

Augmented reality on human anatomy: Venezuelan medical students' perceptions

Realidad aumentada en anatomía humana: percepciones de los estudiantes de medicina venezolanos

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SUMMARY

Introduction: Human anatomy has historically been at the core of all medical specialties regardless of the learning nation. In medical curricula, Human Anatomy is considered a keystone course. The precondition of a deep understanding of human anatomy is essential for safe clinical practice. The adoption of digital alternatives to cadaver-based teaching, using Augmented Reality technologies, is presented as an alternative for teaching human anatomy. **Objective:** To know the degree of acceptance and motivation that augmented reality arouses in first-year medical students, a survey was carried out during January and February 2025. Sixty students enrolled in the subject "Human Anatomy" at the JM Vargas Medical School of the Faculty of Medicine at the Universidad Central de Venezuela. **Method:** The ARCS Keller was used for motivation analysis and acceptance degree. The Technology Acceptance Model was applied to evaluate students' learning objectives. **Results:** The survey revealed that medical students view

Augmented Reality positively for its benefits, including motivation, acceptance, and knowledge acquisition. **Conclusions:** Alternative methods for learning spatial and theoretical concepts in anatomy have been the subject of considerable research over the past decade. Among emergent technologies, Augmented Reality has generated considerable interest, and its potential to supplement current teaching in anatomical education is particularly exciting to Generation Z students. Curricula developers alike, Augmented Reality was positively rated by medical students. They recognize its relevance, usefulness, and its role in improving the learning of human anatomy.

Keywords: Emergent technologies, digital alternatives education, human anatomy, teaching resources.

RESUMEN

Introducción: La anatomía humana ha sido históricamente el núcleo de todas las especialidades médicas, independientemente del país en el que se estudie. En los planes de estudio de medicina, la anatomía humana se considera una de las asignaturas fundamentales. Es imprescindible tener un profundo conocimiento de la anatomía humana para ejercer la medicina de forma segura. La adopción de tecnologías de realidad aumentada en la enseñanza basada en cadáveres constituye una alternativa para la enseñanza de la anatomía humana. **Objetivo:** Para conocer el grado de aceptación y motivación que la realidad aumentada suscita en los estudiantes de primer año de Medicina, se realizó una encuesta durante los meses de enero y febrero de 2025 a 60 estudiantes matriculados en la asignatura «Anatomía

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*Humana» de la Escuela de Medicina JM Vargas de la Facultad de Medicina de la Universidad Central de Venezuela. **Método:** Se utilizó el modelo ARCS de Keller para analizar la motivación y el grado de aceptación. Se aplicó el Modelo de Aceptación de la Tecnología para evaluar los objetos de aprendizaje de los estudiantes. **Resultados:** Los resultados de la encuesta revelaron la valoración positiva de los estudiantes de medicina hacia la Realidad Aumentada por sus beneficios, como la motivación, la aceptación y la adquisición de conocimientos, entre otros. **Conclusiones:** A lo largo de la última década se han investigado considerablemente métodos alternativos para el aprendizaje de conceptos espaciales y teóricos en anatomía. Entre las tecnologías emergentes, el uso de la Realidad Aumentada ha generado un interés considerable, y su potencial para complementar la enseñanza actual en la educación anatómica resulta especialmente interesante tanto para los estudiantes de la Generación Z como para los desarrolladores de planes de estudio. La Realidad Aumentada fue valorada positivamente por los estudiantes de medicina, quienes reconocen su relevancia y utilidad, así como su capacidad para mejorar el aprendizaje de la anatomía humana.*

Palabras clave: *Tecnologías emergentes, alternativas digitales en la educación, anatomía humana, recursos didácticos.*

INTRODUCTION

Today's new medical students are part of Generation Z. They were born in the early 2000s, a period that coincided with the rapid global proliferation of mobile devices, digital applications, and social media. Students from Generation Z favor an educational environment that provides regular, supportive feedback to help them develop skills and confidence with electronic resources and innovative technologies (1,2). Given these conditions, it is unsurprising that a multifaceted approach to learning about human anatomy yields optimal outcomes (3). Historically, human anatomy has been fundamental to all medical specialties, irrespective of the educational system or country. In medical curricula, Human Anatomy is considered an essential course. A profound comprehension of human anatomy is a prerequisite for safe clinical practice (3,4). By studying human anatomy, medical students gain an initial understanding

of the human body's structure, which serves as the foundation for recognizing pathological and clinical issues and enhancing proficiency in physical examinations, which cannot be performed accurately without a comprehensive grasp of gross and topographical human anatomy. Physicians must possess sufficient knowledge of human anatomy to effectively examine, diagnose, and treat patients (4,5). However, over the past two decades, the time allocated to anatomy instruction has decreased, along with cadaver-based teaching and available laboratory hours. This decline in cadaver utilization has created a need for innovative, effective tools to teach anatomical relationships. In the 21st century, medical education is evolving, and human anatomy is no longer viewed solely as a dissection-based, research-oriented discipline. The practice of anatomical dissection is now complemented by digital resources, including augmented reality, virtual reality simulations, artificial intelligence applications, and others. Augmented Reality (AR) stands out among these emerging technologies and educational resources. In recent years, there has been an increasing interest in the application of augmented reality in anatomy education. Augmented Reality (AR) is the instantaneous integration of digital and physical information via various technologies. It employs a range of technological tools that enhance the physical world with virtual information, thereby introducing a synthetic virtual component into the tangible world. AR facilitates the integration of virtual objects into real environments, enabling real-time interaction (6). This technology offers highly engaging experiences, merging a significant degree of realism with virtual realms and enriching the real world with computer-generated virtual entities. It has the potential to foster genuine learner engagement and interactivity in real-time (7-9). In the context of augmented reality, virtual entities (such as anatomical models) are overlaid onto the user's perception of the real environment. The application of AR in educational settings is a significant area of scholarly inquiry. Nevertheless, the adoption of this technology remains constrained. This limitation may stem from apprehensions about the costs of acquisition and software development, as well as doubts about the technology's usability

or effectiveness (10). The aim was to evaluate first-year medical students' viewpoints on the impact of an Augmented Reality app on anatomy learning motivation, based on the Motivational Design for Learning and Performance: The ARCS Model (11,12) and the Technology Acceptance Model (TAM) (13), using a survey.

MATERIALS AND METHODS

Study Design

A Survey in GOOGLE FORMS was conducted at the Human Anatomy Department of the JM Vargas Medical School, Faculty of Medicine, Universidad Central de Venezuela, in Caracas, Venezuela, among first-year medical students from 8th January to 16th January 2025.

Materials

The materials for this research consisted mainly of human anatomy images and single-display augmented reality experiences that explore the circulatory, respiratory, urinary, and digestive systems through immersive video. In this research, AR implementation in anatomical education involves the use of a mobile display device. Its camera scans human anatomical images from a T-Shirt. Via an application, the images are detected and recognized as a marker. When students look at the T-shirt on the display device, they can see superimposed multimedia human anatomical images that allow them to interact with them. The demonstration lasted 30 minutes on a Magic t-shirt EVO via Body Planet's apps on tablets and smartphones (14). The app works with an augmented reality T-shirt to provide a detailed, realistic simulation of anatomy by pointing tablets and smartphones at it (Figure 1).

Sampling Method

All first-year medical students were invited to participate in an anonymous and voluntary survey in GOOGLE FORMS about their perception of human anatomy learning through Augmented Reality. The total student population was 110.



Figure 1. Augmented in Reality T-shirt (photo by Rafael Romero Reverón).

Inclusion Criteria

First-year medical students from the Human Anatomy Department of the JM Vargas Medical School at the Faculty of Medicine of Universidad Central de Venezuela in Caracas, Venezuela.

Exclusion Criteria

Those students who did not consent to participate were excluded from the survey.

Ethical Approval

Ethical approval was obtained from the Ethics Review Committee of the JM Vargas Medical School, Faculty of Medicine, Universidad Central de Venezuela.

Data Collection

The questionnaire consisted of four sections. The first part obtained demographic information from the participants; the second part focused on their knowledge about augmented reality; the third part used the ARCS model as a method for improving the motivational aspect of digital educational materials, and the last part examined the TAM model (13), which in this case evaluates perceived usefulness and ease of use of augmented reality. The four dimensions of the ARCS Keller model (11,12), i.e. Attention (A), Relevance (R), Confidence (C) and Satisfaction (S) were measured through questions that used a 5-point Likert-scale: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree. The TAM (Technology Acceptance Model) was used (15). It measures two dimensions that predict augmented reality use: perceived usefulness and perceived ease of use. The students were informed about the survey during their anatomy lectures from 8th January to 16th January 2025. Their emails were collected.

Consent

The survey was administered online after obtaining informed consent via email. Students who provided consent to participate in the study were asked to complete the questionnaire. Students were also required to pledge that they would not contact others about the answers to this survey and would not refer to any external sources while completing the study. The approval to use the app and *Magic t-shirt EVO* was obtained from *Magic t-shirt EVO* through the *Body Planet* company.

RESULTS

A total of 60 of 110 students (66%) participated in the study. The gender breakdown included 43 females (71.7%) and 17 males (28.3%). Among the participants, 75% were aged 18-20 years (n=45). Regarding prior experience with augmented reality (AR), 78.3% of students (n=47) reported this was their first encounter with AR. Furthermore, 57% of participants recommended using augmented reality for

learning anatomy (95%). In the context of the ARCS Keller framework, concerning Attention, 53.8% of medical students strongly agreed that AR is beneficial for understanding anatomy. Additionally, 43 students (73.3%) strongly affirmed that augmented reality is pertinent to anatomy education (Figure 2).

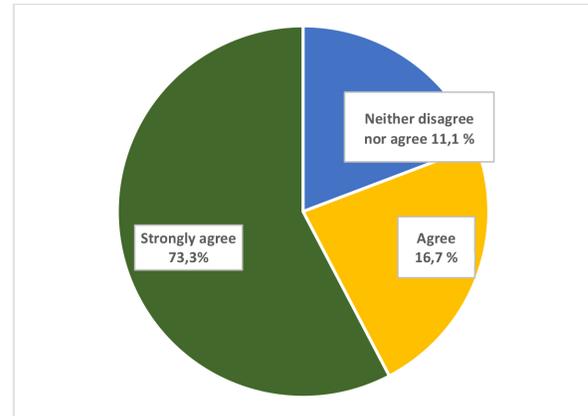


Figure 2. Augmented reality relevance in anatomy learning.

In terms of Confidence, 27 students (45%) believed that the well-structured material instilled confidence in their ability to learn the content. After the introduction, 16 students (26.7%) felt confident they understood what they needed to learn during the AR lesson. Regarding Satisfaction, 42 students (70%) reported enjoying the AR lesson so much that they wished to explore the topic further. In the Technology Acceptance Model (TAM) section, 55% of students (n=33) believed that utilizing AR during lectures would enhance their comprehension of specific concepts. For 34 students (56.6%), the application of AR in human anatomy was seen as a means to improve their learning and performance in this area. The incorporation of an AR tool made learning more engaging for 29 students (48.3%). Regarding perceived ease of use, 29 students (48.33%) considered the implementation of AR in the classroom a favorable idea. Additionally, 34 students (53.96%) expressed a desire to use AR in their anatomy classes if given the opportunity.

Furthermore, 32 students (53.33 %) agreed to use AR for studying other medical subjects, while 36.66 % (n=22) strongly agreed (Figure 3).

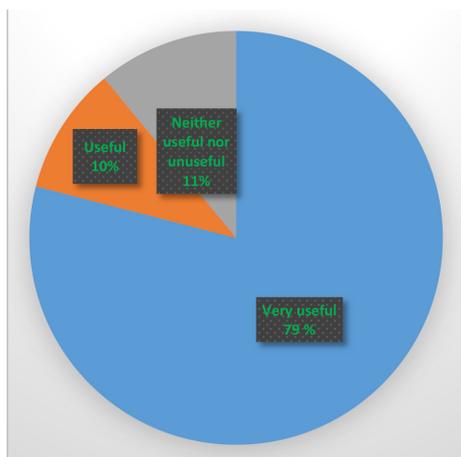


Figure 3. Perceived usefulness of augmented reality for learning anatomy.

DISCUSSION

The increasing adoption of numerous emergent teaching technologies has been notable in recent years. Among these educational resources is Augmented Reality (AR), which is anticipated to achieve significant integration into all educational institutions, including universities, in the forthcoming years. AR is defined as the seamless integration of non-existent elements into the existing environment, providing users with an enhanced or augmented perception of their surroundings. Consequently, it is a technology that merges real-world components with additional virtual elements to create a novel communicative scenography (6). However, research on the applications of AR in education is in its nascent phase, with limited studies examining its effects and implications in the educational domain. The impact of AR implementation on anatomical education has yet to be thoroughly examined. To our knowledge, AR systems have not been extensively adopted in university classroom environments. Therefore,

this represents a crucial area for exploration within technology-enhanced education (9,16). Among the students who participated in this survey, 78.3 % reported this was their first encounter with AR, yet 95 % recommended it as a learning tool for anatomy. The ARCS model serves as a framework for crafting motivational learning environments. It addresses the issue through four dimensions of learner motivation: attention, relevance, confidence, and satisfaction. The components associated with Attention include perceptual arousal, inquiry arousal, and variability. The components related to relevance encompass goal orientation and motive matching. For Confidence, the components consist of learning requirements, success opportunities, and personal responsibility, while Satisfaction includes intrinsic reinforcement, extrinsic rewards, and equity. According to the ARCS motivational model, students' attention can be enhanced and sustained to foster their development. According to the Technology Acceptance Model (TAM), perceived usefulness and perceived ease of use are the key factors influencing our intention to use a technology, which, in turn, predicts our actual use behavior. The main aim of the Technology Acceptance Model (13) is to elucidate the mechanisms that underlie technology acceptance, thereby predicting behavior and providing a theoretical framework for the effective implementation of technology. In the TAM segment of our study, most of the students surveyed acknowledged the usefulness of Augmented Reality (AR) for learning anatomy. Consequently, due to their perception of ease of use, 53.96 % of medical students (n=34) expressed a desire to incorporate AR into their anatomy classes if given the chance. Despite the potential of AR, its application in anatomical education has not been widespread (16). It is posited that integrating AR as a supplementary tool alongside traditional learning methods in anatomical education could render the learning experience more student-centered, thereby enabling students to build on previously acquired knowledge (10,17).

This research encountered several limitations. The survey was conducted with a limited number of Generation Z medical students. Additionally, the study was confined to a single medical school, which may limit the generalizability

of the findings to the broader population of medical students in the country. Regarding the application of AR in anatomy education, AR can provide a highly realistic learning experience that supports complex medical learning scenarios (7). A significant advantage of AR over physical models and cross-sections in anatomy education is its ability to allow thorough examination of anatomical structures by virtually disassembling and reassembling anatomical components. However, a potential drawback of AR is the lack of tactile feedback.

CONCLUSIONS

While cadavers are primarily utilized for instructing medical students in anatomy, there exist significant financial, ethical, and supervisory limitations regarding their application. Consequently, various alternative approaches to understanding the spatial and theoretical aspects of anatomy have been extensively investigated over the last decade. Among emerging technologies, augmented reality (AR) has attracted substantial interest, and its potential to enhance existing anatomical education is appealing to both Generation Z students and curriculum developers (10,18). One of the key advantages of AR as a tool for anatomical education is that most individuals already have the devices needed to operate it, making it a cost-effective, easily accessible option that does not require specialized equipment. Although it has been established that students from Generation Z find learning through AR highly enjoyable, it remains uncertain whether these tools offer a more effective means of acquiring knowledge (10,18,19). The existing literature suggests a lack of comprehensive research on the effects of AR in educational settings. There is an opportunity to investigate how augmented reality can enhance the motivation to learn among Generation Z students and improve academic performance (19-22). Despite the relatively limited research on the application of AR in anatomical education, encouraging findings have emerged regarding its teaching capabilities (23,24). Such results may motivate anatomy educators to incorporate this technology into their instructional strategies. Further

randomized controlled studies are essential to determine whether AR can effectively replace or augment traditional anatomy teaching methods.

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Notes on Contributors

RRR was involved in the study by conceptualizing the idea, reviewing the literature, formulating the methodological framework, data acquisition, formal analysis, designing and writing the original draft, and graphics design.

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