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New Technologies Applied to the Improvement of Human Anatomy Learning

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Abstract
The present chapter aims to explore the new digital tools applied to enhance teaching in the field of anatomy. Thus, tools such as the virtual dissection table for human bodies, interactive anatomical atlases, supplementary virtual material to traditional textbooks, and platforms for interacting with students in class, among others, will be thoroughly analyzed to assess the possibilities that new technologies offer to health science students in the 21st century.

Keywords: anatomy, teaching innovation, Artificial Intelligence, new technologies.

15.1. Historical Context of Anatomy Education

Since its inception, the learning of anatomy has embraced pedagogical models imposed by society. Over time, teaching strategies for this discipline have evolved in accordance with different educational paradigms, primarily focusing on cadaver dissection. The use of wax to model figures has ancient origins, especially in the artistic field, initially employed for the creation of objects with religious significance, such as statues of saints and nativity scenes.

At present, our legal system lacks specific and systematic regulation governing the donation of cadavers for educational and research purposes in Human Anatomy, although there is regulation for other activities related to cadavers. Anatomical practices are currently governed by various technical documents such as the Barcelona Act of 1996 and the Madrid Act of 2015, both developed by the Spanish Anatomical Society.

Throughout the early 20th century, a modern period for anatomy, following the discovery and description of all anatomical organs and structures in the human body, a technological race began for the visualization of structures or organs of living humans, i.e., bioscopic anatomy. This era includes milestones such as Roblat obtaining the first image through nuclear magnetic resonance in 1948, Ian Donald's development of echography (1950), and Computed Tomography developed by Hounsfield in 1967. In 1990, the German scientist Gunther Von Hagens successfully plastinated his first human body through a process known as plastination. In this process, water is extracted from

the body using cold acetone, and then it is replaced with a hard-enable plastic solution (Zurdo, 2007). Despite all this, until very recently, the most accessible aid for anatomy students has been anatomical atlases in paper form, with Eduard Pernkopff's Atlas of Human Anatomy (1888-1955) considered the most perfected (Hildebrandt, 2009).

The rapid development of science and technology in the last half of the 20th century has also been incorporated into the study and teaching of anatomy, influencing the institutions where it is taught and the methods of knowledge transmission (Araujo-Cuauro, 2018). In 1991, an online resource for the training of surgeons and anatomy students emerged; it was an interactive atlas with high-resolution three-dimensional images, known as the 'Vesalius Project' (Mccracken & Spurgeon, 1991). Many other atlases have followed suit since the introduction of this project.

In the teaching and learning of this basic science, the current 21st century has witnessed methods based on group work, anatomical software enabling virtual dissection, body painting anatomy, body projection anatomy, and palpation anatomy, among others. All of this is within the context of teaching to learn a 'living anatomy,' a dynamic anatomy based on both virtual and real-world realities.

Visual information in anatomical education is crucial, transitioning from 2D materials with static two-dimensional images (anatomical atlases, slides, etc.) to 3D visualization technologies, considering the human body as a three-dimensional spatial form. In this regard, an example is the integration of 3D videos (with visual and auditory information) as auxiliary teaching tools in current curricula, as it could be beneficial in enhancing students' understanding of spatial relationships among different structures and their reasoning skills (Bernard et al., 2020). Prior to the emergence of 3D videos, this issue has been partially addressed using commercial synthetic disassemblable models or plastination models. However, it is important to note that virtual reality contributes to anatomy education, but manipulating a living human body or cadaver, in most cases, has no possible substitute. Therefore, while virtual reality serves as an excellent didactic method, it remains a complementary alternative to the traditional method of dissection (Araujo-Cuauro, 2018).

Now the question is: Are these methods preferred by students over traditional methods? (Grignon & Duparc, 2021). According to the work of García-Barrios and colleagues, specifically in the Medicine Degree, students, even with the aid of modern tools, still prefer to practice with cadavers (García-Barrios et al., 2023).

15.2. Artificial Intelligence in Anatomy

Definition and available evidence of AI usage

AI is defined as the capability of machines to use algorithms, learn from data, and apply that learning in decision-making, akin to a human being (Rouhiainen, 2018). Currently, AI is considered a powerful tool with multiple applications, ranging from the financial world to education, and extending to its use in clinical settings (Chan & Zary, 2019). It is being utilized as a support for the study and practice of anatomy, as evidenced by the work of Ghosh (2022) and Moro (2023). So much so that Tolsgaard and colleagues, in the past year, determined that the use of AI is more widespread than other technologies in terms of learning and assessment (Tolsgaard et al., 2023).

The study of anatomy is crucial for diagnosis and treatment across all healthcare professions. Students in medical undergraduate and postgraduate programs, as well as medical professionals, regard macroscopic anatomy as fundamental. This significance arises from the fact that surgical procedures and other invasive interventions require anatomical knowledge for proper execution, making this field the cornerstone of medical education. The study of anatomy has often been perceived as tedious by students, mainly due to outdated teaching approaches. While the most effective teaching method has not been definitively determined, success is known to lie in the integration of multimodal methods in learning.

In recent years, numerous studies have explored the various applications of AI in medical education, leading to the conclusion that one of its most valuable features is the ability to identify specific knowledge gaps in each student and assist in reinforcing learning in those areas. This proves particularly beneficial for students with special needs. Additionally, the integration

of AI in health sciences education has been observed not only to enhance the teaching of the subject matter but also to increase student engagement, indirectly fostering greater motivation and satisfaction with the learning process (Bayne, 2015; Holmes et al., 2019; Savage, 2021).

A study published in 2022 identifies several advantages of implementing AI in the education of medical students. Firstly, it promotes self-directed learning tailored to the individual needs of each student. Secondly, it reduces the resources required for effective learning. Additionally, the learning process is characterized by greater depth, divergence, and a reduction in errors, thereby enabling efficient problem-solving. Other benefits include the use of automated and remotely controlled systems capable of storing vast amounts of valuable data. Finally, this methodology is considered user-friendly for the newer generations (Abdellatif et al., 2022).

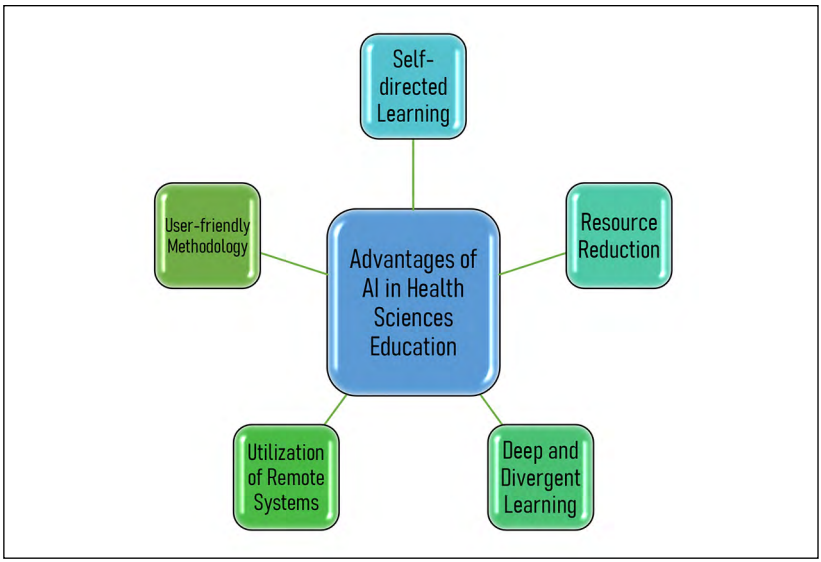

Figure 15.1. Diagram outlining the advantages of AI application in medical student education based on the study by Abdellatif and colleagues in 2022.

Among the tools currently propelled by Artificial Intelligence (AI), we encounter Virtual Reality (VR), Augmented Reality (AR), and Robotics (Sousa et al., 2021). The distinction between VR and AR lies in the fact that VR illustrates anatomical structures

on mobile devices without a connection to the real world, whereas AR contextualizes these images in our lived environment, resulting in a more impactful experience. Both tools signify a shift in the anatomy learning process, involving increased student interaction with a subject that has often been considered theoretical, challenging, and static. AR and VR provide enhanced visualization of specific complex anatomical structures and body regions. Although they seem to contribute to improved learning, it is crucial to conduct well-designed research studies analyzing academic performance and student satisfaction when utilizing these tools (Bölek et al., 2021; Chytas et al., 2020; Karbasi & Niakan Kalhori, 2020; Mendez-Lopez et al., 2022).

Historically, the learning of human anatomy has been grounded in cadaveric models, proving to be a valuable resource for students' learning processes. However, over the past few decades, there has been an imbalance between the supply and demand for anatomy studies. The availability of cadavers for dissection has decreased, while the number of students and institutions dedicated to the study of anatomy has been on the rise. Given this scenario, the necessity to apply AI for anatomical studies has grown, leading to the development of more sophisticated AI models, particularly highlighting artificial or convolutional neural networks. These networks have the capability to search for optimal solutions, functioning almost like a human brain, and even could plan surgeries remotely (Ramesh et al., 2004).

While this situation does not replace learning from cadaveric models, it proves to be immensely helpful as an assistant in practice. Moreover, it is imperative for teaching methods in anatomy to evolve and undergo restructuring in line with changes in educational curricula. Simultaneously, educating students in various AI tools is of great importance, as their application in clinical settings is on the rise. This approach not only enhances anatomical knowledge but also develops skills and competencies essential for professional healthcare practice (Guimarães et al., 2017; Rockarts et al., 2020).

Recent research determines that AI can be integrated into the teaching of anatomy through the development of applications for more intricate branches such as embryology or pathological anatomy. These applications can provide the option to utilize 3D models for analyzing complex dissectible structures. The im-

plementation of AI in anatomy education offers the potential for continuous feedback to students, akin to simulating clinical anatomy sessions through robotic systems that guide students in interventions, fostering self-confidence. Additionally, its application would involve the creation of an updated repository of literature, the facilitation of online self-assessments through digital tools (which will be discussed later), and the development of practical study videos for use outside the classroom (Abdellatif et al., 2022; Lazarus et al., 2022).

Critical analysis of the impact and necessity of AI in the study of anatomy

Despite the undeniable potential positive qualities that artificial intelligences present in the future global landscape, we must not forget that these technologies are still in the developmental stage, and their subsequent results depend on the training methods employed. Therefore, numerous crucial factors in the professional and personal development of health sciences students hinge on the proper use of these technologies.

Development and maturity of the student: critical thinking

One of the fundamental elements of higher education should be the development of critical thinking, accompanying the student in a process of intellectual maturation throughout their instruction. However, it is evident that the current educational system often emphasizes the ability to complete assessments purely reliant on memorization skills, at the expense of reasoning, comprehension, and even the ability to understand the "why" behind fundamental aspects of a subject.

In this regard, the implementation of digital tools, along with the technological revolution brought about by text processing AIs, such as chat-GPT, could entail a significant loss of one of the fundamental pillars of the educational process in higher education. If students lose the opportunity to develop their capacity for creative writing, to hone their skills in creating scientific content, and ultimately, the ability to craft academic manuscripts – which form the bedrock of intellectual progress in society – we are confronted with a problem of great complexity and magnitude.

Social aspects

We must be aware of the kind of healthcare professionals we aim to empower; numerous aspects related to interpersonal skills, emotions, and social abilities qualitatively and quantitatively influence what could be termed a "fully qualified professional." The ability to excel in a written test is a skill that can be entirely trained in a virtual environment. However, it does not allow the student to develop all the capacities and skills required for the optimal development and execution of their future profession.

Firstly, the student-teacher relationship, in capable hands, can be a paradigm-shifting revolution for motivated students. Paraphrasing Newton, we can see farther because we stand on the shoulders of giants. A teacher with extensive professional and teaching experience has the potential to broaden the minds of their students, molding them so that successive generations of healthcare professionals become increasingly competent. This almost relegates the educational capacity of artificial intelligences to a nearly anecdotal level. Human relationships, in general terms, and especially in professions such as medicine or nursing, constitute one of the central axes of the profession. Trust between healthcare provider and patient, human interaction, the ability for empathy, dialogue, and emotional support are fundamental aspects acquired and developed through human interaction.

Furthermore, in the context of anatomy, there is another fundamental element that is currently impossible to replace with AI: anatomical dissection. Human dissection involves a real connection with the human body, accompanied by a set of ethical aspects related to the relationship between the student and the donor. Such activities not only enhance teamwork but also help develop crucial competencies, such as self-reflection or "detached concern"[1] through emotional interaction with the donor (Böckers, 2020; Cornwall et al., 2023). Ultimately, for many students, it is their first clinical encounter with death, which undoubtedly brings benefits to their future professional development. While it is true that practice might be a stress-inducing element for the student, evidence suggests that the most intense reactions occur in anticipation (Böckers, 2020). In any case,

1. Describes the effort of medical professionals/students to "care" for the patient/body donor, but yet "not get too close". (Böckers, 2020)

there are currently no substitutes that can match the benefits of dissection (Romo-Barrientos et al., 2020).

15.3. Digital Tools for Learning Improvement

Virtual anatomical dissection tables

Recently, a life-sized computerized table has been designed, integrating Computed Tomography, X-rays, Ultrasound, and Magnetic Resonance Imaging to generate stereoscopic images of various parts of the human body. This innovative tool, known as Anatomage (3D Anatomy and Physiology Simulation Systems Anatomage), facilitates virtual dissection and reconstruction of the human body. Through a fully interactive multitouch screen, students can dissect the body, navigating through layers of tissue or using a virtual knife to cut and visualize internal structures. The precise details and rich content it provides capture the attention and interest of students. Moreover, it finds extensive applications in surgical education (García-Martín et al., 2018).

In a study conducted in the USA, the effectiveness of learning anatomy for specific body regions using the Anatomage table was compared with traditional cadaveric dissection. The results indicated a higher level of enthusiasm and perceived learning when utilizing the Anatomage table, especially in specific anatomical regions such as the musculoskeletal system of the upper and lower limbs (Baratz et al., 2019). For other authors, the combination of the virtual dissection table with traditional methods of anatomical training and the use of real cadavers enhance the effectiveness of learning in this subject (Kavvadia et al., 2023).

Interactive 3D Atlases

Interactive 3D atlases are digital tools that enable science students to move and rotate anatomical elements, aiding in the spatial understanding of the subject (Park et al., 2019). This is made possible through the development and easy accessibility of technologies such as smartphones, tablets, and computers, which are user-friendly and typically have intuitive interfaces. Two well-known

3D atlases are 3d4Medical and Visible Body, as reflected in the work of Park et al. (2019), where the majority of the 155 analyzed students used them. It is noteworthy that, in their study, a small percentage of students did not use them due to a lack of electronic equipment, concerns about functionality, economic cost, or a perception of them as unnecessary. However, it has been observed that their combined use with traditional study materials can exhibit good synergy (Park et al., 2019), increasing student interest and empowering them to acquire skills and competencies during the learning process (Rodríguez-López et al., 2020).

3D Printing

3D printing technology goes beyond three-dimensional visualization, adding a tactile component to the sensory experience involved in the learning process. In the context of anatomy, human dissection allows students to develop numerous competencies and skills, as discussed in section 2.2. However, there are many anatomical structures that are difficult to access or of small size, making them challenging to study in the traditional way. Since the size limitations of 3D printing are solely based on the printing area capacity of the printer itself, anatomical models used in the educational process can be freely scaled. This is particularly advantageous in the case of human embryology, where the ability to print 3D models of different human embryonic stages and even increase the scale of the model qualitatively enhances teaching capacity, facilitating the understanding of complex processes that require three-dimensional visualization. Scientific evidence shows that students have better learning outcomes and higher satisfaction in the study of anatomy, and future perspectives point towards the enhancement of these complementary applications alongside classical methods (Ye et al., 2020).

15.4. Other Tools for Educational Innovation

Currently, there are other technological tools, such as various applications that promote student motivation and participation in the classroom. The most widely used and engaging tools for stu-

dents include Kahoot, Quizizz, Wooclap, and Socrative (Grzych & Schraen-Maschke, 2019). These applications are based on gamification, making them particularly attractive for theoretical subjects that may seem static, such as Anatomy.

All these tools share the common feature of utilizing a game-like format, where the teacher can pose questions and students, using their mobile devices, can answer and interact with each other in real-time. These applications bring a dynamic approach to classes, enabling the assessment of intra-class acquired knowledge, which can lead to meaningful and collaborative learning among students (Donkin & Rasmussen, 2021; Sailer & Homner, 2020; Singhal et al., 2019; Sugiura et al., 2020).

A study conducted in 2019, comparing the use of various applications mentioned earlier, revealed statistically significant differences in academic performance before and after their use on all platforms. Additionally, the learning experience for students was found to be better than in an expository class format (Orhan Göksün & Gürsoy, 2019). In line with this, Garza and colleagues observed that students exposed to activities using these platforms demonstrated better academic performance at the end of the course compared to those who did not undergo such training, and their performance could be predictive of the final grade (Garza et al., 2023).

15.5. Conclusions

In agreement with Winkelmann, anatomical knowledge is too crucial for future medical professionals to be left to the educational trends of the moment (Winkelmann, 2007). Regardless of the educational model, according to Professor DiDio (1920-2004), students should learn anatomy with the teacher, without the teacher, despite the teacher, and even against the teacher if necessary (DiDio, 1998).

The field of artificial intelligence has brought about a technological revolution that is currently at the forefront of expertise in every field or branch of knowledge. The convenience and immediacy of information are evident strengths of AI, but it is important to remember that they have potential negative effects on the development and maturation of students' skills and knowledge.

In essence, it is crucial to foster each student's development of their own professional identity (Cruess et al., 2014); that is, to become a well-rounded healthcare professional, encompassing technical knowledge, intellectual capacity, and maturity, as well as social skills. This is based on the premise of the "good professional" concept conveyed by the teacher, whose human interaction is essential to complete their education.

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