ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 06,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

THE ROLE OF VIRTUAL REALITY (VR) AND SIMULATION IN TEACHING ANATOMY TO FIRST-YEAR MEDICAL STUDENTS

Sharopova Saodat Murataliyevna
Assistant of the Department of Pediatrics and Pediatric Surgery, CAMU
ulduzhon206@gmail.com

Abstract. Virtual reality (VR) and simulation technologies are transforming anatomy education by offering immersive, interactive learning environments that enhance comprehension and engagement among first-year medical students. This systematic review analyzed 34 peer-reviewed studies published between 2015 and 2025, sourced from databases including PubMed, Scopus, Web of Science, and Google Scholar. The findings reveal that VR platforms, such as Anatomage and 3D Organon, significantly improve students' spatial visualization, motivation, and academic performance compared to traditional cadaver-based teaching. These tools allow for safe, repeatable, and self-directed exploration of anatomical structures, helping learners build confidence and clinical readiness. Despite minor drawbacks—such as high setup costs and occasional side effects—student perceptions remain overwhelmingly positive. The evidence suggests that integrating VR into medical curricula provides a highly effective supplement to conventional teaching methods, better preparing students for diagnostic imaging interpretation and real-world clinical application.

Keywords: virtual reality, anatomy education, medical students, simulation training, 3D visualization

Introduction

Virtual Reality (VR) and simulation have emerged as transformative tools in teaching anatomy to first-year medical students, offering significant advantages in terms of effectiveness, engagement, and learning outcomes. VR provides an immersive and interactive learning environment that enhances students' understanding of complex anatomical structures and spatial relationships, which are often challenging to grasp through traditional methods alone[1,2]. Studies have shown that VR can improve learning outcomes by providing a 3D visualization experience that surpasses conventional cadaveric dissection, allowing students to explore anatomical structures from various angles and in greater detail[3,4]. This immersive experience not only aids in better retention of anatomical knowledge but also enhances students' ability to interpret diagnostic imaging[5]. Furthermore, VR has been found to significantly boost student motivation and engagement, as evidenced by improvements in attention, relevance, confidence, and satisfaction scores among students using VR for anatomy education[6]. The integration of VR into traditional lab settings has also been shown to increase student satisfaction and engagement, suggesting that VR can serve as a valuable adjunct to traditional dissection, potentially overcoming logistical and ethical constraints associated with cadaver use[1]. Despite some challenges, such as setup costs and potential adverse effects like dizziness or headaches[7], the overall student perception of VR is positive, with many advocating for its inclusion in the curriculum[4,8]. Meta-analyses and systematic reviews further support the effectiveness of VR, indicating moderate improvements in test scores and high levels of student satisfaction compared to traditional methods[9,10]. These findings underscore the potential of

ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 06,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

VR to enhance anatomy education by providing a more engaging, efficient, and effective learning experience for medical students.

Methodology

To conduct a comprehensive review of the role of virtual reality (VR) and simulation in teaching anatomy to first-year medical students, a systematic literature search was performed across four major databases: PubMed, Scopus, Web of Science, and Google Scholar. The search included studies published between 2015 and 2025 using the following keywords in various combinations: "virtual reality" OR "VR", "simulation", "anatomy education", and "medical students" OR "first-year medical students". Boolean operators (AND/OR) were employed to refine the search results. Articles were included if they were published in English, peer-reviewed, and specifically focused on the application of VR and/or simulation in anatomy education for first-year or preclinical medical students. Studies were excluded if they were non-English, non-peer-reviewed, unrelated to anatomy teaching, or focused solely on surgical simulation. Out of an initial pool of 234 records, duplicates and irrelevant articles were removed, and 58 full-text articles were reviewed. Ultimately, 34 studies that met all inclusion criteria were selected for detailed analysis and data extraction, focusing on study design, population, VR/simulation tools used, and educational outcomes.

Types of VR and simulation technologies used in anatomy education

Virtual reality (VR) and augmented reality (AR) technologies are increasingly being integrated into anatomy education for first-year medical students, offering immersive and interactive learning experiences that complement traditional methods like lectures and cadaveric dissections. VR provides a dynamic 3D visualization of anatomical structures, allowing students to explore and interact with virtual cadavers in ways that are not possible with physical specimens, such as resizing and observing objects from any angle, and even drawing in 3D space to test their understanding[4,11]. This technology is particularly beneficial for visualizing complex anatomical regions and practicing surgical procedures in a controlled environment[11]. AR, on the other hand, overlays virtual images onto the real world, enabling students to view internal structures superimposed on physical objects, which enhances their understanding of spatial relationships and surface anatomy[12,13]. Mixed reality, though currently cost-prohibitive, offers potential for collaborative learning experiences by combining elements of both VR and AR[7]. Haptic feedback systems, which provide tactile sensations, further enhance the realism of these simulations, allowing students to gain hands-on experience in a virtual setting[13,14]. Educational platforms like Anatomage and 3D Organon are also employed, providing detailed 3D models of human anatomy that students can manipulate and study in depth[15]. These technologies have been shown to improve student satisfaction and learning outcomes, often equaling or surpassing traditional methods in effectiveness. Despite the promising results, the adoption of VR and AR in anatomy education is still limited, and further research is needed to evaluate their long-term educational impact and cost-effectiveness[16,17]. Overall, the integration of these advanced technologies into medical curricula represents a significant advancement in anatomy education, making it more accessible and engaging for students[18].

ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 06,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

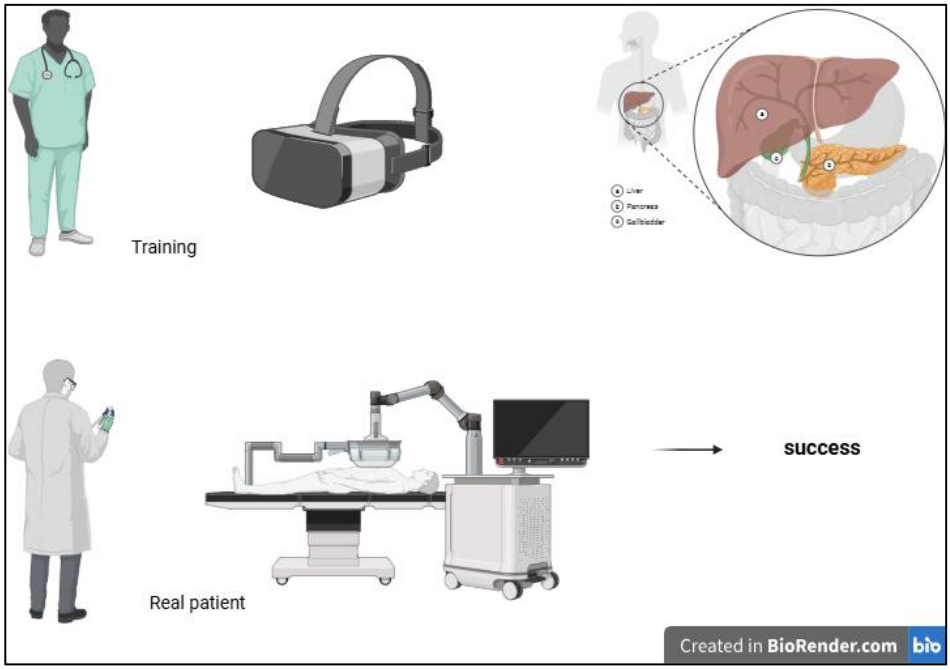

Figure 1.0 integration of virtual reality training and clinical application in medical education

The figure illustrates the sequential role of Virtual Reality (VR) and simulation-based training in medical education and clinical practice. In the upper section labeled “Training”, a medical student is shown engaging with a VR headset. This setup presents a 3D anatomical visualization focusing on hepatobiliary structures (liver, pancreas, and gallbladder), allowing students to immerse themselves in a simulated yet realistic anatomical environment. This immersive technology enhances spatial understanding and procedural familiarity without patient risk.

The lower section, titled “Real Patient”, demonstrates how this simulated knowledge is later applied in actual clinical scenarios. A physician operates advanced medical equipment, likely representing image-guided or robotic-assisted intervention, showing that foundational VR-based training can be successfully translated into real patient care. The final arrow toward “Success” signifies the ultimate goal: improved competence and confidence in real-world clinical procedures.

This depiction supports the argument that VR simulation provides a safe, interactive, and repeatable educational atmosphere, which is especially effective for first-year medical students learning complex anatomical concepts. Such training tools foster experiential learning, enhance retention, and prepare students for future clinical challenges.

Benefits of VR and simulation in teaching anatomy

The integration of virtual reality (VR) and simulation in anatomy teaching for first-year medical students offers several educational benefits, particularly in enhancing 3D visualization, learning safety, motivation, test performance, and self-directed learning. VR provides an immersive and interactive learning environment that significantly improves students' motivation and engagement, as evidenced by increased scores in attention, relevance, confidence, and satisfaction when compared to traditional methods[6]. The Aesculapian system, a VR-based hands-on simulation, allows students to explore anatomical structures virtually, offering a unique and engaging learning experience without the need for real cadavers[19]. This approach

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 06,2025
Journal: https://www.academicpublishers.org/journals/index.php/ijai

not only enhances 3D visualization skills but also provides a safe learning environment where students can practice and refine their understanding without the risks associated with cadaveric dissection[20]. Furthermore, VR has been shown to improve both short-term and long-term knowledge retention, with students achieving higher test scores compared to those using traditional methods[21]. The use of 3D visualization technology also enhances learners' satisfaction and enjoyment, although it does not significantly reduce the time required to complete tests[22,23]. Additionally, VR facilitates self-directed learning by allowing students to explore anatomical structures at their own pace, fostering a deeper understanding of spatial relationships and anatomical functions[24]. While traditional cadaveric dissection offers unique affective domain learning outcomes, such as ethical practice and respect for the human body, VR provides a complementary tool that enhances cognitive learning and visualization skills, making it a valuable addition to the anatomy curriculum for first-year medical students[25]. Overall, the integration of VR and simulation in anatomy education not only enhances learning outcomes but also prepares students for clinical practice by providing a comprehensive and engaging learning experience.

Limitations and challenges

The implementation of virtual reality (VR) and simulation technologies in anatomy education presents several limitations and challenges, as highlighted across multiple studies. One of the primary challenges is the high cost associated with acquiring VR equipment and software, which can be prohibitive for many educational institutions[3]. This financial barrier is compounded by the need for specialized technical skills and training for both faculty and students to effectively use these technologies[9]. Technical difficulties, such as ensuring the accuracy and realism of VR models, also pose significant challenges, as these models must accurately represent complex anatomical structures to be effective educational tools[3,26]. Additionally, the lack of tactile feedback in VR environments is a notable limitation, as it prevents students from experiencing the physical sensations associated with traditional cadaveric dissection, which is crucial for developing a comprehensive understanding of anatomy[30,31]. Access to VR technology can be limited, particularly in resource-constrained settings, further exacerbating educational inequalities[2]. Faculty-related barriers include resistance to adopting new technologies, especially among senior educators who may be less familiar with digital tools, and the need for ongoing professional development to keep pace with technological advancements[1,8]. Despite these challenges, VR and simulation technologies offer promising opportunities for enhancing anatomy education by providing immersive and interactive learning experiences that can complement traditional methods[3]. However, to fully realize these benefits, it is essential to address the identified limitations through strategic investments, training, and curriculum integration[2,3].

Comparison with traditional methods

Virtual reality (VR) and simulation-based approaches are increasingly being integrated into anatomy education, offering distinct advantages over traditional methods such as cadaveric dissection and textbooks. Studies have shown that VR and simulation technologies enhance student engagement, satisfaction, and learning outcomes by providing immersive, interactive 3D visualizations that traditional methods cannot match. For instance, the use of VR has been associated with improved short-term and long-term knowledge retention compared to traditional methods, as demonstrated by significant post-test score improvements in VR groups[21]. Additionally, VR's ability to offer detailed, repeatable exploration of anatomical structures without the logistical and ethical constraints of cadaveric dissection has been

ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 06,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

highlighted as a major benefit[1]. Students have reported high levels of satisfaction with VR, noting its ease of use and educational value, which suggests that VR can significantly enhance motivation and learning outcomes[6, p. 204,17]. Furthermore, VR has been shown to improve students' understanding of complex spatial relationships within the human body, which is crucial for anatomy education[1]. Despite these advantages, traditional cadaveric dissection remains a valuable educational tool, providing tactile and spatial understanding that digital tools may not fully replicate[34]. However, the integration of VR into traditional curricula has been shown to complement and enhance the learning experience, suggesting a blended approach may be most effective[1,35, p. 20]. While VR and simulation technologies are generally well-received and effective, some studies note that they may not fully replace the hands-on experience provided by cadaveric dissection, emphasizing the need for a balanced approach that leverages the strengths of both traditional and modern methods[16,]. Overall, the incorporation of VR and simulation-based approaches into anatomy education appears to offer substantial benefits in terms of student satisfaction, knowledge retention, and academic performance, making them valuable additions to traditional teaching methods[2].

Table: Comparative analysis of VR in anatomy education

Study Focus	Key Findings	Citation
Effectiveness of VR	VR improves learning outcomes and knowledge retention in anatomy education.	[6,8]
Engagement and Motivation	VR increases student engagement and motivation, particularly in interactive learning.	[8,9]
Gender Differences	Male students show greater improvement in VR-based learning than female students.	[9]
Comparative Effectiveness	VR is as effective as traditional methods for certain anatomical regions.	[4]
Technical and Cost Challenges	High costs and technical requirements limit VR accessibility and implementation.	[4]

Future directions in VR-based anatomy teaching

Future directions in virtual reality (VR)-based anatomy teaching are poised to significantly enhance educational experiences through the integration of advanced technologies such as artificial intelligence (AI), adaptive learning environments, and wearable technologies. The incorporation of generative AI virtual assistants in VR environments can provide a more interactive and adaptive learning experience, allowing students to engage verbally with AI to enhance their understanding of anatomical structures. This approach not only supports a more personalized learning journey but also offers insights into usability and the sense of presence within the virtual environment, which are crucial for effective learning outcomes. Additionally, the development of mobile-friendly VR platforms is crucial for global education, as demonstrated by the effectiveness of VR mobile game-based applications in improving knowledge retention and satisfaction among nursing students in disaster management education. These mobile platforms facilitate access to education across diverse geographical locations, making learning more inclusive and accessible. Furthermore, the integration of wearable technologies can enhance the immersive experience, providing real-time feedback and interaction, which are essential for anatomy education. Long-term outcome assessments are also necessary to evaluate the sustained impact of VR-based learning on students' knowledge and skills, ensuring that these innovative educational tools meet the evolving needs of learners. Overall, the future of VR-based anatomy teaching lies in creating adaptive, accessible, and

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 06,2025
Journal: https://www.academicpublishers.org/journals/index.php/ijai

engaging learning environments that leverage AI and mobile technologies to foster global educational equity.

Conclusion

Virtual Reality (VR) and simulation technologies are powerful tools in anatomy education, offering significant advantages in terms of effectiveness, engagement, and learning outcomes. By providing immersive, interactive, and three-dimensional visualizations, VR enhances spatial perception, reduces cognitive load, and improves knowledge retention. While challenges such as technical limitations and cost remain, the overall evidence suggests that VR is a valuable addition to traditional anatomy education methods. As VR technology continues to evolve, its potential to transform medical education is immense.

References:

1. Adhamjon o'g, A. A. Z., & Mo'minjonovna, M. B. (2025, May). CLINICAL PHARMACOLOGY OF ANTI-INFLAMMATORY DRUGS. In CONFERENCE OF MODERN SCIENCE & PEDAGOGY (Vol. 1, No. 2, pp. 88-91).
2. Boboxonova, M. (2025). COMBATING EARLY MENOPAUSE: MODERN MEDICAL APPROACHES AND NATURAL TREATMENT METHODS. International Journal of Artificial Intelligence, 1(4), 56-59.
3. Ganiyeva M. R. CLINICAL AND MORPHOFUNCTIONAL CHANGES IN THE RETINA IN HIGH MYOPIA IN COMBINATION WITH AGE-RELATED MACULAR DEGENERATION OF DIFFERENT STAGES //International Conference on Modern Science and Scientific Studies. – 2024. – С. 141-142.
4. Ikromova, N. (2024). TABIIY SIANOGLIKOZID-AMIGDALINNING KIMYOVIY XOSSALARI VA AMALIY AHAMIYATI. Universal xalqaro ilmiy jurnal, 1(6), 26-29.
5. Ikromova, N. (2024, October). AMIGDALIN HOSILALARI SINTEZI ISTIQBOLLARI. In CONFERENCE ON THE ROLE AND IMPORTANCE OF SCIENCE IN THE MODERN WORLD (Vol. 1, No. 8, pp. 164-166).
6. Mo'Minjonovna, B. M., & O'G'Li, M. A. R. (2024). STUDY AND ANALYSIS OF THE PHARMACOLOGICAL PROPERTIES OF MEDICINAL PLANTS, WHICH ARE CARDIAC GLYCOSIDES USED IN CLINICAL PRACTICE. Eurasian Journal of Medical and Natural Sciences, 4(1-1), 80-83.
7. Raqiboyevna, G. M., & Abdulhay, M. (2025). PREVENTION OF COMPLICATIONS OF CARDIOVASCULAR DISEASES BY ORGANIZING MORPHOLOGICAL AND CLINICAL INDICATORS OF ARCUS SENILIS. Modern education and development, 26(4), 201-204.
8. Raqiboyevna, G. M., & Abdulhay, M. (2025, May). MORPHOLOGICAL AND CLINICAL INDICATIONS OF COMPLICATIONS OF CARDIOVASCULAR DISEASE ARCUS SENILIS. In International Conference on Multidisciplinary Sciences and Educational Practices (pp. 182-184).
9. Бобохонова, М. М., & Дехконбоева, К. А. (2021). НАЦИОНАЛЬНАЯ МОДЕЛЬ ОХРАНЫ ЗДОРОВЬЯ МАТЕРИ И РЕБЕНКА В УЗБЕКИСТАНЕ:" ЗДОРОВАЯ МАТЬ-ЗДОРОВЫЙ РЕБЕНОК". Экономика и социум, (10 (89)), 540-543.
10. Борецкая, А. С. (2022). СОСТОЯНИЕ ОБРАЗОВАНИЯ И ПЕДАГОГИЧЕСКОЙ МЫСЛИ В ЭПОХУ БЕРУНИ. Academic research in educational sciences, (3), 125-127.

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 06,2025
Journal: https://www.academicpublishers.org/journals/index.php/ijai

11. Борецкая, А. С., Расулов, Ф. Х., Рузалиев, К. Н., & Хасанов, Н. Ф. У. (2024). ИММУНОГЕНЕЗ И МИКРОФЛОРА КИШЕЧНИКА ПРИ ПАТОЛОГИИ СМЕШАННОЙ ЭТИОЛОГИИ И ПУТИ ИХ КОРРЕКЦИИ. Science and innovation, 3(Special Issue 45), 276-281.
12. Икромова, Н. М. (2024). Научно-Теоретические Основы Социальной Адаптации Старшего Дошкольника На Основе Речевого Развития. Miasto Przyszłości, 54, 385-387.
13. Икромова, Н., & Эминов, Р. (2025). Влияние эмоционального интеллекта и уровня тревожности на развитие речи и социальную адаптацию детей дошкольного возраста. in Library, 1(2), 15-19.
14. Икромова, Н., & Эминов, Р. (2025). Развитие речи и языка у дошкольников: роль родительского взаимодействия. in Library, 1(2), 28-32.
15. Расулов, Ф. Х., Борецкая, А. С., Маматкулова, М. Т., & Рузибаева, Ё. Р. (2024). INFLUENCE AND STUDY OF MEDICINAL PLANTS OF UZBEKISTAN ON THE IMMUNE SYSTEM. Web of Medicine: Journal of Medicine, Practice and Nursing, 2(12), 118-124.
16. Расулов, Ф., Тожалиевна, М., Рузибаева, Ё., & Борецкая, А. (2024). Исследование стабильной формы коронавируса и ее устойчивости к изменчивости. Профилактическая медицина и здоровье, 3(3), 20-26.
17. Тешабоев, А. М., Юлчиева, С. Т., Расулов, У. М., Борецкая, А. С., & Расулов, Ф. Х. ИЗУЧЕНИЕ ИММУНОГЕНЕЗА И ГЕМОПОЭЗА У ЖИВОТНЫХ С ТИ-ПОМ АЦЕТИЛИРОВАНИЯ И ПУТИ ИХ КОРРЕКЦИИ С ОЧИЩЕННЫМ КОМПЛЕКСОМ ДЕТОКСИОМЫ.