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Diversified Methods and the Use of Technology in the Teaching of Anatomy in Undergraduate Medical Courses

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ABSTRACT

Introduction: Human anatomy began to be studied in Egypt, and documents show that some of the first anatomical descriptions were recorded on papyri between 3000 and 2500 BC. Given the constant transformations observed in the social context, the university's main challenge today is to introduce a professional into the job market with a very solid education, so that their profile is that of a creative person facing the various situations of everyday life, with a good grasp of current technology and group dynamics. Objectives: The aim of this article was to point out the technological innovations that can be used to make learning Human Anatomy more interesting and contribute to the quality of Anatomy teaching. It is also important to provoke reflection and a re-evaluation of educational practice, providing alternatives to introduce the social reality of a health professional into the teaching-learning process. Methodology: This study is a literature review based on two electronic databases: PubMed and Science Direct. The descriptors used in the search were "anatomy" AND "medical education" AND "technological development". The study was divided into five stages: (1) formulation of the question, (2) location of the studies, (3) evaluation and selection of the studies, (4) analysis and synthesis, and (5) description of the results. Final Considerations: The article led us to conclude that there is a strong demand for technological development, which is already embedded in areas of health such as research to develop prostheses, medicines, vaccines, as well as improved surgical techniques such as laparoscopy and others. For this reason, it is worth highlighting the importance of instigating discussions and reflections on the effectiveness of the use of technology associated with the teaching of human anatomy in undergraduate medical courses.

Key words: Anatomy; Medical education; Technological development.

INTRODUCTION

Human anatomy has a prestigious history and was considered the most prominent of the biological sciences until the 19th and early 20th centuries. Study methods have improved dramatically, allowing study from examination through dissection of bodies to the use of technologically complex techniques (BOFF et.al, 2020).

Anatomy is one of the foundations of medical education and has been taught since at least the Renaissance. The format and amount of information taught to young doctors has evolved and changed in line with the demands of the medical profession. What is taught today differs significantly from the past, but the methods used to teach have not changed much. For example, the famous public dissections that took place in the Middle Ages and early Renaissance can today be considered the 'anatomical demonstrations' used in practical classes (PERSAUD et.al, 2014).

Malomo (2006) described in his studies that the evolution of human anatomy is intertwined with the history of humanity itself. For a long time relegated to the margins of world historiography, the practice of dissection has its first records in humans in the 2nd century BC in Alexandria.

Around the 2nd century, when the use of human cadavers was forbidden for ethical and religious reasons, the practice of dissecting animals predominated, with Galen, a doctor from Rome, as its main exponent. Through this practice on animals, he sought to create theories of comparative anatomy that could also be applied to the human body (BRENNA et.al, 2022).

For Kobayashi (2022), it was only 700 years after Galen's time that the first University of Medicine was created in Salerno, Italy. At this point, the Renaissance period marked the beginning of unstoppable advances in anatomy. These advances were due to the significant increase in the number of people with an interest in the field, such as artists who looked to the technique of dissection as a way of portraying the human figure more accurately in their works, the main exponent being Leonardo da Vinci, known as "the explorer of the human body".

In 1543, the first anatomy atlas book - "De humanis corporis fabrica" - was produced by the Belgian physician Andreas Vesalius. With the spread of knowledge and the growing search for answers, at the end of the 17th century, other scholars began to produce pieces to be exhibited in anatomy museums. Nowadays, the study of human anatomy combined with the practice of dissection has become one of the greatest tools for awakening self-perception, exercising empathy and advancing science, based on valuing the human being, not only for understanding the body, but also for understanding one's own existence (BRENNA et.al, 2022).

Although Anatomy is essential to teaching in the health area, students only realize the importance of Anatomy when they find themselves next to a patient's bed or operating table, a situation that is so common in the life of a health professional, when they have the opportunity to prove all the knowledge they have acquired during their academic life (AHMED et.al, 2011).

Chapman et al (2013), cites that in the face of such social demands, educational institutions have a responsibility to generate knowledge and scientific production taking into account the needs of the community that guides them, sharing science, engaging in social causes, collaborating in the training and lives of citizens.

With the constant transformations observed in the social context, the University's great challenge today is to bring a professional with a solid education into the job market, so that their profile is that of a creative person facing the various situations of everyday life, with a good grasp of current technology and group dynamics; also, an individual without prejudice and capable of dealing with the pluralism of difficulties that can be found in a given population.

With this in mind, this study aims to carry out a literature review to evaluate the use of technology in the teaching of human anatomy. In this sense, the aim is to assess whether there is a considerable discrepancy between the face-to-face study environment (in the laboratory with the use of parts and cadavers) and the study through the technological environment (with the use of technologies such as apps, robots and others). The aim is to analyze whether there is any prospect of higher quality anatomy learning with the inclusion of technology in the conventional laboratory environment.

METHODOLOGY

This study is a literature review based on two electronic databases: PubMed and Science Direct. The descriptors used in the search were "anatomy" AND "medical education" AND "technological development".

The study was divided into five stages: (1) formulation of the question, (2) location of the studies, (3) evaluation and selection of the studies, (4) analysis and synthesis, and (5) description of the results.

The inclusion criteria were: studies evaluating the use of technological development in the teaching of human anatomy; and exclusion criteria: studies involving the surgical area or surgical technique.

The studies were selected after reading and analyzing the titles of the abstracts and the full texts. The collection of data and information was divided into three areas: I) which technologies have been developed for the study of human anatomy; II) how medical students perceive the use of technology in learning and III) what are the results of using active methodologies with the use of technology in the teaching of human anatomy. Finally, due to the descriptive nature of this study, the risk of bias/methodological quality of each study was not assessed.

LITERATURE REVIEW

Teaching Anatomy through New Technologies

We live in a time of continuous evolution of computer-based multimedia technology. In the revolution, the medical sciences have taken advantage of the power of these tools. Molecular biology, manuscript preparation, data manipulation, Medline searches

data manipulation, Medline searches, diagnostic imaging, the sequencing of the human genome, etc. are hundreds of examples. Anatomy education has also taken advantage of these inventions and applied them to teaching and visualizing complex structures (ESTAI, 2016).

Technology stands out as an agent of progress, especially in the area of health. However, in many universities the study of human anatomy in medical courses remains traditional with theoretical lectures and dissection of cadavers, so technological methodologies seem to help teaching, making it interactive (CHAPMAN et.al, 2013).

According to Colares et.al (2013), the Virtual Reality application aims to simulate an anatomy laboratory, allowing it to present a space similar to the one that students enjoy at their universities. This interface consists of the virtual environment and its interactivity. For Davis et,al (2014), there should be a motivation for other forms of learning and for seeking more interactive and alternative ways of teaching in practical classes in the discipline of human anatomy and physiology, since traditional teaching models, such as the use of anatomical and biological casts are not using virtual reality for the field of human anatomy as a tool in medical education such as the use of three-dimensional printed models (3DP) as a way of replacing or improving existing methodological resources in the study of human anatomy.

Over time, there have been authors who have disagreed to a certain extent, but who have agreed on most of the observations related to the product of the teaching-learning relationship, its didactic approach and the breaking down of an exclusively objectivist mechanism of the information provided, in the face of a student who is less of a listener and more of a participant in the construction of knowledge (ESTAI, 2016).

Iwanaga et al (2021) argues that these references are preceded by a constitution that deals with contemporary learning and that uses new forms of language to achieve communion between teacher and student: the technical-informational transposition through technological bias and 3D as a facilitator.

According to Murgitroyd et.al (2015), themes that analyze issues such as technological systems, technological tools and technological innovations are the main topics on the agendas and debates between public bodies, private companies and development agencies, with the guiding principle being their real benefit and integration into the social good, community development and their application, above all, in the areas of health.

Raftery (2007) described that new pedagogical practices emerge as technology points to a new field of exploration in academia, allowing students to be the coordinators of their own learning pace, while enabling autonomy in the teaching process. With this, not only does the teacher overcome the barriers previously established by the traditionally rigid teaching method, but the student also achieves the possibility of feeling important.

According to Zargaran et.al (2020), the implementation of 3D technology in anatomy classes allows for 1) a 3D view of the anatomy of the face from different angles; 2) a 3D external and internal view of anatomical structures; 3) a 3D interface between anatomical structures (FIGURES 1 to 3) as an auxiliary tool in educational processes, enabling the teacher to use creativity to the full, based on previously acquired technical knowledge, providing new configurations of educational spaces in order to explore the quality of the work carried out.

Figure 1. 3D view of the anatomy of the face from different angles. Source: Zargaran et.al, 2020.

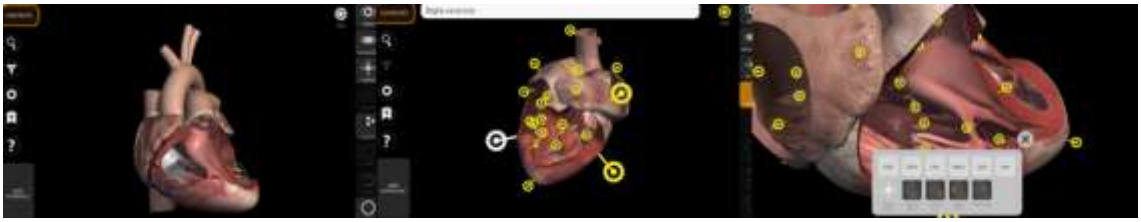

Figure 2. External and internal 3D view of the anatomy of the heart. Source: Zargaran et.al, 2020.

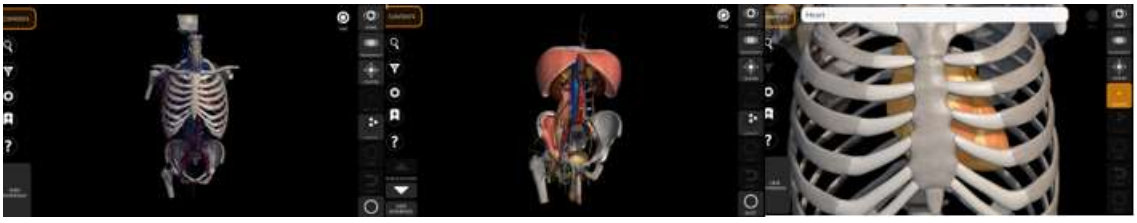

Figure 3. 3D interface between anatomical structures. Source: Zargaran et.al, 2020.

Nowadays, the speed with which transformations take place in the field of science demands new ways of dealing with situations from professionals, who in turn, the more capable they are of dealing with adversity during their professional training, the greater the possibilities of dealing with it in search of the best possible solutions for a given case (YANG, 2020).

Torres (2014) mentions that technology should join methodologies and processes aimed at teaching anatomy, making it as present as it is necessary, both for the teacher, the methodologies already practiced in cadavers and images, while using a tool to qualify the teaching-learning processes, and for the student, who takes the lead in their learning, becoming responsible for the very meaning of the content covered in class by the teacher.

For Duarte et al (2020), the use of technology with a focus on education, points out that among the various means used as an educational strategy in the learning of medical students, they have a considerable significance in impacting on the conception of the information obtained by the students, supporting the development of studies and facilitating the absorption of the content taught. With this, the role of the teacher educator goes beyond the traditional framework of traditional teaching methods, representing the adaptation of technological tools by the subjects involved.

To this end, Davis (2014) points out that the use of technology in educational processes focused on medicine provides a moment that reflects on the participation and exchange of experiences between the teaching leader and the students by subsidizing the multiple forms of teaching and making what is called health education more dynamic.

According to Zargaran (2020), the way in which the student is prepared and how they will develop their skills to achieve understanding and stimulate reflection. Thus, in medical courses, the use of educational tools in 3D technology makes it possible to adapt the student's understanding to what was previously based only on theory, and thus makes it possible for them to understand the entire health-disease process that emerges from the professional-patient relationship.

Raftery et al (2007), cites that technology in the educational environment allows innovative fields to be explored that in the more traditional lines remain harsh, rigid and theoretical, through the development of creative reasoning and the formation of new perspectives during the manipulation of physical or visual simulators of the human body.

Zargaran et al (2020), states that the use of technology is considered a facilitator for technique, whether it is the technique of teaching based on didactic examples or the professional technique exercised in the doctor's daily life.

Taking this as a parameter, technology unfolds in a multitude of knowledge and innovations that increase the efficiency and productivity of services and processes (YANG, 2020).

Estai (2016) adds that it is unwise to stick to practices that are often routine, stereotyped, often based on simplified ideals, almost clichés that have lost their potential for critical analysis of reality and tackling educational problems.

Many universities and countries encounter difficulties in acquiring cadaveric specimens for practical anatomy classes. In this regard, Barrovecchio et al (2018) interviewed 727 students, using a form with voluntary and anonymous answers. They divided the subject matter into topics: practice, teaching materials, teaching quality, exams, organization, among others. The most frequent responses from students (26%) referred to the need to increase practical classes with more hours dedicated to practical work with cadavers and the use of better teaching materials. In an attempt to explain the high rate of complaints about the quality of teaching materials, the authors of this study listed, among other factors: a large number of students supervised by a small number of teachers, scarce teaching resources and difficulties in acquiring cadavers, making it very difficult to provide adequate cadaveric material for everyone.

According to Zargaran et.al (2020), analyzing the other side of the issue, given the great technological advances in the area of information technology, especially in the development of software aimed at Education, combined with the reduction in acquisition costs for learning Human Anatomy can be greatly facilitated with the aid of multimedia systems.

Some Examples of Technologies Applied to Anatomy Teaching

Csanmek 3D Multidisciplinary Platform (BRA)

The 3D Multidisciplinary Platform, developed by Brazilian startup Csanmek, has brought medical education much closer to the reality of the profession. The technology, used in 20 medical training courses in the country, has a system for integrating hospitals and classrooms for case studies and real clinical examinations, as well as replacing the use of cadavers in the classroom (CSANMEK, 2023).

The system allows medical images from CT and MRI scans to be converted into 3D, so that students can carry out virtual dissections and anatomical studies on human and animal bodies, which are reconstructed in real time (CSANMEK, 2023).

The 3D Multidisciplinary Platform functions as a table that displays highly detailed and anatomically correct three-dimensional models of all the systems of the human body, including a system for connecting to digital whiteboards and overhead projectors.

A 3D anatomy atlas is shipped with the equipment, with technology that makes it possible to perform physiological movements and move each part of the human body in isolation, allowing full access to each structure of the human body (CSANMEK, 2023).

The platform also has a tool for searching and locating anatomical structures by name, as well as dynamic models of muscle structures and modules for physiology and histology classes. It also has a connection to a digital microscope and touch projection (CSANMEK, 2023).

In addition to medical courses, the technology can also be used in veterinary, engineering, technical health courses and basic education. The system brings together educational tools from various disciplines in a single device and caters for a range of subjects, making it a complete alternative for use in education in the various areas of health (CSANMEK, 2023).

Inspired by European and American technologies and methodologies, the national product has more than 5,000 identified anatomical structures, including all the organs and systems of the male and female body (CSANMEK, 2023).

Healthy Simulator Virtual Anatomical System (USA)

Virtual Anatomy is a technological tool that allows the visualization and interactive learning of anatomy. By using this digital anatomy, students, educators and professionals can explore and better understand the human body. Making anatomical learning virtual, the tools can include 3D models, animations, quizzes, augmented reality and much more (HEALTHY SIMULATOR, 2023).

FIGURE 4 shows Healthy Simulator's Virtual System technology.

Figure 4. Healthy Simulator Virtual System Technology. Source: healthysimulation.com/virtual-anatomy

The use of Virtual Anatomy can help teach concepts of anatomy, physiology, muscles, the skeleton and the circulatory system. The technology also makes it possible to bridge the gap between macroscopic anatomy and cutting-edge medical imaging. Virtual Anatomy also offers the opportunity to learn cross-sectional anatomy and radiological images alongside cadaver dissection (HEALTHY SIMULATOR, 2023). Often, a real cadaver, both male and female, can be visualized and transformed into 3-D models that students can manipulate. Students can rotate these models, dissect them virtually and perform essentially the kinds of experiments they would normally do in an anatomy lab. For example, users can search for body parts and terms, use interactive features to change the depth of their cuts, visualize tissues through high-resolution images and obtain multiple views (HEALTHY SIMULATOR, 2023).

Although this tool is an effective way of advancing digital technology, Virtual Anatomy will probably not completely replace macroscopic anatomy. This is because many educators and healthcare leaders still believe that early exposure to real anatomy will become a reference point that will stay with students for the rest of their careers (HEALTHY SIMULATOR, 2023).

Simulators from MORE THAN SIMULATORS (POR)

There are many types of Virtual Anatomy learning, including the incorporation of virtual cadavers, radiology workstations (RAD), ultrasound sessions and volumetric reconstruction. Each type of Virtual Anatomy helps to teach skills and procedures that are imperative in a range of healthcare roles and positions. The information also helps with a general understanding of bodily functions, regardless of profession (MORE THAN SIMULATORS, 2023).

For example, a virtual cadaver table will display life-size virtual cadavers, allowing students to experience macroscopic anatomy in axial, sagittal and coronal sections. The technology also allows full control of the cutting plane. These features also make it possible to explore anatomical images and reinforce anatomical relationships. A virtual cadaver also provides a powerful link between cadaveric anatomy and radiology images, such as Cerebral Tomography (CT) and Magnetic Resonance Imaging (MRI) scans (MORE THAN SIMULATORS, 2023).

Alternatively, radiology workstations (RAD) give users access to a library of unidentified patient images. These images include radiographs, CT scans, MRI scans and diagnostic procedures using a PACS viewer. Users then apply their anatomical knowledge to the workstation to navigate and interpret clinical and diagnostic images (MORE THAN SIMULATORS, 2023).

Another feature, volumetric reconstruction, can be used in CT and MRI scans to show students how to use game technology to navigate and explore anatomical structures from any orientation. With visualization features that allow users to quickly and effectively view and interact with data from MRI and CT scans, they can practice and perform tasks in 3D (MORE THAN SIMULATORS, 2023).

Other examples of Virtual Anatomy

Complete Anatomy is a cloud-based 3D animated learning platform from 3D4Medical that allows users to investigate the finest details of human anatomy in 3D. Validated by an academic advisory board and in-house anatomical experts, this is one of the most accurate and complex 3D anatomical atlas platforms available today (MORE THAN SIMULATORS, 2023).

Figure 5. Virtual Dissection Table Fonte: https://morethansimulators.com/pt-pt/simulador/anatom age-table-virtual-dissection-table/

Unlike other anatomy apps, 3D4Medical allows you to use 2D and 3D pen modeling tools to cut, fracture, grow, spike or show pain on specific body parts, while adding saved 3D images and labels with full model interactivity (MORE THAN SIMULATORS, 2023).

Anatomage Digital Dissection Trainers (USA)

Anatomage, a product development company based in San Jose, CA, has developed a series of medical Virtual Anatomy models. The company has designed an ecosystem of 3D anatomy hardware and software, allowing users to visualize anatomy with the highest level of precision. Anatomage's goal is to become a platform that improves all aspects of healthcare with its virtual anatomy lab (ANATOMAGE, 2023).

To achieve this goal, the company has created the Anatomage Table, a technologically advanced 3D anatomy visualization system for teaching anatomy and physiology. The operating table's form factor, combined with Anatomage's radiology software and clinical content, helps students to truly experience virtual anatomical learning (ANATOMAGE, 2023).

By using this virtual machine, users can visualize anatomy exactly as they would on a fresh cadaver. Individual structures are accurately reconstructed in 3-D, resulting in images of real, accurate anatomy that can also be dissected in 3-D. With the Anatomage Table, use is presented as a fully interactive, life-size tactile experience in the shape of an operating bed (ANATOMAGE, 2023).

Touch of Life Technologies Inc. (ToLTech) manufactures another form of Virtual Anatomy table, which the company calls the Sectra Table. Based in Aurora, Colorado, the company's visualization table is powered by a custom Sectra PACS workstation. Sectra's visualization techniques allow students to interact with an immediate presentation of large data sets, such as high-resolution whole-body scans (ANATOMAGE, 2023).

This visualization table brings clinical-level images directly into an anatomical teaching environment. Using Sectra's clinical PACS, the visualization table is able to quickly and directly import DICOM studies for automatic 2-D and 3-D presentation (ANATOMAGE, 2023).

The technology also comes with built-in presets, allowing students to instantly visualize air, skin, soft tissue, contrast-injected vasculature, bone or surgical interventions. Precision controls also allow students to further customize their view to obtain unique views of CT and MRI datasets (ANATOMAGE, 2023).

BioDigital direct patient representation system (USA)

Another company, the North American BioDigital, Inc., was created with the aim of allowing people to see inside the body using interactive 3D technology. The company has developed a cloud platform that makes it easy to visualize the human body through an app (BIODIGITAL, 2023).

Based in New York City (USA), BioDigital's 3D body platform offers male and female anatomy, with basic and professional-level details. Helping with the overall use of the product, each system is fully segmented, labeled and dissectible for easy configuration according to any educational

need. Together, these features help guide students through the progression of disease, treatment and body systems with virtual tours of the anatomy (BIODIGITAL, 2023).

The company's 3-D body technology also helps students understand spatial relationships in the human body with interactive anatomy labels. Another advantage of this Virtual Anatomy tool is that the technology allows users to customize the look and feel of 3-D anatomy models to highlight anatomical structures or to highlight key function (FIGURES 6 and 7) (BIODIGITAL, 2023).

Figure 6. Radiological images. Source: https://www.biodigital.com/

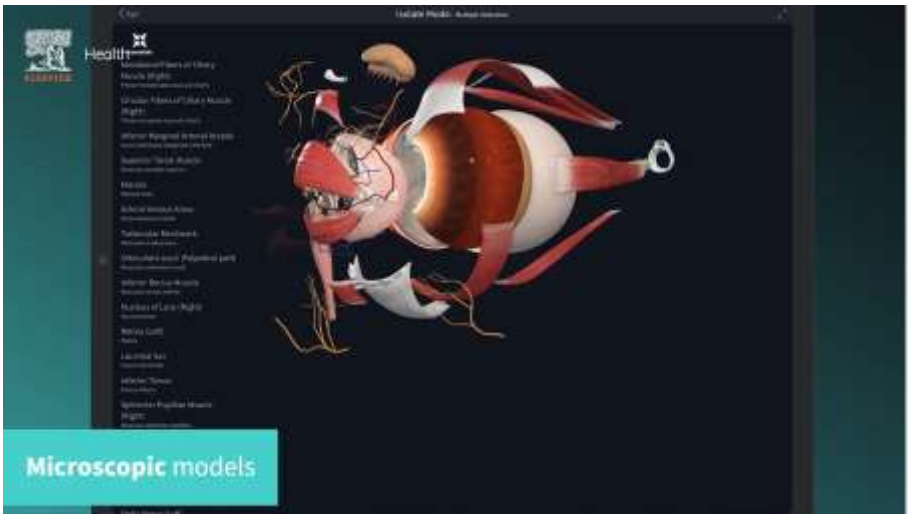

Figure 7. Microscopic models. Source: https://www.biodigital.com/

FINAL CONSIDERATIONS

The article allowed us to conclude that there is a strong demand for technological development, which is already being incorporated into areas of health such as research to develop prostheses, medicines, vaccines, as well as improved surgical techniques such as laparoscopy and others. It is therefore worth highlighting the importance of instigating discussions and reflections on the effectiveness of the use of technology associated with the teaching of human anatomy in undergraduate medical courses.

In this sense, the introduction of methodologies that make use of technology associated with the traditional anatomy laboratory environment is currently one of the most effective methods for student learning, since most studies have proven its enriching potential in evaluations that have achieved equal or better results than teaching with traditional practices alone.

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