONS:** Please indicate your level of agreement with these educational outcomes during Dissections (1=completely disagree; 5=completely agree)

| | Completely Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Completely Agree **(5)** |
|---|---|---|---|---|---|
| Clear Instructions | | | | | |
| Ease of Use | | | | | |
| Met Learning Outcomes | | | | | |
| Increased Knowledge | | | | | |
| Gained Marketable Skills | | | | | |
| Desire to Use Again | | | | | |

19. **AFFECTIVE EXPERIENCE WITH DISSECTIONS**: Please indicate your level of agreement with these psychological states during Dissections (1=completely disagree; 5=completely agree)

Completely Completely

| | Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Agree **(5)** |
|---|---|---|---|---|---|
| Anxiety | | | | | |
| Lack of Privacy | | | | | |
| Out of Control | | | | | |
| Fear of Physical Harm | | | | | |
| Unresponsive Technology | | | | | |
| Unnatural | | | | | |

* 20. **PHYSICAL EXPERIENCE WITH DISSECTIONS:** Please indicate your level of agreement with these physiological conditions during animal dissections (1=completely disagree; 5=completely agree

| | Completely Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Completely Agree **(5)** |
|---|---|---|---|---|---|
| Nausea/Motion Sickness(N) | | | | | |
| Dizziness/Vertigo(D) | | | | | |
| Eye Strain(O) | | | | | |
| Headache(O) | | | | | |
| Neck Pain(P) | | | | | |
| Muscle Cramp(P) | | | | | |

21. Please describe your overall experience with Dissections in your Anatomy course(s).

* 22. I am a student at West Coast University.

◯ Yes

◯ No

## Learning Human Anatomy

### Decision Tree - 3D4Medical App (also known as Complete Anatomy)

* 23. Did you use 3D4Medical App in your Anatomy course(s)?

◯ Yes

◯ No

## Learning Human Anatomy

### 3D4Medical App

* 24. **EDUCATIONAL EXPERIENCE WITH 3D4Medical APP:** Please indicate your level of agreement with these educational outcomes regarding the 3D4Medical App (1=completely disagree; 5=completely agree)

| | Completely Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Completely Agree **(5)** |
|---|---|---|---|---|---|
| Clear Instructions | ◯ | ◯ | ◯ | ◯ | ◯ |
| Ease of Use | ◯ | ◯ | ◯ | ◯ | ◯ |
| Met Learning Outcomes | ◯ | ◯ | ◯ | ◯ | ◯ |
| Increased Knowledge | ◯ | ◯ | ◯ | ◯ | ◯ |
| Gained Marketable Skills | ◯ | ◯ | ◯ | ◯ | ◯ |
| Desire to Use Again | ◯ | ◯ | ◯ | ◯ | ◯ |

25. **AFFECTIVE EXPERIENCE WITH 3D4Medical APP:** Please indicate your level of agreement with these psychological states while using the 3D4Medical App (1=completely disagree; 5=completely agree)

| | Completely Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Completely Agree **(5)** |
|---|---|---|---|---|---|
| Anxiety | | | | | |
| Lack of Privacy | | | | | |
| Out of Control | | | | | |
| Fear of Physical Harm | | | | | |
| Unresponsive Technology | | | | | |
| Unnatural | | | | | |

## Decision Tree - Augmented Reality (AR)

* 26. **PHYSICAL EXPERIENCE WITH 3D4Medical APP**: Please indicate your level of agreement with these physiological conditions while using 3D4Medical App (1=completely disagree; 5=completely agree)

| | Completely Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Completely Agree **(5)** |
|---|---|---|---|---|---|
| Nausea/Motion Sickness(N) | | | | | |
| Dizziness/Vertigo(D) | | | | | |
| Eye Strain(O) | | | | | |
| Headache(O) | | | | | |
| Neck Pain(P) | | | | | |
| Muscle Cramp(P) | | | | | |

27. Please describe your overall experience with 3D4Medical Technology in your Anatomy course(s).

* 28. Did you use Augmented Reality (AR) TECHNOLOGY with the HoloLens and AnatomyX in your Anatomy course(s)?

- Yes
- No

## Learning Human Anatomy

### Augmented Reality Technology (AR)

* 29. **EDUCATIONAL EXPERIENCE WITH AR TECHNOLOGY:** Please indicate your level of agreement with these educational outcomes regarding the AR Tech (1=completely disagree; 5=completely agree)

| | Completely Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Completely Agree **(5)** |
|---|---|---|---|---|---|
| Clear Instructions | ◯ | ◯ | ◯ | ◯ | ◯ |
| Ease of Use | ◯ | ◯ | ◯ | ◯ | ◯ |
| Met Learning Outcomes | ◯ | ◯ | ◯ | ◯ | ◯ |
| Increased Knowledge | ◯ | ◯ | ◯ | ◯ | ◯ |
| Gained Marketable Skills | ◯ | ◯ | ◯ | ◯ | ◯ |
| Desire to Use Again | ◯ | ◯ | ◯ | ◯ | ◯ |

* 30. **AFFECTIVE EXPERIENCE WITH AR TECHNOLOGY:** Please indicate your level of agreement with these psychological states while using the AR Technology (1=completely disagree; 5=completely agree)

| | Completely Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | Completely Agree **(4)** |
|---|---|---|---|---|---|
| Anxiety | ◯ | ◯ | ◯ | ◯ | ◯ |
| Lack of Privacy | ◯ | ◯ | ◯ | ◯ | ◯ |
| Out of Control | ◯ | ◯ | ◯ | ◯ | ◯ |
| Fear of Physical Harm | ◯ | ◯ | ◯ | ◯ | ◯ |
| Unresponsive Technology | ◯ | ◯ | ◯ | ◯ | ◯ |
| Unnatural | ◯ | ◯ | ◯ | ◯ | ◯ |

31. **PHYSICAL EXPERIENCE WITH AR TECHNOLOGY:** Please indicate your level of agreement with these physiological conditions while using AR Technology (1=completely disagree; 5=completely agree)

Completely Completely Agree

| | Disagree **(1)** | **(2)** | Neutral **(3)** | **(4)** | **(5)** |
|---|---|---|---|---|---|
| Nausea/Motion Sickness(N) | ○ | ○ | ○ | ○ | ○ |
| Dizziness/Vertigo(D) | ○ | ○ | ○ | ○ | ○ |
| Eye Strain(O) | ○ | ○ | ○ | ○ | ○ |
| Headache(O) | ○ | ○ | ○ | ○ | ○ |
| Neck Pain(P) | ○ | ○ | ○ | ○ | ○ |
| Muscle Cramp(P) | ○ | ○ | ○ | ○ | ○ |

32. Please describe your overall experience with AR Technology in your Anatomy course(s).

Learning Human Anatomy

## End of Survey

**Thank you for your participation in this survey. If you would like to be in the drawing for a chance to receive a $50.00 Amazon gift card or WCU Merch please state your name and email address below.** 33. Name

34. Email Address

Appendix B: IRB Decision Form

# INSTITUTIONAL REVIEW BOARD (IRB) DECISION FORM

**Review Date** September 22, 2021

**Reviewer ID#** **Reviewer**

**Category** ☒ Expedited Review 45 CFR 46.110

☐ Full Board Review 45 CFR 46

| | |
|---|---|
| IRB Application # | **Ticket #6032** |
| Title of Project | **Learning Anatomy through Augmented Reality** |
| Principal Investigator Name (PI) | **Annette Stelter** |
| PI Email (use CUI email, if applicable) | **Annette.stelter@eagles.cui.edu** |

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**DECISION**

☒ **Approved**

**Effective duration of the IRB Approval: 9/22/2021 to 9/21/2022**

**For Expedited and Full Board Approved, Please Note**:

*a.* *The IRB's approval is only for the project protocol named above. Any changes are subject to review and approval by the IRB.*
*b.* *Any adverse events must be reported to the IRB.*
*c.* *An annual report or report upon completion is required for each project. If the project is to continue beyond the twelve month period, a request for continuation of approval should be made in writing. Any deviations from the approved protocol should be noted.*

☐ **Needs revision and resubmission**

☐ **Not approved**

## COMMENTS

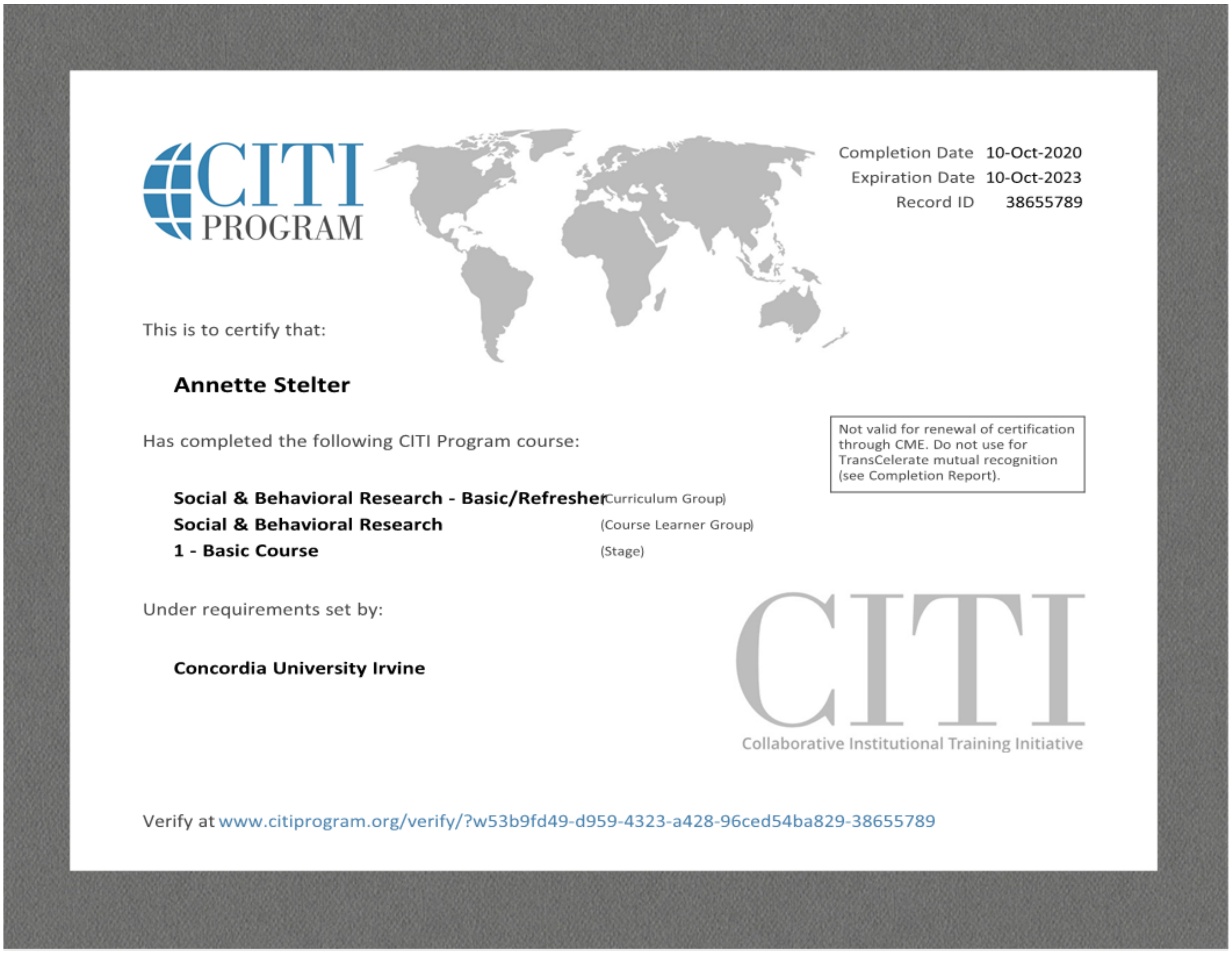
### Required Changes:

*All requested changes have been made by the principal investigator.*

### Suggested Changes:

*Not Applicable*

# Appendix C: Citi Completion Certificate



CITI PROGRAM

Completion Date 10-Oct-2020
Expiration Date 10-Oct-2023
Record ID 38655789

This is to certify that:

**Annette Stelter**

Has completed the following CITI Program course:

Not valid for renewal of certification through CME. Do not use for TransCelerate mutual recognition (see Completion Report).

**Social & Behavioral Research - Basic/Refresher** (Curriculum Group)
**Social & Behavioral Research** (Course Learner Group)
**1 - Basic Course** (Stage)

Under requirements set by:

**Concordia University Irvine**

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w53b9fd49-d959-4323-a428-96ced54ba829-38655789

# Appendix D: Time Line

## Annette Stelter

## Administrative Checklist A: Dissertation Proposal Timeline (Phase Three)

October. 28, 2020 a. Write & Submit to Chair - Dissertation Chapter 1: Introduction (10 pages) 2 months

December 15, 2020 b. Write & Submit to Chair - Dissertation Chapter 2: Lit Review (40 - 50 pages) 4 months

January 31, 2021 c. Write & Submit to Chair - Dissertation Chapter 3: Methodology (10-15 pages) 2 months

• Validation: Pilot Survey/Interview questions (5-10 subjects)

• Discuss results with chair/methodologist

• Revise questions as needed

February 7, 2021 d. Upon receipt of Form C: Dissertation Committee Assignment from the Doctoral Program Office 1 week

- Inform committee member of membership on the dissertation committee
- Secure respective signatures on the form to verify each member's willingness to serve
- Upload Form C with signatures to the designated assignment slot on Blackboard:DTMS
- Email the preliminary dissertation proposal in Word to committee members for feedback. [Allow two weeks for members to read and comment.]

February 14 2021 e. Continue to write and revise chapters one, two, and three. 2 weeks

• Consider feedback from committee members and revise the dissertation proposal as warranted.

• Submit drafts to Grammarly and make corrections as warranted.

February 28,2021 f. Submit draft to chair for feedback. Gain approval from the chair on final draft of proposal. 1 week

March 7, 2021 g. No later than two weeks before the proposal defense, upon approval of the chair 2 weeks

- Upload the dissertation to Blackboard DTMS for the Doctoral Program Office to check for plagiarism, using SafeAssign
- Email the dissertation proposal in a Word document to each dissertation committee member
- Notify committee members of the date and time of the Dissertation Proposal Conference Call

March 21, 2021 h. Revise dissertation proposal based on committee member feedback 1 month

April 11, 2021 i. Application to the Institutional Review Board (IRB) 2 weeks

- Gain approval from your chair
- Submit required documents to the IRB and other entities as warranted to gain their approval.
- Revise documents as required by IRB and resubmit until approval is secured.

May 7, 2021 j. Defend the comprehensive dissertation proposal at the Dissertation Proposal Conference Call 1 month

- Make final edits to the Dissertation Proposal
- Gain approval of the dissertation proposal by the committee with modifications as warranted

June 4, 2021 k. Upload to Blackboard DTMS Form E: Defense of the Dissertation Proposal 2 weeks

- Request pdf file of Dissertation Rubric from your chair for you to upload to Blackboard DTMS under Dissertation Rubric (Chapters 1-3)

## Administrative Checklist B: Dissertation Research (Phase Four)

September 30, 2021 l. Data Collection – surveys/interviews

- Complete qualitative and quantitative phases of the research
- For quantitative, calculate your ideal sample size based on a CI of 95% and MoE of 5%

November 1-15, 2021 m. Data Transcription – type all data into excel or word 2 weeks

November 16-31, 2021 n. Data Coding – code any qualitative data 2 weeks

December. 1-31, 2021 o. Data Analysis – statistical and QDA analysis on the data 1 month

January 1-30, 2022 p. Write Chapter 4 – Results (40), including graphs and tables

- Submit to committee and get feedback
- Rewrite and revise as needed

February. 1-25, 2022 q. Write Chapter 5 – Conclusions (20), including summary, answers, limitations and prescriptions

- Submit to committee and get feedback
- Rewrite and revise as needed

February 26, 2022 r. Review and Revise

- Submit the dissertation sections to Grammarly and make corrections as warranted.
- Using SafeAssign, check for plagiarism
- Send to outside copyeditor to clean up copy

February. 1-31, 2022 s. Chair's Approval of the Dissertation

- Upon approval of the chair upload the dissertation to Blackboard DTMS

February 1-31, 2022 t. Upon approval by the Doctoral Program Office, prepare for the oral defense of the dissertation.

• Complete and submit on Blackboard DTMS Form F: Application for Dissertation Oral Defense

• Gain approval of the date and time of the defense by the Doctoral Program Office

• Notify committee members of the date and time of the Dissertation Conference Call

• No later than 4 weeks prior to the defense, distribute copies of the dissertation for each committee member to review and provide feedback in a timely manner to the chair to share with the candidate, and for the candidate to make any further revisions if warranted before the oral defense

March 1-16, 2022 u. Oral Defense of the Dissertation

• Orally present and defend the dissertation to the committee and public observers on the Dissertation Conference Call

• Gain approval of the dissertation and oral defense.

• Secure signatures of committee members on Form G: Defense of the Dissertation on the DTMS, with required signature of each committee member on one page.

• Request file of Dissertation Rubric from your chair for you to upload to Blackboard DTMS under Dissertation Rubric

• Secure signatures of committee members on ACCEPTANCE page of the dissertation. **All signatures must be original and in blue ink.**

• Submit the Application for Graduation approved by the academic advisor along with application fee.

## Administrative Checklist C: Degree Completion and Commencement

Mar. 18-31, 2022 v. Committee-driven Revisions to Dissertation 1 week

• Make necessary revisions to the dissertation based on committee directive(s) if warranted, and submit

to the chair for review and approval. (Upon approval, chair notifies academic advisor by email that the

candidate is ready to complete an Application for Graduation)

April 1, 2022 w. External Review of Dissertation Draft 2 weeks

• First Review: if the dissertation passes the first external review, then proceed to x.

• Second Review: if the dissertation does not pass the first external review, then students will have the

opportunity to edit and resubmit once. If it does not pass the second review, then the external reviewer

will copy edit the entire dissertation at cost to the student.

April 15, 2022 x. Follow Form H: Pre-Bookbinding Process directions 1 day

• Submit Form H along with Word document of dissertation to the Doctoral Program Office on Blackboard

DTMS for final review by the Office.

April 18, 2022 y. Upon receiving the final pdf file of the dissertation by the Doctoral Program Office, the candidate

follows Copyright and Hardcover Book directions. 2 weeks

• Submit copy of copyright document and one bound copy of the dissertation to:

Doctor of Education Office, Beta 109

School of Education

Concordia University, Irvine

1530 Concordia West

Irvine, CA  92612

• Settle all financial obligations to the university.

May 7. 2022    z. Commencement Participation

• Follow guidelines set forth by the Office of the Registrar and Doctor of Education Program to participate in Commencement.

• Invite guests to your commencement ceremony.