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Perception of Learning in Human Anatomy Students Regarding the Use of Multitouch and Three-Dimensional Tools

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ABSTRACT: With the invention of tools that incorporate technology as a didactic, educational, and promising innovation to enhance knowledge of human anatomy, current teaching and learning methods are being significantly impacted.The aim of this work was to evaluate the perception of second-semester medical students regarding the implementation of multitouch and three-dimensional technological tools for learning human anatomy. A quantitative, descriptive, cross-sectional study was conducted with a non-probabilistic, non-interventional purposive sample of 117 medical students who voluntarily signed informed consent. An instrument with 10 items was designed, evaluated through perception scales, one for the Sectra© multitouch table and another for the Cyber-Anatomy Med™ software. Data were collected and analyzed using SPSS version 24. A univariate analysis and some variable associations were performed. Demographic characteristics of the study population were identified, with a mean age of 19.56 ± 2.3 years; 41.2 % were male and 54.8 % female. Students showed varied perceptions regarding detailed and realistic learning of human anatomy through the technologies used. Overall, perceptions were positive, particularly regarding interactivity, which supported the development of certain skills. Didactics supported by technological tools show considerable importance in the learning of human anatomy, where perception and sensory activation facilitate experiences and emotions that serve as support for the advancement of specific competencies in medical education.

KEY WORDS: perception, student, anatomy, technology, learning.

INTRODUCTION

Throughout the history of medicine, key milestones have marked the study of the human body, among them, the birth of anatomy. Although its origins date back to prehistoric times, the Bronze Age, and Antiquity, it was during the Middle Ages, shaped by the context of Claudius Galen and his school, and then the Modern Era, with Andreas Vesalius, the father of modern anatomy, that major shifts occurred. The Contemporary Era, influenced by the incorporation of the microscope into anatomical studies, brought further advancement. In 1543, Vesalius published De humani corporis fabrica libri septem (On the Fabric of the Human Body in Seven Books), a groundbreaking work that laid the foundation of modern anatomy through direct observation and cadaveric and surgical dissection. This contributed profoundly to the style and content of anatomical description. A major shift in anatomical knowledge began, with various anatomists progressively building the anatomical framework and even correcting their predecessors. As Zambrano (2011) notes, “Vesalius corrected more than two hundred errors made by Galen, thus initiating modern scientific medicine” (p.38). Laín Entralgo (1946) adds, “In turn, Valverde and Fallopius corrected Vesalius. Thus, the history of anatomy can be seen as an ascending path, both additive and corrective, towards a complete and perfectible understanding of the human body” (p.419). Le Breton (1994) argues that perhaps “the entire history of science and technology since the 17th century is essentially the history of corrections made to the body's perceived insufficiencies (as seen by technicians and scientists)” (p.202).

By the 19th century, descriptive approaches expanded significantly, with anatomists such as Jean Léon Testut contributing extensively to the knowledge of macroscopic human structure. His Treatise of Human Anatomy, awarded by the Paris Academy of Medicine in 1902, remains one of the most widely used anatomy textbooks by medical students worldwide over the past 100 years (Zambrano, 2011). He also recalls that during this period, "Wilhelm Conrad Roentgen, in 1896, discovered X-rays, allowing the observation of deep anatomical structures and the development of radiological anatomy." Likewise, inventions such as the ophthalmoscope, laryngoscope, bronchoscope, and endoscope enabled deeper visualization of anatomical structures in the living human body.

At the end of the 19th and during the 20th century, a technological race began to observe internal organs in living humans. In 1967, Hounsfield integrated X-rays with computerized systems to develop Computed Axial Tomography (CAT scans), later followed by magnetic resonance imaging (MRI), laparoscopy, and other advancements in science and technology (Zambrano, 2011). Continuing along this timeline, Araujo (2018) states, "In the latter half of the 20th century and the early 21st, the emergence and development of informatics have permeated all fields of knowledge and education, playing a leading role" (p.96).

The reduction of dissection-based instruction in medical education has been linked to limitations in acquiring cadavers and anatomical specimens, the maintenance of these resources, and the facilities required for their preservation (McMenamin, 2014). Additionally, ethical uncertainties have arisen (Shaikh, 2015), prompting the search for complementary alternatives. These include techniques such as plastination (von Hagens, 1979), 2D and 3D imaging (Estevez, 2010), and the imperative development of web-based 3D atlases based on anatomical models using virtual reality technologies. These tools allow the creation and display of 3D objects and environments with animation, audio, video files, and hyperlinks that simulate realistic internal and external views (Li Jianyi, 2012).

In this context, one of anatomy's historical achievements has been the enhancement of graphic tools through the incorporation of virtual communication media. Today, 3D resources enable spatial understanding and comprehensive structural analysis (Casallas & Quijano, 2018) through digital tools that bring students closer to real-life contexts (Lizana, 2012), creating scenarios that support the learning process (Moragón-Arias, 2013). In general, the systems used to graphically represent anatomical structures can be classified into three main generations, as noted by Prats Galino and Juanes Méndez (2010):

The first generation includes printed materials such as general anatomical treatises, topographical anatomy texts, system-based manuals, and clinically oriented anatomy resources. The second generation emerged with multimedia formats, typically 2D digital images. The third generation encompasses software applications featuring 3D views and computer-generated models. These allow the generation and export of first- and second-generation images (Prats, 2010, p.190).

Over the past decades, anatomy teaching has increasingly incorporated multimedia applications, embracing third-generation tools as a technological method. These tools have proven highly valuable for interactive exploration and self-directed learning, supported by advances in computing. Today, a wide variety of digital anatomical models exist, most used in commercial applications based on 3D reconstructions of the human body from imaging. Many other 3D models have been developed with open-source software, based on the Visible Human Project, aiming to create accurate and detailed 3D anatomical models (Zilverschoon *et al*., 2017). Additionally, the use of virtual dissection tables has become evident. These include touchscreens and incorporate patient imaging data, sometimes featuring digitized cadavers scanned via CT or MRI and reconstructed in 3D (Chytas, 2023).

Currently, at the Universidad de Boyacá (Colombia), interaction with two technological tools is being carried out. One is the Sectra© Visualization and Dissection Table, a life-sized multitouch screen designed for interactive learning and teaching of the human body. It features virtual representations of real, rendered bodies and supports various healthcare education programs (Sectra, 2015). The other tool is the Cyber-Anatomy Med™ virtual reality system for anatomy learning. This immersive stereographic 3D technology allows users to wear active lenses and interact with anatomical structures through an intuitive 3D interface (Didaclibros, 2016). Each of these tools offers specific technical features that students can explore in the anatomy labs as part of their basic training, while also providing exposure to clinical and radiological orientation and the acquisition of relevant knowledge.

For this reason, the aim of the present study is to evaluate the perception of second-semester medical students regarding the implementation of multitouch and three-dimensional technological tools for learning human anatomy, as applied in the medical program at Universidad de Boyacá (Colombia).

MATERIAL AND METHOD

This was a quantitative, descriptive, cross-sectional study conducted as a classroom experience at the Universidad de Boyacá (Colombia). It employed a purposive, non-probabilistic, and non-interventional sample of 117 medical students enrolled in the Morphology course during the first academic semester of 2019. The participants received no academic incentives and voluntarily agreed to participate by signing an informed consent form.

The instrument titled "Perception of Learning in Human Anatomy Students Regarding the Use of Multitouch and Three-Dimensional Tools (PA-HM/3D)" was designed by the author MBG. It consisted of 10 items rated on a qualitative Likert-type perception scale (Strongly Agree, Agree, Neutral, Disagree). The general structure of the instrument was divided into two sections, corresponding to the academic settings where the technological tools were used: the first part assessed student perception in the Integrated Anatomy Laboratory, which utilized the multitouch tool Sectra© Table, while the second part assessed perception in the 3D Anatomy Laboratory, which used the Cyber-Anatomy Med™ tool. At the end of the instrument, three comparison criteria were included to contrast perceptions of the two technological tools.

The instrument was self-administered by each participant, with an estimated completion time of no more than 20 minutes.

Data were collected at the end of the third academic term and stored in a Microsoft Excel version 19.0 file. They were subsequently exported for analysis using SPSS Statistics version 24.0. A univariate analysis was performed on the categorical qualitative variables, which were rated on a four-level polytomous scale, to obtain frequency distributions and percentages of the quantitative variables in each part of the instrument. For the final three comparison criteria, which were dichotomous qualitative variables (Yes/No), a contingency table was used as a bivariate analysis technique to relate the two technological tools used in different settings and to calculate percentages in order to identify differences. Finally, variable comparison was assessed using the Chi-square statistic.

RESULTS

The characteristics of the study population were identified based on the variables of age, with a mean of 19.56 ± 2.3 years, and sex, with 41.2 % male and 54.8 % female participants.

In the first part of the instrument, regarding perception in the Integrated Anatomy Laboratory using the Sectra© multitouch table workstation, the highest values were concentrated in items 3, 4, and 5, with scores above the 50% midpoint, indicating a general agreement among students. Items 1 and 2 each received 40.2 %, showing little variability in perception. Notably, 21.4 % rated item 2 as "neutral," and 18.8 % "disagreed."

A positive perception was found regarding the Sectra© multitouch table, particularly in the use of basic touch gestures (tap and hold, swipe, zoom, quick taps, element selection, etc.) typical of interaction with a human-scale touchscreen, which allowed students to access and control the tool. Perceptions were also positive regarding the navigation of anatomical structures through a variety of diagnostic images, from simple projections to MRI and CT scans, thanks to the tool's zoom function and multiplanar interaction on the table's surface. Students also viewed group work around the Sectra© table favorably, particularly when discussing clinical cases.

Lower levels of agreement were observed regarding the exploration of different body regions using virtual anatomy atlases and rendered real bodies, which demanded greater prior knowledge and study effort. The virtual scalpel was also rated less favorably, with 21.4 % of students reporting indifference, likely due to the need for more practice and technical familiarity. Frequencies and percentages for the five items are presented in Table 1.

In the second part of the instrument, concerning the 3D Anatomy Laboratory using the CYBER-ANATOMY MED™ workstation, the highest ratings were in items 1 and 4, slightly above the 50 % midpoint, again indicating student agreement. Items 2 and 3 followed with 42.7 % and 40.2 % respectively. For item 5, 33.3 % of participants expressed disagreement. Overall, the perception of the CYBER-ANATOMY MED™ tool was consistent and favorable.

Item 1 received the highest agreement score (59.0 %), relating to the sensation of immersion in augmented reality and the sensory experience it provided. Students recognized that the environment artificially stimulated their senses, acting as observers in a virtual space. The VR system

Table 1. Perception in the Integrated Anatomy Laboratory Using the Sectra© Multitouch Table.

Item	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	The multitouch workstation allows you to explore different parts of the human body, learning in more detail than with the preserved cadaver in the dissection room	29.1 % (n=34)	40.2 % (n=47)	10.3 % (n=12)	17.9 % (n=21)	2.6 % (n=3)
2	When you simulate a cut with the virtual scalpel, it improves your precision skills, making them feel real	12.8 % (n=15)	40.2 % (n=47)	21.4 % (n=25)	18.8 % (n=22)	6.8 % (n=8)
3	The tactile gestures you perform on the various representations of real human bodies, structures, and organs on the multitouch screen facilitate your learning	25.6 % (n=30)	51.3 % (n=60)	10.3 % (n=12)	11.1 % (n=13)	1.7 % (n=2)
4	Interpreting anatomical details through navigation of different diagnostic images enhances your knowledge	37.6 % (n=44)	56.4 % (n=66)	3.4 % (n=4)	2.6 % (n=3)	–
5	Group interaction while working on clinical-anatomical cases around the multitouch table supports understanding of the topic	23.1 % (n=27)	55.6 % (n=65)	16.2 % (n=19)	2.6 % (n=3)	2.6 % (n=3)

in the 3D lab transmitted spatial sensations directly through the use of virtual realityglasses, guided by the instructor to ensure comprehension, observation, and analysis. While this generated a sense of safety in navigating the virtual space (item 4), individual differences in spatial perception and emotion were noted.

Items 2 and 3, with lower percentages, revealed that 3D visualization of anatomical organs and structures alters their realism. Students with frequent dissection experience emphasized the importance of tactile perception, texture, pressure, temperature, friability, and contact, in anatomical understanding. Although 40.2 % felt mentally immersed in VR, they missed the physical sense of touch.

In item 5, 33.3 % disagreed with the claim that diagnostic images in VR complicate spatial understanding. On the contrary, VR-enhanced imagery was perceived as improving anatomical detail comprehension. Frequencies and percentages for the five items are presented in Table 2.

Finally, in the comparison of both technological tools used in the anatomy laboratories:

* 81.2 % of the 117 participants believed that CYBER-ANATOMY MED™ promotes critical thinking and curiosity, compared to 68.3 % for the Sectra© table. Conversely, 22 % and 37 % respectively disagreed with this view.
* A similar majority, 82.9 % and 82.0 %, stated that neither tool replaces the use of cadavers, anatomical blocks, or specimens in the study of human anatomy.
* 86.3 % believed that the interactive experience in the 3D Anatomy Laboratory with CYBER-ANATOMY MED™ was necessary for their learning, compared to 81.2 % for the multitouch table in the Integrated Anatomy Lab. Disagreement rates were 18.8 % and 13.6 %, respectively.

To evaluate statistical significance between these two technological tools, a Chi-square test was applied using

Table 2. Perception in the 3D Anatomy Laboratory Using the CYBER-ANATOMY MED™ Workstation.

Items	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
	f	%	*f*	%	*f*
1. During the immersion in augmented reality, do you believe your sensory experience was artificially stimulated?	23	19.7 %	69	59.0 %	16
2. Do you perceive that the presentation of human anatomical organs/structures in three dimensions alters their realism for your understanding?	27	23.1 %	50	42.7 %	20
3. Do you feel mentally immersed in the virtual reality presented?	21	17.9 %	47	40.2 %	34
4. Do you believe you are emotionally prepared to comprehend the practices developed in this environment?	35	29.9 %	59	50.4 %	18
5. Does the use of diagnostic images affect the spatial complexity of your learning?	14	12.0 %	31	26.5 %	31

OpenEpi software with the observed frequency and percentage data. A statistically significant result (p = 0.025) was found for criterion 1, indicating that students perceive CYBER-ANATOMY MED™ as a more effective learning tool for anatomy than the Sectra© multitouch table.

The 3D environment was also perceived as more practical and contextually appropriate. It accommodated up to 70 students per session, with the instructor operating the computer, keyboard, and mouse. In contrast, the Sectra© table was limited to 20 students, who directly interacted with the screen. This required more tactile skills, prior study, and changed peer dynamics, making it more demanding.

Regarding criterion 2, 82.9 % and 82.0 % of students reaffirmed that neither ICT tool replaces the use of cadavers, anatomical blocks, or specimens, highlighting the indispensable value of traditional anatomical materials in laboratory settings. A summary of all three comparative criteria is shown in Table 3.

Table 3. Comparative Perception of the Two Technological Tools.

CRITERIA	DEPENDENT VARIABLE (to explain)	Technological Tool (INDEPENDENT VARIABLE)	Significance	YES *f* / %	NO *f* / %
1	The approach to studying human anatomy through this ICT (Information and Communication Technology) tool promotes critical thinking and curiosity to investigate	**SECTRA© Table**	0.025	80 / 68.3 %	37 / 31.6 %
		CYBER-ANATOMY MED™		95 / 81.2 %	22 / 18.8 %
2	Do you believe this ICT tool replaces the use of cadavers, blocks, and anatomical specimens for studying human anatomy?	**SECTRA© Table**	0.86	20 / 17.1 %	97 / 82.9 %
		CYBER-ANATOMY MED™		21 / 18.6 %	96 / 82.0 %
3	Th0 interactive experience in this laboratory is necessary for your learning	**SECTRA© Table**	0.29	95 / 81.2 %	22 / 18.8 %
		CYBER-ANATOMY MED™		101 / 86.3 %	16 / 13.6 %

DISCUSSION

New trends in technological contexts, adopted out of both necessity and innovation for educational purposes, have rapidly transformed the teaching and learning of human anatomy in medical education. This transformation is largely driven by increasingly advanced information and communication technologies. Within this framework, the present classroom-based study, involving the implementation of two technological tools, reveals that students perceive CYBER-ANATOMY MED™, used in the 3D anatomy lab, as more effective for learning anatomy than the Sectra© multitouch table, used in the integrated anatomy lab at Universidad de Boyacá (Colombia).

In this regard, 3D visualization software facilitates the detailed identification of anatomical structures and serves as a powerful and versatile technological tool that enhances essential cognitive resources in teaching-learning processes (Prats, 2010). Augmented reality systems share three characteristics: they combine the natural and virtual worlds, are interactive in real time, and are perceived in three dimensions with varying levels of complexity. Meanwhile, virtual reality represents computer-generated images that simulate the real existence of objects, with immersion levels depending on the method (immersive or non-immersive). These applications primarily target sensory engagement (Aranciba & González, 2017) and are designed with educational intent, presenting content in virtual formats to complement and enrich real-world contexts by enhancing immediacy and intuitive interactivity in learning (Moreno, 2016). However, even though today's so-called "digital natives" are familiar with technology and possess strong digital skills, their ability to evaluate and learn through digital media may still be limited (Gallardo-Echenique, 2012).

Various studies have explored the implementation and use of ICT in medical education, particularly in students' perception of learning through technological tools. In Cabrero's (2016) study with 79 medical anatomy students, participants found these tools neither difficult nor complex and considered them helpful in improving comprehension. Kockro (2017) also reported a clear preference among students for 3D and VR-based tools, findings similar to the present study. However, Wu *et al*. (2013) found that students in such digital environments may experience cognitive overload due to the volume of information, the number of devices used, and the complexity of tasks.

Núñez *et al*. (2018) conducted a perception study involving 92 students who worked with life-sized 3D anatomical models. Students reported increased motivation, enhanced learning, and improved spatial skills, results echoed by Tourancheau *et al*. (2012). Casallas, Angie, and Quijano (2018), in their study on 3D tool usage, concurred with Lim *et al*. (2010) and Hopkins *et al*. (2011) that students prefer combining traditional study tools with 3D technologies.

A meta-analysis evaluating the effectiveness of three-dimensional visualization technologies (3DVTs) in anatomy education found significant advantages over other teaching methods, particularly 2D methods, and in acquiring spatial anatomical knowledge. However, it concluded that due to rapid technological evolution, future improvements in 3DVTs may further enhance their educational efficacy. The authors also suggested that 3DVTs are particularly useful in settings where cadaver dissection is unavailable or as a complementary tool (Yammine & Violato, 2014a). In a subsequent meta-analysis, physical models were shown to yield significantly better results for spatial learning and long-term knowledge retention, although students with lower spatial ability struggled more with 3D computer-based tools. The authors concluded that 3D physical models could provide practical solutions to support student learning (Yammine & Violato, 2016b). Likewise, a systematic review recognized the educational value and feasibility of 3D printed anatomical models (3DPAMs) as another relevant tool (Brumpt *et al*., 2023).

Further studies have evaluated the educational benefits of interactive virtual dissection tables. In one study with 122 first-year medical students, over half (51 %) agreed that the "Anatomage" virtual dissection table improved their understanding, and 87 % felt it deepened their knowledge. A majority (55 %) enjoyed using it as a learning tool, and 89 % said it helped them better visualize the relative size of brain and spinal cord regions. Moreover, 90% believed it enhanced their understanding of anatomical relationships (Anand & Singel, 2017). Another study involving 10 medical students using the Anatomage table for an anatomy module concluded that students became proficient with the tool over time and appreciated both its advantages and limitations. They valued not just structure identification but also the ability to relate them across anatomical planes, supporting knowledge integration. The tool demanded basic theoretical knowledge, visuospatial awareness, and constant curiosity to maximize its usefulness (Bravo, 2019).

Similarly, a study with 105 first-year medical students participating in a case-based virtual dissection program using 3D CT scans on life-sized touchscreen dissection tables found the experience beneficial for anatomy and radiology learning. Students appreciated the opportunity to work in groups, integrate clinical cases, and engage with radiological content at the preclinical level (Darras, 2020). A recent literature review, including six eligible studies, found that in all cases, participants were satisfied with the educational value of such interventions and affirmed that virtual dissection tables could enhance academic performancewhen used alongside cadavers (Chytas, 2023).

Software continues to improve, incorporating new functions (Zilverschoon, 2017). Despite progress in virtual dissection tools over recent decades, these technologies are still evolving and considered innovative (Bernal-García *et al*., 2022). Tools like 3D visualization and immersive environments have been shown to improve short-term anatomical memory (Weeks, 2021), support deeper and more accurate understanding of the human body, and foster more dynamic learning. Nevertheless, in medical education, a balance must be maintained between technological tools and traditional practice to ensure students develop both technical skills and comprehensive anatomical knowledge (Schmidt, 2025).

In the present classroom experience, students agreed that neither of the two ICT tools fully replaces cadavers, anatomical blocks, or real specimens for studying human anatomy, a finding consistent with previous studies. These technologies can be used as complementary learning strategies (Bernal-García *et al*., 2022), but virtual tools cannot fully replicate the experience of handling a human body, whether living or deceased. The reflective process that students undergo during dissection, contemplating life, death, health, illness, and the human person, is not replicable through multiplanar or 3D imaging programs (Araujo, 2018).

CONCLUSION

Emerging knowledge through technological tools used to learn human anatomy, where perception and sensory activation bring students closer to meaningful experiences and emotions, plays a vital role in the development of specific competencies in medical education. This implies a significant responsibility: for instructors, to train themselves in using these tools, interact with them, enhance their teaching practice, and even create their own digital materials; and for students, to assume multiple roles, including that of active learners who must engage creatively and collaboratively, while integrating knowledge autonomously and interactively.

Both faculty and students must embrace ongoing transformation, driven by the global influence of technology in response to 21st-century educational and societal demands. Nevertheless, the perception among participants in this study reaffirms that while technological tools may complement, they do not replace the use of cadavers, anatomical blocks, or real specimens in learning human anatomy.

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