Literature review

Journals BAHIANA
SCHOOL OF MEDICINE AND PUBLIC HEALTH

Application of active methodologies in the teaching of anatomy supported by technological resources: narrative review

Aplicação de metodologias ativas no ensino da anatomia sob respaldo de recursos tecnológicos: revisão narrativa

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ABSTRACT | INTRODUCTION: Starting from a concentric bias to integrative practice in the academic environment, innovation and interactivity are fundamental alternatives in the progression of learning program content, supporting the complementation of the traditional expository model of class. Focusing on the human anatomy component, there have been no significant changes in teaching practice, even with technological advances. **OBJECTIVE:** Review the literature on active methodologies with the help of innovative technological resources that are used in the teaching-learning process of anatomy. **METHODOLOGY:** This is a descriptive narrative review, carried out by searching for scientific articles and theses in portuguese and english published in the last five years in the National Library of Medicine (PubMed MEDLINE) and Virtual Health Library (VHL) databases. The following keywords were used in the Health Sciences Descriptors (DeCS): "Aprendizagem Ativa" AND "Anatomia" AND "Tecnologia Digital" AND "Active Learning" AND "Anatomy" AND "Digital Technology". **RESULTS AND DISCUSSION:** Among the main active methodologies, we highlight didactic software, social networks, construction of interactive 3D materials, gamification and virtual reality, analyzed in 11 articles, as a way of promoting active and integrated education, making it possible to expand interactivity in classes, serving as a stimulus to sharpen skills such as creativity and protagonism in the training process, as well as providing innovation in conventional pedagogical structure. However, the implementation of these practices still faces challenges mainly related to cost, teacher training and curriculum adaptation. **CONCLUSION:** Active methodologies integrated with innovative technological resources represent a promising way to modernize the teaching of human anatomy in line with new educational demands.

KEYWORDS: Active Learning. Anatomy. Digital Technology.

RESUMO | INTRODUÇÃO: Partindo de um viés concêntrico à prática integrativa no ambiente acadêmico, a inovação e a interatividade são alternativas fundamentais na progressão do aprendizado dos conteúdos programáticos, respaldando a complementação do modelo tradicional expositivo de aula. Em anatomia humana, não houve mudanças expressivas na prática pedagógica, mesmo com os avanços tecnológicos. **OBJETIVO:** Revisar na literatura as metodologias ativas, sob respaldo de recursos tecnológicos inovadores, que são utilizadas no processo de ensino-aprendizagem da anatomia. **METODOLOGIA:** Trata-se de uma pesquisa descritiva do tipo revisão narrativa, realizada por meio da busca de artigos científicos e teses em português e inglês publicadas nos últimos cinco anos, nas bases de dados National Library of Medicine (PubMed MEDLINE) e Biblioteca Virtual em Saúde (BVS). Foram utilizadas as palavras-chave presentes nos descritores em Ciências da Saúde (DeCS): "Aprendizagem Ativa" AND "Anatomia" AND "Tecnologia Digital" AND "Active Learning" AND "Anatomy" AND "Digital Technology". **RESULTADOS E DISCUSSÃO:** Dentre as principais metodologias destacam-se softwares didáticos, redes sociais, materiais interativos em 3D, gamificação e realidade virtual, analisados em 11 artigos, como vias de promoção ativa e integrada da educação, possibilitando ampliar a interatividade nas aulas, servindo de estímulo à aguça de competências como criatividade e protagonismo no processo de formação, além de propiciarem inovação da estrutura pedagógica convencional. No entanto, a implementação dessas práticas ainda enfrenta desafios, principalmente relacionados ao custo, à formação docente e à adaptação curricular. **CONCLUSÃO:** As metodologias ativas integradas a recursos tecnológicos inovadores representam um caminho promissor para modernizar o ensino da anatomia humana, alinhado às novas demandas formativas.

PALAVRAS-CHAVE: Aprendizagem Ativa. Anatomia. Tecnologia Digital.

Submitted May 8th, 2025, Accepted July 16th, 2025,
Published Oct. 14th, 2025
Inter. J. Educ. Health, Salvador, 2025;9:e6241
https://doi.org/10.17267/2594-7907ijeh.2025.e6241 | ISSN: 2594-7907
Assigned editors: Iêda Aleluia, Ana Cláudia Carneiro

How to cite this article: Carmo GS, Medina KSF, Sousa CRA, Ribeiro LCV, Azevedo JM. Application of active methodologies in the teaching of anatomy supported by technological resources: narrative review. Inter J Educ Health. 2025;9:e6241. http://dx.doi.org/10.17267/2594-7907ijeh.2025.e6241

1. Introduction

Higher education in the health sciences faces distinct challenges because of the complexity of its content and the simultaneous need to cultivate both practical and theoretical abilities that are indispensable for safe patient care. Emerging pedagogical approaches are responding to technological change and the contemporary demands of professional training, offering a learning experience that is more interactive, dynamic, and engaging, with the potential to enhance learning outcomes[1,2].

The study of human anatomy is essential for training health professionals, providing the foundation for understanding bodily structure and function[3]. Illustrations and cadaveric dissection have traditionally been central to anatomical learning, a practice that also nurtures respect, ethics, and professional values[4]. Nonetheless, cadaveric dissection entails substantial hurdles: it requires purpose-built facilities, trained staff, and a stable supply of bodies, often limited by scarcity of voluntary or unclaimed donors and by bureaucratic procedures[5]. Lectures are usually delivered separately from practical sessions, which makes it harder for students to connect theory with practice, given the large number of structures and the complexity of anatomical terminology[6].

Active learning methods combined with innovative technological resources have gained prominence, allowing students to take a leading role through flexible, accessible, interactive, and visually enriched study experiences that align with an increasingly digital world[3]. The COVID-19 pandemic accelerated the adoption of digital platforms and virtual tools for teaching anatomy, highlighting their potential to promote greater engagement and better spatial understanding of anatomical structures[7,8].

Several digital technologies, including augmented reality (AR), virtual reality (VR), three-dimensional printing, and tablet-based applications with complementary features[8] can serve as viable alternatives for anatomy instruction[1]. Three-dimensional models, emphasized in the study by Duarte et al.[9], stand out for their versatility and pedagogical value. Printed 3D models, reviewed by Brumpt et al.[10], are feasible, low-cost, and beneficial in anatomy education, especially when they replicate complex regions and are used by early-stage medical students. More realistic models, however, demand higher-end printers and considerably longer design periods, increasing overall costs. From an educational standpoint, such models improve learning outcomes and student satisfaction. Technologies based on AR are particularly promising for topics that require spatial visualization of anatomical relationships, enhancing learners' engagement and understanding[11].

In light of these considerations, it is important to examine in depth the advantages, constraints, and challenges of these approaches. This narrative review therefore aims to analyze how active learning methodologies integrated with technological resources have been applied in human anatomy education, offering guidance for modernizing pedagogical practice. Such modernization can help achieve a more rounded professional preparation suited to a constantly evolving health-care system, bearing in mind that the best way to teach contemporary anatomy is to combine multiple complementary resources.

https://doi.org/10.17267/2594-7907ijeh.2025.e6241 | ISSN: 2594-7907

2. Methodology

This study takes the form of a narrative literature review. Searches were carried out in two databases regarded as pre-eminent for research on human anatomy: the National Library of Medicine (PubMed/MEDLINE) and the Virtual Health Library (BVS). The Boolean operator “AND” was combined with the following Health Sciences Descriptors (DeCS): “Aprendizagem Ativa,” “Anatomia,” “Tecnologia Digital,” “Active Learning,” “Anatomy,” and “Digital Technology.”

Inclusion criteria were: (i) original research articles or reviews that dealt explicitly with active learning methodologies combined with technological tools in anatomy teaching; (ii) availability of the full text; and (iii) publication between 2018 and 2024 in either Portuguese or English. This time frame was chosen to focus the analysis on the most recent body of scientific output. Studies published outside that period, written in other languages, or lacking a link between active methodologies and technology were excluded.

The initial search retrieved 84 studies from PubMed/MEDLINE and 13 from the BVS. Of these, 32 were excluded for not meeting the selection criteria, and 21 duplicates were discarded after manual screening.

Nineteen articles were read in full, and a further six were excluded because they did not address a technological resource in the process of learning human anatomy. Consequently, 13 articles were included in the narrative review.

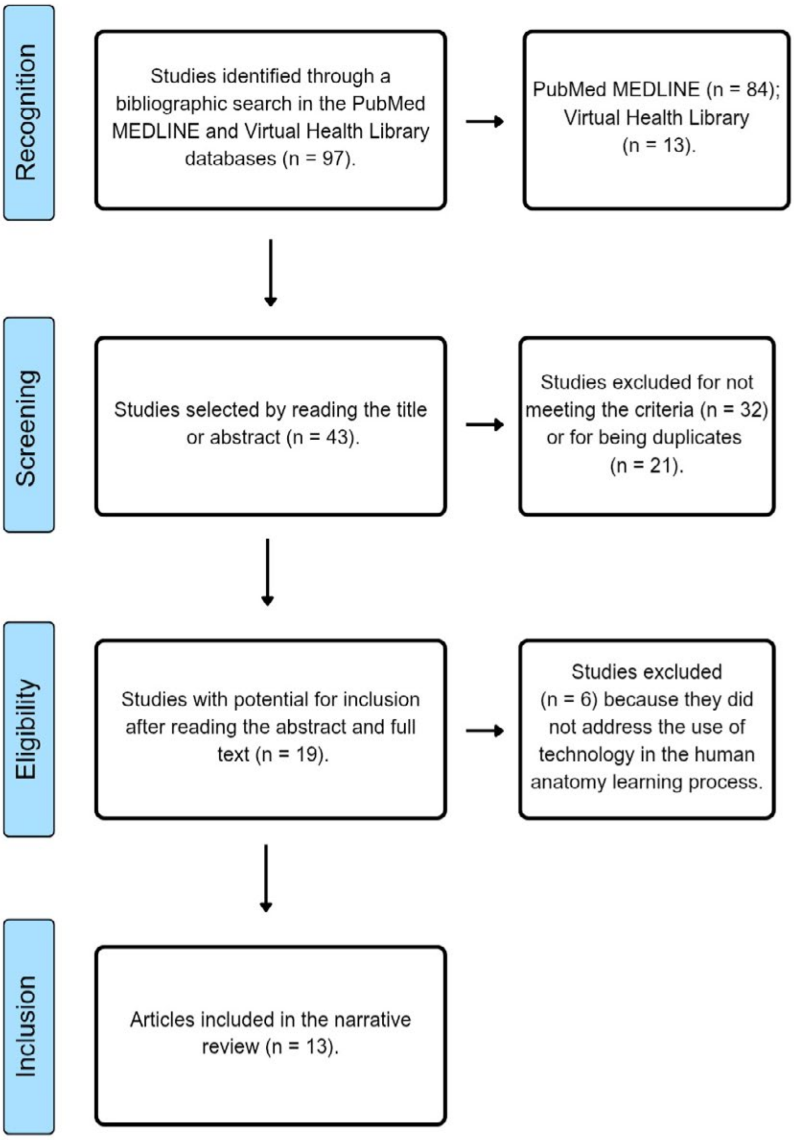
Data extraction was performed with Microsoft Excel, recording the following variables: authorship and year of publication, study methodology, technological resources employed, and the reported advantages and limitations of those resources.

3. Results

A total of 97 studies were initially identified across both databases. After the screening process, which involved reviewing titles, abstracts, and full texts, 13 articles were selected for inclusion in this review (Figure 1).

Analysis of the selected studies highlights a range of active learning methodologies integrated with technological resources, such as smartphones and social media, three-dimensional anatomical models (3D), gamification, and augmented and virtual reality (AR/VR). Reported benefits include increased student engagement, promotion of active participation, and the development of competencies such as critical thinking and problem-solving. However, challenges were also noted, such as the need for faculty training, high costs associated with acquiring and maintaining advanced technologies (3D models, VR, and AR), and the risk of distraction when mobile devices are used without clear pedagogical guidance.

Figure 1. Flowchart of the selection process for studies on active methodologies integrated with technological resources in human anatomy education



Source: the authors (2025).

Marchiori and Carneiro[12] reported the use of digital tools (interactive atlases, software, and computer programs) combined with Problem-Based Learning (PBL) in anatomy teaching. The integration of PBL with technology facilitates visualization and understanding of anatomical structures, making learning more effective. Nevertheless, the authors highlighted challenges such as faculty resistance and the need for professional development.

Several studies have examined technological tools in anatomy education, including 3D models, VR, virtual dissection tables, software applications, social networks, online platforms, and gamification. These tools enhance comprehension of anatomical structures and make learning more accessible. Nonetheless, barriers such as high implementation costs and the need for teacher training to ensure effective use were consistently emphasized[1,13,14].

The use of Kahoot! as an educational game platform for histology and anatomy was analyzed in studies published between 2013 and 2021. This tool fostered active student participation, provided immediate feedback, and reinforced class content, leading to more effective learning. Still, issues such as dependence on internet connectivity, superficiality of some questions, and potential distractions from mobile phone use were reported[15,16].

https://doi.org/10.17267/2594-7907ijeh.2025.e6241 | ISSN: 2594-7907

Backhouse et al.[17] investigated the use of 3D-printed models for learning the anatomy of the orbital cavity. During practical classes, students received a 3D orbital model to mark suture lines and color orbital bones. Findings indicate that students preferred 3D-printed models over two-dimensional images or textbooks for knowledge consolidation.

Bogomolova et al.[18] explored the combined use of AR and VR to create a three-dimensional virtual environment for anatomical assessment. Using a Design-Based Research (DBR) approach, the authors developed and tested an assessment model with HoloLens, allowing real-time interaction between students and evaluators. The methodology involved developing an anatomical test that integrated an augmented-reality application, enabling virtual dissection and manipulation of joints. Benefits included improved spatial understanding and collaborative learning; challenges included high costs and the need for faculty training.

During the COVID-19 pandemic, a range of technologies replaced cadaver-based teaching. A narrative review analyzed both traditional approaches and technological alternatives such as AR, VR, 3D printing, social media, and online learning, concluding that these solutions were viable substitutes under pandemic restrictions. The authors advocated for a blended approach combining traditional and technological strategies to maximize learning and compensate for reduced access to cadavers for dissection[19]. Hisham et al. similarly intertwined the pandemic context with the implementation of active learning methods in anatomy teaching, which integrated online quizzes, discussion forums, and 3D results into the learning process. This enabled comprehensive training on human anatomy, in which 3D models complemented the digital strategies discussed in the study[20].

Gloy et al.[21] compared VR to printed atlases in anatomy instruction to assess knowledge retention. Students using VR achieved better performance in follow-up evaluations. However, limitations such as small sample size and differing intervals between assessments at the two institutions were noted.

Xiao et al.[22] conducted a study involving 145 health sciences students at Swinburne University of Technology, implementing a flipped classroom model combined with interactive materials, online 2D and 3D anatomical models, virtual dissection tables, and virtual human dissectors. Results showed improved learning experiences and performance, although the authors emphasized challenges such as equipment costs and the need for curricular adjustments.

Pettersson et al.[23] analyzed the digital resources used by students at Karolinska Institutet (Sweden) during anatomy studies. Frequently cited tools included Visible Body, Anki, and 3D Slicer, which students associated with a deeper understanding of anatomical structures and relationships. Nonetheless, a minority reported not using these tools, arguing that conventional textbook-based study was sufficient.

Comparative data extracted from the articles were consolidated in Table 1, summarizing the advantages, limitations, and contexts of application for each methodology analyzed.

Table 1. Comparative overview of selected studies (to be continued)

Article	Method	Technological Resources	Advantages	Limitations
Boff et al.[14]	Literature review	1) Smartphone use; 2) Virtual reality; 3) 3D models.	1) Apps such as Medical Dictionary, Medscape, and Google/Wikipedia support learning; 2) Stereoscopic glasses allow deeper immersion and better visualisation of structures; 3) Anatomical structures can be viewed precisely.	1) Improper use may lead to dependence, sleep disorders, headaches, and eye strain; 2) The study reported no drawbacks for this method; 3) 3D models are less realistic than plastinated Specimens.
Almeida et al.[13]	Literature review	1) 3D technologies; 2) Virtual anatomy table; 3) Social media.	1) Motivates students, keeps their attention, and enables visualisation of small structures; 2) Enhances students' knowledge; 3) Facilitates Synchronous and asynchronous exchange of ideas and teaching materials.	1) No disadvantages reported; 2) High purchase and maintenance costs; 3) Excessive daily use may cause distraction and dependence.
Marchiori and Carneiro[12]	Literature review	General use of digital resources (high-quality images, interactive atlases, video lectures, clinical videos, games).	Promote student autonomy and interest, improve theoretical knowledge of anatomical structures, stimulate the senses and self-reflection, and modernise education.	Possible dependence depending on student maturity; need for staff training and adaptation.
Campos et al.[1]	Literature review	1) 3D models; 2) Radiological images; 3) Simulators and games.	1) Allow visualisation of structures from many angles; 2) It helps in the identification of bone structures, promoting learning, in addition to helping in diagnoses and recognition of structures; 3) Create a playful environment, encourage participation, foster content retention, and develop critical thinking and memory.	1) High cost of models; 2) High cost of full-body scanning and a need for intensive supervision and specialised staff; 3) Headaches, difficulty focusing when using VR, technical problems, lack of tactile experience, and software-use challenges.
Backhouse et al.[17]	Mixed-methods study	3D-printed model of the human orbit.	3D orbit model improved spatial understanding and could be accessed at any time.	Limited fidelity of the model; students were wary of errors arising during co-creation and of how to correct them.
Donkin et al.[16]	Literature review	Gamification via the quiz app Kahoot!	Enhances engagement, problem-solving, teamwork, and short-term knowledge retention; fosters collaboration.	Smartphones can be used for non-academic purposes, causing distraction.
Xiao et al.[22]	Mixed-methods study	Flipped classroom for neuroanatomy and regional anatomy, integrating digital dissection table and a group multimedia task.	Increased learning experience and confidence in anatomy; Improved performance in clinical assessments; Team-based teaching is associated with increased motivation, improved student perception, and better learning outcomes compared to those who are taught alone; The in-person environment encouraged active learning with an emphasis on knowledge generation; The laboratory classroom environment promoted not only student-tutor interactions, but, most importantly, student-student interactions; Research, scientific presentation, critical thinking, and digital literacy in the application areas of functional anatomy.	Since the flipped-classroom model presented in this study redirects anatomy teaching from large, didactic lectures to small, team-based interactive sessions, it makes a noteworthy contribution to pedagogical innovation by integrating multimodal digital resources and a group multimedia task, thereby promoting authentic, digitally mediated learning; however, the study does not discuss potential drawbacks.
Bogomolova[18]	Qualitative study	Real time interaction between assessor and examinee, both using a HoloLens and sharing the same 3D stereoscopic augmented-reality anatomical model.	Enhances 3D spatial understanding and appreciation of anatomical relationships, especially for students who struggle with 2-D images.	Technical difficulties with AR applications can induce anxiety during assessments; the anatomical test in the study was limited to the lower leg, constraining generalization to more complex regions such as the brain.

Table 1. Comparative overview of selected studies (conclusion)

Article	Method	Technological Resources	Advantages	Limitations
Iwanaga et al.[19]	Literature review	1) Online resources; 2) Social media (YouTube, Facebook, Twitter); 3) 3D printing; 4) AR and VR.	1) Enabled an online dissection-based anatomy course for preparation and review; 2) Increased interactivity in anatomy teaching, leading to greater student engagement and improved teacher–student communication; 3) Three-dimensional learning accommodates diverse learning styles, allowing students to engage with the material in ways that best match their individual preferences, thereby improving overall learning outcomes; 4) The use of AR and VR lets students visualise and interact with anatomical structures in three dimensions, enhancing their understanding and retention of complex concepts.	1) Preference for traditional methods was noted despite audiovisual resources; 2) Challenge of avoiding distractions on social media during the educational process; 3) Educational effectiveness of 3D compared to cadaver dissection is not yet proven, requiring further studies; 4) Student preference for traditional methods and limitations in research on the effectiveness of AR in anatomy teaching; 5) Appropriate use may depend on prior knowledge.
Côrtes et al.[15]	Literature review	Kahoot! in teaching morphofunctional sciences.	Offers challenge, content review, and a continuous, active, immersive, and enjoyable learning experience that fosters self-reflection, motivation, and quick thinking; promotes collaborative learning, encouraging attendance, creativity, and knowledge consolidation, while adding dynamism and reducing fear of failure.	Connectivity issues; inability to accommodate open-ended questions; gamification timing, content overload, and distractions; heightened competitiveness and restlessness; loss of motivation when questions are answered incorrectly; for some students, the platform failed to support learning and offered little motivational value; insufficient time to review material after mistakes; and lack of supplementary printed study resources.
Gloy et al.[21]	Research report	Virtual reality vs. textbooks.	Better long-term effects on learning anatomy; high immersion and the ability to explore a realistic human representation freely and interactively; useful as a complement to cadaver-dissection courses; enhanced knowledge acquisition.	Assessment timing differed between the schools for the initial learning phase and the knowledge test, limiting comparability of results. The study contrasted immersive VR with anatomy textbooks, yet other approaches to learning human anatomy were not examined. The sample size was small.
Pettersson et al.[23]	Mixed-methods study	1) 3D imaging tools (Visible Body, 3D Slicer); 2) Flashcards (Anki).	1) Engagement with the 3D visualisation gave students a broader sense of whole-body anatomy, placing individual parts in context and providing an overall view; 2) The flashcards helped students memorise terminology and learn the location of anatomical structures.	No disadvantages or limitations were reported regarding the use of the platforms. Some participants, however, stated that they did not use technological resources and confined their studies to anatomy textbooks.
Hisham et al.[20]	Experience report	Integration of online histology quizzes, discussion forums, and 3D printed models in anatomy teaching.	Discussion forums fostered collaborative learning, encouraging students to debate and substantiate each other's critical thinking. Three-dimensional prints of body tissues and organs complemented the digital strategies, promoting broad-based knowledge of human anatomy.	An increased demand for teachers to upgrade their skills with online tools, provoked by the abrupt post-pandemic shift in teaching methods and strategies has led to heavier workloads. Moreover, in the digital realm, there remains a lack of universal opportunity and adequate conditions for student use, as not all learners have access to suitable technological devices.

Source: the authors (2025).

4. Discussion

The findings of this review underscore the importance of integrating active learning methodologies with digital technologies as a strategy for modernising human anatomy education. Digital tools have emerged as innovative educational resources that bridge theory and practice, fostering an active teaching–learning process. Students' interest in modern media can stimulate motivation and autonomy, contributing to the development of more critical professionals who are better equipped to work in an increasingly digitised environment.

4.1 Mobile devices and social media

The growing digitisation of academic life has brought social media and mobile devices to the centre of discussions on active methodologies in anatomy education. Quick-reference apps such as Medical Dictionary, Medscape and Wikipedia have become common sources of anatomical information, revealing students' familiarity with integrating learning and technology[14].

Platforms such as Facebook and Instagram are also being used to foster academic interaction through study groups, the sharing of teaching materials and even anatomical quizzes and challenges. This approach appears to increase engagement beyond the formal classroom, giving students more relaxed and continuous contact with course content[19].

Maintaining student focus and discipline while using digital platforms during class remains difficult, as social media can be a source of distraction that disrupts learning[24]. It is therefore essential to promote intentional, responsible use of these technologies and to reinforce digital education so that students develop the skills needed for critical participation in classroom technology. The main challenge is to incorporate these tools in a planned way, using strategies that encourage critical and safe engagement. Teacher training is likewise crucial so that instructors can use mobile devices as pedagogical instruments and steer student learning effectively.

Mobile electronics also enable interactive teaching–learning platforms that provide three-dimensional images. Pettersson et al.[23] described tools such as Visible Body and 3D Slicer as useful for improving understanding and perception of the human body as a whole. In general, many online resources remain under-explored. Later we discuss another platform that has been gaining popularity as an active-learning tool: Kahoot!.

4.2 Three-dimensional models

Three-dimensional printing has become a practical option for anatomy teaching at a time when universities struggle to obtain fresh cadavers and anatomical specimens. Printed models let students inspect fine details, which fosters interest and engagement[17].

A study on upper-limb 3D models showed that, beyond enabling precise identification of muscles, nerves, and vessels, colour coding made it easier to understand and memorise structures. Despite this favourable response, students noted that plastinated models still deliver a more lifelike representation[14].

Campos et al.[1] observed that printed models help to build spatial perception by allowing learners to recognise and analyse anatomical structures from multiple angles. In research with optometry students, three-dimensional models of the orbital cavity improved understanding of spatial relationships, though participants asked for greater anatomical detail[17].

Besides their instructional value, printed models remove the need for specimen preservation and bypass the ethical and legal procedures linked to cadaver acquisition, making them available for consultation outside the laboratory. On the other hand, the cost of printers and materials remains an obstacle for many institutions, especially in public education[13]. Moreover, the learning gains offered by printed models still require robust comparison with traditional dissection[19]. Printed pieces can nevertheless complement digital resources. Hisham et al.[20] reported that combining online quizzes with three-dimensional prints provided students with a well-rounded grasp of human anatomy.

4.3 Gamification

The COVID-19 pandemic accelerated the adoption of digital platforms as pedagogical resources. Kahoot! a gamification tool based on interactive questions has been linked to greater student participation and engagement in anatomy classes delivered both remotely and face-to-face[16].

Kahoot! works through a competitive format with immediate feedback, which prompts rapid problem-solving and continuous content review. The platform's playful atmosphere also encourages active student involvement[25,26].

Research indicates that learners respond positively to digital games, finding them more engaging and participatory. Challenges remain, however: distractions stemming from excessive mobile-phone use, limited depth of content on gamified platforms, and difficulty adapting the quiz format to more complex questions[1].

Campos et al.[1] advise using Kahoot! as a supplementary tool for review and reinforcement after core content has been delivered, rather than as a replacement for established pedagogical practices.

4.4 Virtual and augmented reality

Virtual reality (VR) is emerging as a valuable tool in human-anatomy education. Using stereoscopic headsets and dedicated software, students can explore three-dimensional anatomy in immersive environments, interacting directly with structures and their spatial relationships[14].

VR's main advantage lies in its ability to display anatomical structures in great detail, allowing learners to manipulate, enlarge, and rotate images to suit their needs. Studies indicate that such interaction improves understanding of functional anatomy and enhances knowledge retention, especially for students who struggle with spatial visualisation[18].

Augmented reality (AR) overlays virtual elements onto the real world, enabling students to link digital anatomy images to concrete settings such as textbooks or physical specimens. When real and virtual elements are combined, the learning gains can be substantial[27,28].

Despite general enthusiasm, the effectiveness of VR and AR depends on factors such as model quality, students' prior familiarity with virtual environments, and the alignment of digital content with pedagogical goals[29]. High equipment costs and the need for suitable infrastructure also limit widespread adoption, particularly in public institutions.

An important consideration is the need for faculty development. Many instructors struggle to use these new technologies, even while acknowledging their benefits. This underscores the importance of institutional continuing-education programs that address not only the technical operation of these tools but also their effective pedagogical application.

Moreover, it is essential to assess students' profiles and maturity in the use of digital technologies. Unrestricted access to mobile phones and social media does not necessarily translate into effective pedagogical use. In this context, the teacher's role is pivotal: instructors must guide and mediate technology use to ensure that these tools serve as facilitators of learning rather than sources of distraction.

This narrative review has limitations, including the omission of descriptor synonyms in the search strategy and the small number of databases consulted. Consequently, although advances and advantages are documented, more robust research, particularly within Brazil is still required to evaluate the long-term effectiveness of these methodologies and their suitability for health-education institutions in the country.

5. Conclusion

The adoption of active learning methodologies combined with technological resources, such as 3D models, gamification platforms, and virtual-reality simulations has shown promise for modernising and innovating human-anatomy teaching. These tools increase student engagement and make anatomical structures easier to grasp, thereby fostering more meaningful learning. Implementation, however, is hampered by high costs, the need for faculty training, and curriculum adjustments.

Such methods should not entirely replace traditional practices like cadaver dissection and the handling of real specimens; rather, they should complement them within a diversified instructional approach. To secure this innovative pathway, educational institutions must invest in technological infrastructure, teacher training, and ongoing research that continually evaluates the effectiveness of these practices.

Author contributions

The authors state that they made substantial contributions to the work in terms of the study's conception or design; the acquisition, analysis, or interpretation of data; and the drafting or critical revision of content for important intellectual merit. All authors approved the final version for publication and agree to take public responsibility for all aspects of the study.

Competing interest

No financial, legal, or political conflicts involving third parties (government bodies, companies, private foundations, etc.) were declared for any aspect of the submitted work, including but not limited to grants and funding, advisory-board participation, study design, manuscript preparation, or statistical analysis.

Indexers

The International Journal of Education and Health is indexed in DOAJ and EBSCO.

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