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A BRIEF REVIEW ON INNOVATIVE ANATOMY LEARNING TECHNOLOGIES FOR MEDICAL AND HEALTH STUDENTS' EDUCATION

UMA BREVE REVISÃO SOBRE TECNOLOGIAS INOVADORAS DE APRENDIZAGEM DE ANATOMIA PARA A EDUCAÇÃO DE ESTUDANTES DE MEDICINA E OUTRAS ÁREAS DA SAÚDE

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ABSTRACT
Contribution: Considering the rapidity of the emergence of new technologies in the modern world, it is necessary to identify and describe potential educational innovations and technologies used as tools for improving healthcare students anatomy learning in the last years. The key contribution of this study is to indicate implementation and other challenges to be overcome. Background: Extensive research demonstrated that several different innovative methods have been used for anatomy teaching. Based on these findings, discussing the most recent existing technologies may be worthwhile. Research Questions: What innovative technologies are being used as tools for improving healthcare students Anatomy learning? What are the main challenges and perspectives related to them? Methodology: This review discussed studies published from 2019 to 2021 found in Embase, IEEE Digital Library, Pubmed, ScienceDirect and Web of Science. Inclusion and exclusion criteria were established, and a quality assessment was conducted aiming to mitigate biases and systematic errors. Findings: The databases electronic search identified 149 references and only 10 studies met the minimum cutoff score and were discussed. Compared to traditional methods, alternative learning technologies are excellent ways to improve and transform the education in the health' system, making it more efficient, economic, practical and accessible.

KEYWORDS: Anatomy. Education. Innovation. Technology.

RESUMO
Contribuição: Considerando a rapidez do surgimento de novas tecnologias no mundo moderno, é necessário identificar e descrever potenciais inovações educacionais e tecnologias utilizadas como ferramentas para melhorar o aprendizado de anatomia dos estudantes da área da saúde nos últimos anos. A principal contribuição deste estudo é indicar a dificuldade de implementação e outros desafios a serem superados. Antecedentes: Extensas pesquisas demonstraram que diversos métodos inovadores têm sido utilizados para o ensino de anatomia. Com base nessas descobertas, vale a pena discutir as tecnologias existentes mais recentes. Perguntas da Pesquisa: Quais tecnologias inovadoras estão sendo usadas como ferramentas para melhorar o aprendizado de anatomia dos estudantes de saúde? Quais são os principais desafios e perspectivas relacionados a eles? Metodologia: Esta revisão discutiu estudos publicados de 2019 a 2021 encontrados no Embase, IEEE *Digital Library*, Pubmed, *ScienceDirect* e *Web of Science*. Critérios de inclusão e

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exclusão foram estabelecidos e uma avalição da qualidade foi realizada com o objetivo de mitigar vieses e erros sistemáticos. Resultados: A busca eletrônica nas bases de dados identificou 149 referências e apenas 10 estudos atingiram o escore mínimo de corte e foram discutidos. Comparados os métodos tradicionais, as tecnologias alternativas de aprendizagem são excelentes formas de melhorar e transformar a educação no sistema de saúde, tornando-a mais eficiente, econômica, prática e acessível.

PALAVRAS-CHAVE: Anatomia. Educação. Inovação. Tecnologia.

1 INTRODUCTION

Since the 16th century, learning anatomy has been an important part of medical and healthcare professions education [1]. There were no significant transformations during the last decades related to adopted anatomy teaching methods being theoretical lectures and practical laboratory activities being still predominant [2], [3]. Spatial visualization is essential for the study of human anatomy and it may be difficult for students to understand dynamic aspects of real three-dimensional (3D) structures only by visualizing two-dimensional (2D) representations [3], [4].

Almost 10 years ago, an historical overview expressed the need of technologically developed methods for anatomy education in order to reduce required time for training and cost of education and ensure hygienic and health conditions lacking in some laboratory environments [5]. Zargaran et al. [6] published a narrative literature review in 2019 exploring the current landscape of anatomy learning and, additionally, investigated in a cross-sectional survey medical students preferences. Only two databases were used and five main themes were assessed (3D & Virtual technology, Cadaveric materials, Web-based applications, Imaging tools and Video learning tools). It was concluded that students appreciate the traditional methods of learning, such as cadaveric teaching. However, innovative methods can help develop an interest in anatomy studies.

In recent years with the advent of anatomical 3D visualization technologies (e.g. simulators, augmented reality and virtual reality), active and stereoscopic exploration of anatomy became a new reality for medical curricula along with traditional teaching methods providing new learning possibilities [2], [7]. There are many benefits of the incorporation of simulation training in medical schools with great risk-reduction advantages and potential to revolutionize undergraduate education [8]. Students learn more effectively when combining and integrating multiple pedagogical resources [9]. In surgical trainings, for example, supportive systems guided by technology help increasing the rates of success in difficult procedures and consequently increasing patient’s health and quality of life [10]. Developing effective method and technologies for teaching anatomy is crucial to safe medical practice [9].

The coronavirus SARS-CoV-2 pandemic made anatomy teaching harder for educators all around the world. Incapable of touching dissected human body structures, students were given the chance of enhancing their understanding with the adoption of 3D technologies by teachers during their online lectures [11]. Sophisticated computational models with interactive detailed anatomy displayed have been used [1]. A recent review study conducted by Iwanaga et al [11] revisited traditional and modern anatomy learning methods in the context of Covid-19 pandemic in order to discuss the future of anatomy education and help developing innovations. Dissection, plastination, video, 3D printing, online resources, social media, augmented and virtual reality are discussed in detail in this literature review however its adopted methodology is not clearly stated. Despite the various methods discussed it was concluded that comparing them with traditional methods under unbiased conditions was difficult because of their subjectivity.

In this context, this review aims to identify and describe potential educational innovations and technologies used as tools for improving healthcare students anatomy learning. Considering the rapidity of the emergence of new technologies in the modern world, a well-structured methodology was established and adopted and several databases were used as a source of research in order to produce the most complete discussion possible about recent developments. The key contribution of this study is to indicate implementation and other challenges to be overcome.

This work is organized as follows: Section 2 describes, based on the literature, the most important terms and concepts for understanding this study. Section 3 details the methodology defined and adopted for the conduction of this review. The obtained results and a description of selected works can be found in Section 4. Section 5 is the Discussion section, in which the progress made is analyzed, challenges to be overcome are identified and future prospects are pointed out. In Section 6 are stated the main lessons learned with this study. Finally, in Section 7, the Conclusion summarizes the findings obtained.

2 BACKGROUND

2.1 Traditional anatomy teaching methods

Regardless of nation or specialty, human anatomy has been a scientific subject of great importance for all Health Sciences courses, being relevant to the majority of the programs and compulsory for students during their first year at university [12], [13].

Anatomy teaching is usually based on didactic lectures overloaded with diverse materials (slides, drawings, atlases) used to demonstrate body structures and their function and supplemented with skeletal material, plastic model and dissection practices [14]. Peer teaching is also adopted as a mean of actively engaging students in the learning process [15]. Moreover, technology also contributes to the enhancement of the learning experience through interactive participation [12].

Cadaver dissection is an important tool for a detailed study of the human body structures. This technique is traditionally adopted in many medical schools and universities all around the world and it is also practiced in postgraduate programs [16].

Despite the problems related to cadavers' demand, cadaveric dissection is considered as the best fit for a comprehensive anatomy education [17]. Dissection is time-honored and dates back to the Renaissance period [18]. In the dissection laboratory is provided an introduction to the variability of the human body, and the students can acquire anatomy vocabulary not only by memorization, but also by touching, seeing and feeling the structures [19]. In addition, cadaveric studies give students the opportunity to learn about anatomical and pathological variations, findings that are not usually reproduced in anatomical models [20].

Dissection is a tool of effective understanding of anatomy but also responsible for some unintended uncomfortable physical and psychological negative experiences [21] Furthermore, this traditional methodology is prone to accidental cuts, shocks and other injuries and hazards [17].

Dissection halls should be planned to be a students-friendly environment, teachers should prepare their students previously and help them with strategies to deal with any resultant negative experience, enhancing their learning process [22]. In addition to the aforementioned adverse aspects, cultural changes and scientific progress have been modifying the role of dissection in medical education [23].

Plastination is also a traditional anatomy teaching method widely adopted worldwide. It consists on forced polymer impregnation and is an ideal method for long-term preservation of organs, dissected specimens or body slices [24]. Plastinated prosections can be used adjuvant with dissection, providing an additional anatomy learning tool [12], [24].

2.1 Innovative anatomy teaching methods

2.2.1 Augmented and Virtual reality

With the advancement of health education, several technologies are being inserted into practices, including augmented reality (AR) and virtual reality (VR). Being VR an interaction technology that can be used through 3D resources with a more elaborate view and AR is another method of bringing this virtual reality to the real world. Both combine the ease of learning brought about by technology with a higher educational outcome [25].

It is noted that these technologies transform this learning moment no longer as just an obligation, but as something more pleasurable to study, given the difficulty of learning anatomy, making studies inviting above all for freshmen [2].

Both technologies can be applied in several areas of health, the virtual reality environment that allows the student to interact with a simulated environment of reality, and augmented reality allowing the sensation of this environment. Seeing that these technologies provide an improvement of the students' techniques and also bringing greater support in simulations for real cases. In addition, augmented reality is providing a more complete three-dimensional perception by mixing real and virtual elements [26].

2.2.2 Other methods

a) Mixed reality: Nowadays many modern tools are used to study human anatomy and more interactive and realistic medical experiences take advantage of advanced visualization techniques like mixed reality, improving the understanding [27]. The interpretation of what means MR depends on one's context [28], but MR is so called as the combination of real objects and virtual reality because it allows that the user play with virtual object or real object in a virtual reality [27].

b) 2D and 3D Methods: These methods are based on visualization of images. 2D is visualized in two axes and 3D is visualized in 3 axes. They are efficient tools for improving the students' studies that are utilized at classrooms and universities, providing new possibilities for teaching and to learn. One of the most improvements is in the Human Anatomy studies, which allows an interactive three-dimensional space to learn and thus enhance the understanding [29].

3 METHODOLOGY

This systematic literature review was performed using Parsifalfootnotehttps://parsif.al/, an online tool for designing reviews protocols. The adopted review protocol, objectives, research questions, search strategy, selection criteria and quality assessment are presented in this section. The key contribution of this study is to indicate implementation and other challenges to be overcome. The following research questions were defined for this purpose:

• What innovative technologies are being used as tools for improving healthcare students Anatomy learning?

• What are the main challenges and perspectives related to them?

Relevant articles were identified by searching in Embase, IEEE Digital Library, Pubmed, ScienceDirect, and Web of Science and gathered in Parsifal in November 2021.The basic search logical expression was defined from keywords and their synonyms using Boolean operators (and, or). Its general structure was as follows: ((”Health Sciences” OR ”Healthcare”) AND (”Innovation” OR ”Disruptive technology”) AND (”Anatomy education” OR ”Anatomy learning”)). This review included studies published from 2019 to 2022. Duplicate studies were removed. In order to define studies fitting the scope of this review, the following inclusion criteria were considered: (1) Original research published in peer reviewed scientific journals; (2) Available in English; (3) Published between 2019 and 2022. The following exclusion criteria were defined in order to discard studies that are not relevant to this study: (1) Bibliographic reviews, editorials and letters; (2) Availability of full text. Quality assessment was conducted aiming to mitigate biases and systematic errors. Three researchers performed an eligibility assessment in an unblinded, standardized, and independent manner. A three-item scale (satisfies = 1, does not satisfy = 0, and partially satisfies = 0.5) was used to evaluate the conformity of the selected studies with the quality criteria. A score higher than 2.0 was defined as a cutoff score (max score = 3.0, calculated based on the number of questions and on the answer of greater weight). This initial screening process was performed by assessing the title and abstract of the papers selected after applying the aforementioned selection criteria. Quality assessment questions/criteria used in this review were:

• Does this study present a new technological learning methodology/technique applied to healthcare students learning?

• Does this study mention any challenge to the implementation or to the acceptance of educational innovative technologies?

• Does the title of the study include any of these words:" Health Sciences" AND/OR "Healthcare" AND/OR "Innovation" AND/OR "Technology" AND/OR "Anatomy" AND/OR "Learning" AND/OR "Education"?

Disagreements were resolved through discussions. No consensus situation did not occur during the process.

4 RESULTS

The databases electronic search identified 149 references - 15 in Embase (10.1%), 3 in IEEE Digital Library (2%), 44 in PubMed (29.5%), 80 in ScienceDirect (53.7%) and 7 in Web of Science (4.7%). The number of articles per year are shown in Figure 1, and the number of articles per database are shown in Figure 2 Seventy-nine articles were excluded based on their title and/or abstract analysis according to inclusion and exclusion criteria and 9 were duplicates. Therefore, 61 studies were selected for inclusion according to their titles and abstracts. From the 61 selected articles, 51 were eliminated after scoring lower or equal to the defined cutoff score after Quality Assessment (see Methodology). Finally, 10 studies met the minimum cutoff and were fully read for data extraction. None of them were excluded during data extraction. Thus, these 10 articles were accepted and discussed in detail in this review. A flow diagram showing the study selection process is presented in Figure 3. A narrative synthesis of the articles' results is presented in the following section.

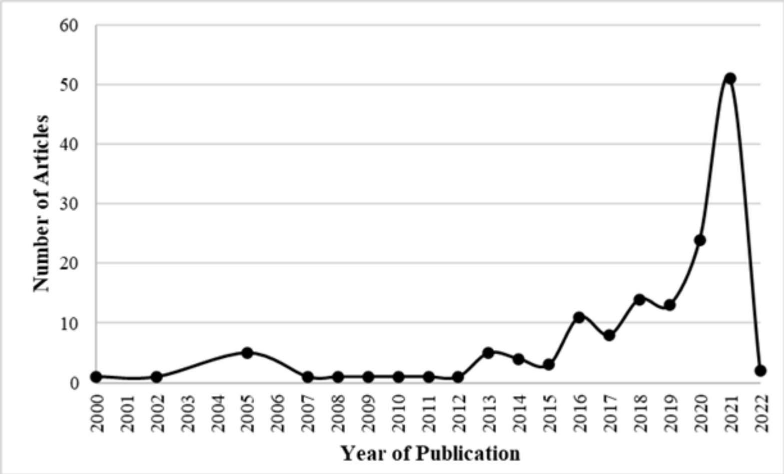

Fig. 1. Number of articles per year.

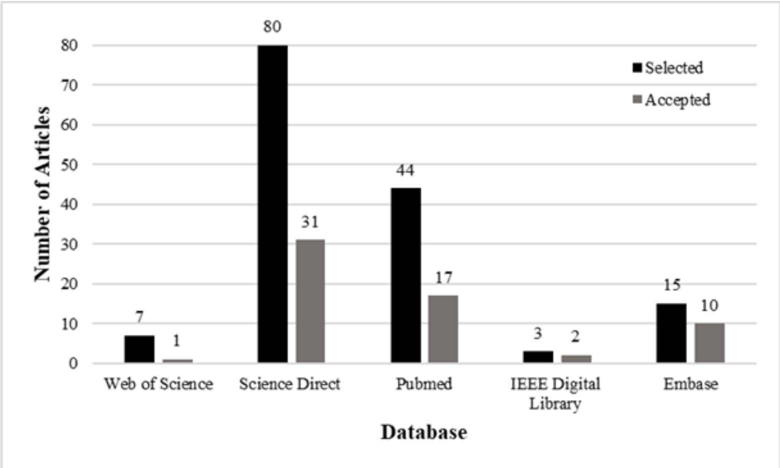

Fig. 2. Number of articles per database.

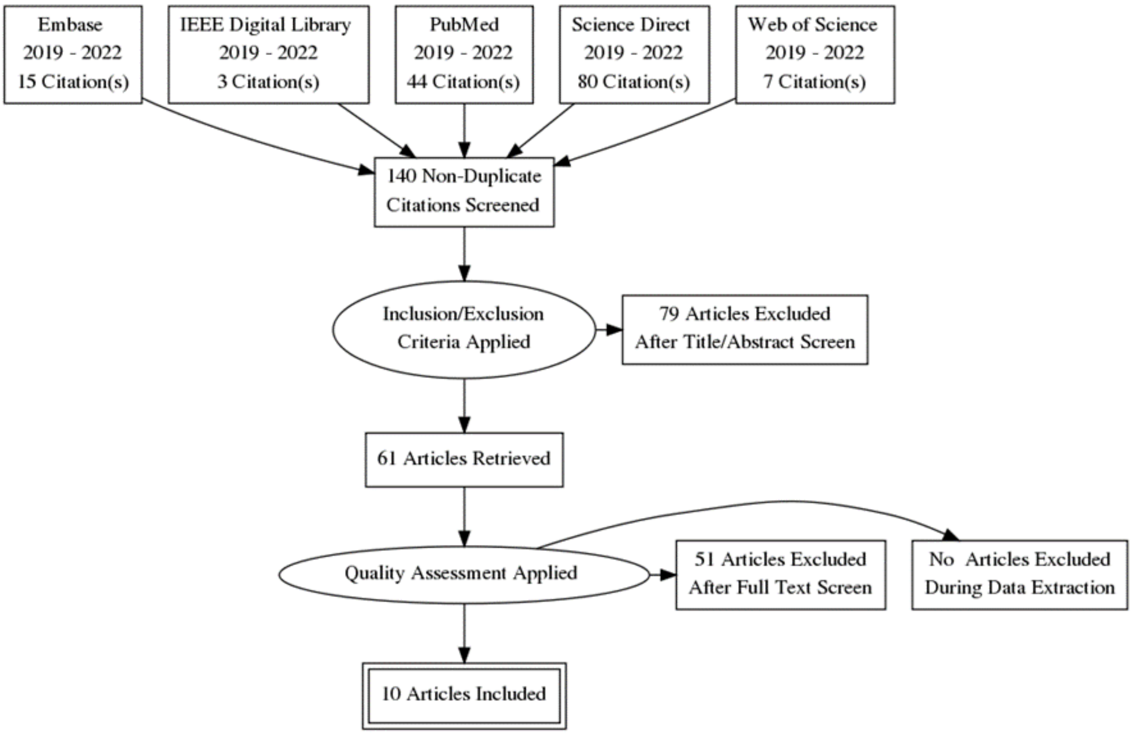

Fig. 3. Review flow diagram.

4.1 Selected Works

Adhikari et al. [30] conducted a two-stage sequential mixed methods study aiming to investigate the impact of Immersive Virtual Reality (IVR) on nurses' self-efficacy and their perception of the acceptability of IVR to their education. Nursing students (N = 19) at Edinburgh Napier University were selected as participants. In stage one a non-randomized pre, post-test assessed the effect of and IVR sepsis game on self-efficacy. It was observed a significant increase in self-confidence (26.1%, P < 0.001) and a significant decrease in anxiety (23.4%, P < 0.001). Stage two consisted of group discussions and one to one interview. It revealed four overarching themes: acceptability, applicability, areas of improvement of IVR sepsis game and limitations of IVR.

Wang et al. [29] developed a methodology to exam students' (N = 52) ability to retain knowledge learned in an anatomy course after 30 days via using three learning tools (text only, 3D visualization in a 2D screen – 3DM - or mixed reality - MR) for 20 minutes. The students took an anatomy test measuring spatial and nominal knowledge immediately after the learning intervention and another 30 days later. When evaluating knowledge acquisition, the average number of correct answers was significantly lower in the MR group (M = 2.32, SD = 1.81) compared to the text-only group (M = 4.83, SD = 1.20, p = 0.001) and 3DM group (M = 3.93, SD = 1.62, p = 0.008). There were no significant differences in the performance of the learning groups when comparing spatial type questions (F(2,49) = 0.353, p = 0.704) or mixed type questions (F(2,49) = 0.776, p = 0.466). When evaluating long-term knowledge retention it was observed significant differences when comparing the differences in anatomy test scores between the learning groups over time (F(2,48) = 5.624, p = 0.006) and question types performance between learning groups (F(2,48) = 3.566, p = 0.036).

Boyaci et al. [10] aiming to investigate the contribution of Augmented Reality (AR) to spinal surgery education performed an experimental education study with 10 candidates (N = 10) who had to apply 36 pedicle screws with C2-C3 posterior transpedicular fixation technique to nine vertebrae models produced via a 3D printer. Due to its fixation difficulty and rarity this study focused on the cervical vertebra segment. In comparison of Grade 0 (safe) screws to other grades: 6/18 screws (33.3%) in the free-hand technique Group (n=18), and 14/18 screws (77.8%) in the AR Group (n=18) were measured for screw insertion safety ratios. The difference was statistically significant (p=0.018) showing that using AR to apply pedicle screws to the experimental vertebrae model increases the safety screw ratio significantly.

Grannum et at. [3] evaluated an interactive 3D dynamic visualization tool (3D Viz) designed to improve spatial thinking and anatomical learning. An experimental intervention was conducted to compare 3D Viz with comparable 2D teaching materials (N = 28). The intervention included a survey, learning tasks using 3D or 2D materials, a spatial anatomy test and a measurement of mental workload using the NASA Task Load Index. The 3D group performance on the spatial anatomy knowledge test was on average 7.55 out of 10 and the 2D group scored on average 5.72 (t-test -6.39 at p<.05). The results of the mental load as measured by the NASA TLX instrument showed that from the six areas examined only two (performance component statement and frustration component statement) showed statistical significance between the 2D and 3D groups confirming that 3D Viz did not increase mental workload compared to customary 2D representations.

Bogomolova et al. [32] highlighted the development of a virtual 3D assessment scenario for students and teachers: a 10-minute session of anatomical knowledge assessment with real-time interaction between assessor and examinee, both wearing a HoloLens and sharing the same stereoscopic 3D augmented reality (AR) model. An AR application for HoloLens®, Version 1, (Microsoft, Corp., Redmond, WA) was developed to integrate the anatomy test and anatomical 3D model into a virtual 3D assessment scenario. Students and trainees (N = 16) reported a preference for the virtual 3D assessment over cadaveric/specimen assessment.

Iwanaga et al. [11] used a free application software (Qlone) to create 3D anatomical models (extracranium and intracranium of adult skull, fetal skull, mandible, temporal bone, second cervical vertebra, and ilium). The visibility of the anatomical structures was scored according to the following rating system: 1, good; 2, acceptable; 3, poor/non-visible. The items with average scores = 2 were recorded as "good/acceptable" and those > 2 were recorded as "poor." A total of 53 anatomical structures were evaluated by nine observers, visibility was good/acceptable for most of the 53.

Wirza et al. [31] presented an interaction method for wearable AR (augmented reality) by using VR box with virtual buttons that react as the user's hand moves through them. Based on the user experience of using the VR Box, 8 out of 10 respondents said the use of the VR Box was very uncomfortable, especially for those wearing glasses. Additionally, the VR Box is a little bit heavy, and users will find it difficult to use it for a long time, while this method requires them to use it throughout their study. As for the accuracy of the virtual button function, 8 out of 10 respondents said that the virtual button had high sensitivity and inaccuracy.

Wainman et al. [32] presented a methodology to check if virtual (VR) and mixed (MR) reality presentations of pelvic anatomy will have an advantage over two-dimensional (2D) presentation. A total of 140 students participated in this study. Participants were randomized into one of four groups. The groups involved the MR model with and without eyepatch, and the VR model with and without eye patch. The MR and VR learning modalities were significantly inferior to the physical model (PM) for learning this anatomy. The VR modality was superior to MR and the MR modality was not different from learning the structures using 2D, key views of the specimen. In the present work, the removal of stereopsis significantly decreased performance on the PM and VR, but not the augmented reality (AR), learning modalities.

Wainman et al. [33] performed a study with 78 undergraduate students who studied female pelvic anatomical structures at both physical and virtual reality (VR) models and were tested on their knowledge immediately and 48 hours after learning. The female pelvis was chosen as the learning model for its 3D complexity and numerous layers required for dissection. Participants in all groups were given 10 minutes to learn the names, locations, and spatial relations of 11 structures from either the VR or physical model. Both models were interactive, allowing participants to manipulate the pelvic structures to display different views of the dissection. There was no within subjects main effect of modality, $F(1,51) = 0.005$, $P = 0.944$, $\eta 2 < 0.0001$, suggesting that participants learned similarly from both physical and VR models. There was no within subjects main effect of test day, $F(1,51) = 1.764$, $P = 0.190$, $\eta 2 = 0.033$, suggesting that participants performed similarly across days. A significant between-subjects main effect of visuospatial ability was found, $F(1,25) = 12.415$, $P = 0.001$, $\eta 2 = 0.349$, with the high visuospatial ability group ($M = 35.4$, $SD = 13.2$) performing better overall than the low group ($M = 54.0$, $SD = 13.2$) with a large effect size (Richardson, 2011). There were no interactions across any factors (modality, test day, visuospatial ability), $F(1,25) < 2.157$, $P > 0.154$.

Brewer-Deluce et al. [34] detailed the development of a smartphone application capable of displaying monoscopic two-dimensional (2D) or stereoscopic 3D images with the use of an inexpensive cardboard headset for use in spot examinations. Participants (N = 51) completed three spot examinations specific to their level of study, one in each of the modalities (2D, 3D, laboratory) as well as a mental rotation test (MRT), Stereo Fly stereotest, and cybersickness survey. A significant effect of modality ($F(2,43) = 4.468$, $P = 0.017$, = 0.172, observed power = 0.736) was found suggesting 2D < 3D and 2D < Laboratory scores ($P = 0.014$ and 0.003, respectively). No other effects were significant.

A summary of the selected works is shown in Table I.

Table I. Summary of selected works.

Authors	Title	Year	Methodology/Technology Studied	Main Conclusions	Main Limitations
Wirza et al.	Mobile Augmented Reality Application with Virtual Buttons as User Interaction and Stereoscopic View for Medical Learning	2019	Mobile augmented reality app with virtual buttons	Virtual buttons interaction let learning experience more interesting.	Virtual buttons size and position.
Wainman et al.	The Critical Role of Stereopsis in Virtual and Mixed Reality Learning Environments	2020	Virtual and mixed reality learning environments	Superiority of physical models over various XR modalities in anatomical education.	Anatomical structures chosen; Monocular and binocular visions differences.
Boyaci et al.	Augmented Reality Supported Cervical Transpedicular Fixation on 3D-Printed Vertebrae Model: An Experimental Education Study	2020	Cervical transpedicular fixation on 3D-printed vertebrae model	Augmented Reality increases the safety ratio of cervical pedicle screw fixation significantly	The size of the tracker; Vertebral column's flexibility.
Wang et al.	A Randomized Control Trial and Comparative Analysis of Multi-Dimensional Learning Tools in Anatomy	2020	Text-only, three-dimension visualization in a two-dimensional screen (3DM), or mixed reality (MR)	An enhanced learning experience is dependent on familiarization and orientation with the adopted tools.	Small sample; Subject choice and generalization; Pressured learning sessions.
Wainman et al.	Virtual Dissection: An Interactive Anatomy Learning Tool	2020	Anatomy learning from VR and physical models	Virtual reality models require further scrutiny to determine the conditions under which they can promote anatomy learning.	Participants number; Plastic model used.

Bogomolova et al.	Development of a Virtual Three-Dimensional Assessment Scenario for Anatomical Education	2021	3D Assessment scenario with HoloLens and augmented reality model	Virtual 3D assessment can address aspects of the growing misalignment between learning, assessment, and clinical practice.	Chosen anatomical region; Different institutions involved.
Iwanaga et al.	Easy three-dimensional scanning technology for anatomy education using a free cellphone app	2021	3D anatomical model with free application software	The 3D scanning app used enables anatomy educators to provide better content during online lectures.	Anatomical structure selected; No comparison with other 3D scanners
Brewer-Deluce et al.	Virtual Reality Bell-Ringer: The Development and Testing of a Stereoscopic Application for Human Gross Anatomy	2021	Smartphone application displaying 2D and 3D images	The application is a promising tool for its portability, affordability, and accessibility.	Potential carry-over effects; Application not fully interactive.
Grannum et al.	Design and evaluation of an interactive 3D dynamic visualization tool for functional anatomy	2021	3D dynamic visualization (3d Viz)	3D Viz can be used to improve spatial thinking and anatomy knowledge	Participants number; Mobile phones used.
Adhikari et al.	A mixed-methods feasibility study to assess the acceptability and applicability of immersive virtual reality sepsis game as an adjunct to nursing education	2021	Immersive Virtual Reality (IVR) sepsis game	The IVR game has a positive impact on knowledge, decision-making skills and confidence outcome.	Small sample; No data on previous exposure to VR technology collected; Self-efficacy measured at a single time point.

5 DISCUSSION

This review indicates an increase in the application of Virtual Reality (VR) [30], [32], [33], Augmented Reality (AR) [10], [31], Mixed Reality (MR) [29] and 3D methods [3], [7], [11] in the teaching of anatomy as a new way to study in the educational environment. Most of the articles present studies with VR or 3D methods using games [30], Hololens [7], cardboard headset [32], free application software [11], eyepatch [32], cellphones [3]. Some articles show benefits, but others show the opposite.

It was observed in the research from teaching using Virtual Reality (VR) methods as used in the sepsis game [30], and Augmented Reality (AR) as used in the mobile augmented reality app with

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virtual buttons [31], that even due to sample size limitations for each research, or due to the impossibility of being able to pick up and rotate the anatomical model, it is possible to notice that the learning process became more dynamic and the content better fixed. In studies with 2D and 3D models, as in the online application [7], in three-dimensional anatomy models [11], and in the cybersickness survey [34], limitations were noted, such as small screens or low quality for displaying content, thus making part of learning difficulty, but not invalidating the effectiveness of teaching with technologies. Moreover, in the study using a sepsis game with Immersive Virtual Reality (IVR) for health education, it was possible to observe the development of skills and competences of the participants resulting in greater interest in 3D assessment rather than traditional methods [30].

Also, it is possible to note that some studies show psychological factors influencing the results, such as trust at the time of decision-making, developed after the experience obtained with a game to simulate real cases in a safe environment once students were not dealing with a real patient in the moment. Participants perceived that the game experience made them more confident and prepared for assessments, as well as contributing to their knowledge. Consequently, being less anxious compared to other situations in laboratories [30] [7].

Continuing, the teaching modality using augmented virtual reality diverged in two testimonies. First, a study using 3D Augmented Reality (AR) claims to be better for people with lower visuospatial abilities, with the strength of being able to interact merging between the real environment and the 3D virtual content that the user can manipulate [7] allowing him to demonstrate his knowledge more effectively. On the other hand, another study shows the difference in the performance of students with high and low visuospatial ability in the use of Virtual Reality (VR), reporting that those with low visuospatial ability had a worse performance in relation to the other group [33] thus reporting the importance of visuospatial ability in the use of virtual models compared to physical models of anatomy. One of the reasons that could explain this divergence would be the difficulty in validating assessment methods using 3D models. Another reason suggested by a study is the fact that they present a lot of information hindering memorization [33] which is a contributing factor to this difference between students with low and high visuospatial ability.

Thereby, some difficulties are identified despite efforts to study these new tools present in the environment of human anatomy education. The biggest barrier present in the literature is the small sample size of participants in these studies, just one article [32] had presented more than 100 volunteers. This makes it harder to confirm search results. Another difficulty present is the little time available to participants in the learning session [7], [29], [32], [33]. Generally, just ten minutes are given, but it is not sufficient for volunteers to memorize the tasks that they are going to do, that may be confusing the results. Other barriers are present, like the repetition of the same test [29]; the mix of physicians and medical students may also be considered as a limitation study, because of the difference in their experience [10]; the application of the survey on-line, the use of mobile phones because the small screen and the reduced resolution may have had an impact on how participants visualized and used the 2D/3D [3]; the non-comparison quantitatively with other 3D scanners and different scan results [11]; problems with the technological supports used [31]; participants that were restricted from picking up or rotating the model, this difficult some participants to learn; the little washout period between the tests [33]; no pre-exposure assessment; lack of interactivity [34].

Thus, further research needs to be implemented, aiming for a larger number of participants, more time in the learning process and better technological support to improve the results about recent tools used in the human anatomy environment.

6 LIMITATIONS

Although a good amount of material was obtained for this study, the main limitation is the number of studies related to new forms and teaching methodologies. Other limitation is the fact that the majority of the included studies did not have more than one hundred volunteers or offered short learning sessions time to the participants. Even with the present limitations, it is noted that the technologies used to introduce this new teaching modality were widely accepted by the participants and provided a better learning experience.

7 LESSONS LEARNED

In this study it can be observed the different ways to introduce anatomy teaching with innovative, studied and tested methods. It can also be observed that health education with the help of technologies that simulate real anatomical structures is already a reality. In addition, it is increasingly essential for the academic and professional enrichment of students, guaranteeing them greater retention of the content and more security when putting into practice what has been taught, contributing to both psychological and emotional factors.

In addition, the inclusion of virtual, augmented and mixed reality in health education is notorious, being increasingly used in order to enhance students' abilities [16]. Ahead of AR, RM stands out for extending the experience using virtual resources in the real world, delivering better and more real learning, thus bringing a study practice as clear as in clinical care [16]. Evidencing that the trend with the increase of technological innovation in teaching and the interest in immersive technologies also grows their use in the coming years. The benefits obtained using them are stated, demonstrating that these resources stand out from more traditional teaching methods, thus having a much more effective learning response and better retention for students [17]. Also, with the advancement of computing, more and more applications arise that insert this reality into the academic environment. One of these that we can mention is the Anatom! application that uses a detailed anatomical model as a simple, didactic, dynamic and enriching way for the continuity of anatomy

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studies, improving your knowledge from anywhere. As the literature states, these technologies make life easier not only for students but also for teachers, due to the practicality of being able to learn from wherever they are and thus not retaining students' knowledge only in class [18].

8 CONCLUSION

This study addresses the most recent surveys based on the filter and review of several studies from current databases about the potential educational innovations and modern methods of teaching human anatomy for healthcare students to enhance the transformations of studies' methods of human anatomy in health due to the advance of technology and to highlight the main forms of students' learning to indicate implementation and other challenges to be overcome.

In this way, compared to traditional methods, like reading books, cadaver visualization and static images, the implementation of Virtual methods, 3D methods, Augmented reality, Mixed reality and other tools intensifies the capacity of learning and retention of students and improves students' education. Furthermore, these new studying tools decrease anxiety, decrease stress in moments when making decisions, and increase the safety sensation in students and the rates of success in different procedures.

Therefore, these new tools have some barriers to be overcome, like the difficulty for implementation, the lack of technological support, but they show big educational potential and are excellent ways to improve and transform education, making it more efficient, economic, practical and accessible.

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