EducaciónMédica 24 (2023) 100820

Educación Médica

www.elsevier.es/edumed

ORIGINAL ARTICLE

Study on the acceptance of virtual reality as a complement to the study of human anatomy

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Received 8 January 2023; accepted 2 April 2023
Available online xxxx

KEYWORDS
Anatomy;
Immersive;
Medicine;
Virtual Reality

Abstract
Introduction: Information and communication technologies have demonstrated their utility adapted to Health Sciences, particularly from an educational perspective. Virtual reality (VR) has become a tool that catalyzes the acquisition of clinical skills before contact with the patient, increasing safety, dexterity in procedures, and reducing the possibility of errors or complications. However, these tools could also offer new approaches for teaching basic subjects for undergraduates (Anatomy, Histology, etc.) and the use of tablets, and especially smartphones, could act as a complementary educational incentive.
Methods: Two hundred seventy-four students from different levels of the degree in Medicine, were invited to use a VR app on their phones with stereoscopic goggles. The users immerse themselves in the bioscopic anatomy, navigating through different anatomical structures.
Results: The questionnaire scores were, in general, above 4, reaffirming a positive opinion, except regarding the use of the tool for student exams.
Conclusion: Universities could increase formative delivery at a reduced cost, while ensuring training quality. The proposed concept of VR also helps to provide a useful learning environment in the COVID-19 scenario. Our results show that the introduction of immersive technology associated with VR and smartphones for medical students can be a welcome complementary or alternative educational tool.

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https://doi.org/10.1016/j.edumed.2023.100820

PALABRAS CLAVE
Anatomía;
Inmersivo;
Medicina;
Realidad virtual

Estudio sobre la aceptación de la Realidad Virtual como complemento para el estudio de la Anatomía Humana

Resumen
Introducción: Las tecnologías de la información y la comunicación han demostrado su utilidad adaptada a las Ciencias de la Salud, particularmente desde una perspectiva educativa. La realidad virtual (RV) se ha convertido en una herramienta que cataliza la adquisición de habilidades clínicas antes del contacto con el paciente, aumentando la seguridad, la destreza en los procedimientos y reduciendo la posibilidad de errores o complicaciones. Sin embargo, estas herramientas también podrían ofrecer nuevos enfoques para la enseñanza de materias básicas para estudiantes universitarios (Anatomía, Histología, etc.) y el uso de tabletas, y especialmente teléfonos inteligentes, podría actuar como un incentivo educativo complementario.
Métodos: Doscientos setenta y cuatro estudiantes de diferentes niveles de la licenciatura en Medicina fueron invitados a usar una aplicación de realidad virtual en sus teléfonos con gafas estereoscópicas. Los usuarios se sumergen en la anatomía bioscópica, navegando a través de diferentes estructuras anatómicas.
Resultados: Las puntuaciones del cuestionario fueron, en general, superiores a 4, reafirmando una opinión positiva, excepto en lo que respecta al uso de la herramienta para los exámenes de los estudiantes.
Conclusión: Las universidades podrían aumentar la entrega formativa a un costo reducido, al tiempo que garantizan la calidad de la capacitación. El concepto propuesto de RV también ayuda a proporcionar un entorno de aprendizaje útil en el escenario COVID-19 Nuestros resultados muestran que la introducción de tecnología inmersiva asociada con la realidad virtual y los teléfonos inteligentes para estudiantes de medicina puede ser una herramienta educativa complementaria o alternativa bienvenida.

Introduction

Advances in computer technology over the last few decades have profoundly affected health care and medical education. Educators have shown great interest in using computer applications in medical-school curricula.[1] These applications augment or, in some cases, replace traditional teaching methods such as lectures, practical laboratory sessions and textbooks.[2] Higher education institutions have experienced a shift in training processes from the traditional apprenticeship model to other areas, which include continuous and autonomous learning, or specialization, with a significant approximation between the labor market and Universities.[3] For educational purposes one of the most useful tools is Virtual Reality (VR). VR is software that creates a simulated environment, requiring a headset and workstation combination. UNESCO[4] concluded that spreading mobile technologies have irreversibly changed the teaching-learning methodologies, including medical studies. In the same way, due to their ubiquity and portability, smartphones have influenced teaching and learning in ways that personal computers never have.

In the coming years, trends in education point out that technology and education are evolving together, and educational needs are moving towards and adapting to technological progress.[5] The learning process can be done anywhere at any time through online and face-to-face interaction. It will be accessible, immediate, interactive, and context-independent. We can assume that using smartphone applications for learning can become an essential ally in teaching. Three-dimensional (3D) computer modeling and interactive VR simulation are validated teaching techniques used throughout medical disciplines.[6,7]

The teaching of Anatomy has traditionally been based on blending theoretical explanations with the support of multimedia material, or representation in two-dimensions. However, new scenarios should be considered in which students have mobile devices (smartphone or tablet) and are very adept at using them. Moreover, a wide variety of didactic and pedagogical applications and programs are under development. They may help complement and enrich the learning experience[1]. Those complementary tools allow students to visualize, analyze three-dimensional anatomical structures, and assist in virtual manipulation of the studied elements.[8] This facilitates an accessibility to studied objects that otherwise would not be available.[9,10]

These innovative technologies hold great promise but must be systematically experienced in real context. Little objective data exist supporting the use of these tools, particularly VR, in teaching Anatomy,[6] and does not gauge the potential interest of undergraduate students. This study's goal was to determine the opinion of students pursuing a degree in medicine concerning the relevance and usefulness of an immersive App by way of employing VR in the teaching process, and then to evaluate VR's potential contribution to students as the first step towards including it for routine use in anatomy-related teaching.

Material and methods

Setting

This study was conducted at the University of las Palmas de Gran Canaria (ULPGC) School of Medicine, Canary Islands, Spain.

Sampling and recruitment

Participants were recruited from three subjects required for a medical degree, Medical Physics and Technology (Medical Tech.), Anatomy III (Anatomy), and Anesthesiology (Anesthesia). These subjects were chosen for connection with medical technology (Medical Tech) or with the anatomy systems presented in the Anatomyou app, (Anatomy III and Anesthesia). The use of the App in an immersive mode was introduced during the academic term as a supplementary laboratory activity. The number of student participants in the study, the number of credits, and the course year are shown in Table 1. The annual new admission capacity for a medical degree in the University of las Palmas de Gran Canaria is 135 per year.

Sessions

The Anatomyou® VR application (Anatomyou®.com) was advised by the ULPGC Chair of Medical Technologies. It was initially developed to help postgraduates improve approaches in minimally invasive procedures. It shows the anatomy of an endoluminal system in an immersive manner. It consists of an app for smart phones. To use Anatomyou® VR, students download the App to their smartphones or tablet, and they can visualize the different anatomic environments (circulatory, respiratory, digestive, urinary, ocular, and female genital systems). However, for the immersive experience, the smartphone must be inserted into a corresponding device (the VR viewer or "glasses") to enjoy the 3D visualization immersive scenario obtaining information from the gyroscope of the smart phone in a three-dimensional space. The users interact with the navigation controls and the anatomical information elements by selecting and activating them with their eyes. The application has been developed in C# language within the Unity (unity.com) development environment and compiled for use on Android and iOS operating systems. The 3D anatomical models have been acquired commercially and adapted, according to the validation of the authors of this work, with the Blender graphic modeling environment (blender.org). The VR glasses used are a commercial model distributed by the company Lakento (Madrid, Spain; https://www.lakento.com/index-en.html).

Table 1 Participant subjects and academic characteristics, teaching load in credits, and number of enrolled student/fulfilled surveys.

Subject	Medical Tech.	Anatomy	Anesthesia
Academic year	1°	2°	4°
Subjects Credits	6	6	3
Students/Surveys	140/103	149/101	63/53

Table 2 Different questions were given to different academic year students.

Learning potential	1.- VR is useful for learning the subject
	2.- VR improves teaching Medicine
	3.- VR is useful for learning Bioscopic Anatomy
	4.- VR is useful for student tests
Experience opinion	5.- VR makes learning entertaining
	6.- VR works well in the learning process
	7.- VR promotes autonomy
	8.- I would repeat VR experience

Satisfaction survey

The medical student participants (Table 1) were surveyed in autumn 2019 about their perception of the new proposed methodology which is based on immersive VR technology. Statements ranging from strongly disagree (1) to strongly agree (5) were used based on a five-point Likert scale.[11] The application satisfaction assessment was voluntary and determined at the end of each experience through a semi-structured and anonymous survey using the Google Form tool.

The survey consists of eight questions focused on learning potential, or their opinion about the experience (Table 2). The student responses expressed their degree of agreement with the questions. The survey was filled out on their mobile phones after the sessions, and with no time limit. The students were free to express any sensation or concern, with a focus on the management of the equipment.

Statistical analysis

An analysis of variance was performed using the statistical package SSPS version 22.0 for Windows. The reliability was verified by Cronbach's alpha coefficient and the significance of the differences between means was analyzed using one-way ANOVA followed by Duncan's multiple range test, for a significance level of $p < 0.05$.

Result

The results of the study are presented according to the experiences obtained from their use during the different medical school courses. The study attempts to evaluate the contribution of these experiences to those courses, or the detection of improvements to adapt them to teaching. The obtained scores are shown in Figures 1 and 2, and the corresponding *P*-values displayed in the Table 3. The questions were grouped according to learning applicability (Figure 1) and general opinion (Figure 2) of the experience. The Cronbach's alpha coefficient indicates that 91% of the variability of the obtained scores represents true differences among people, and 9% reflects random fluctuations. This result allows us to assert that the elements are homogeneous and that the scale consistently measures the characteristic for which it was developed.

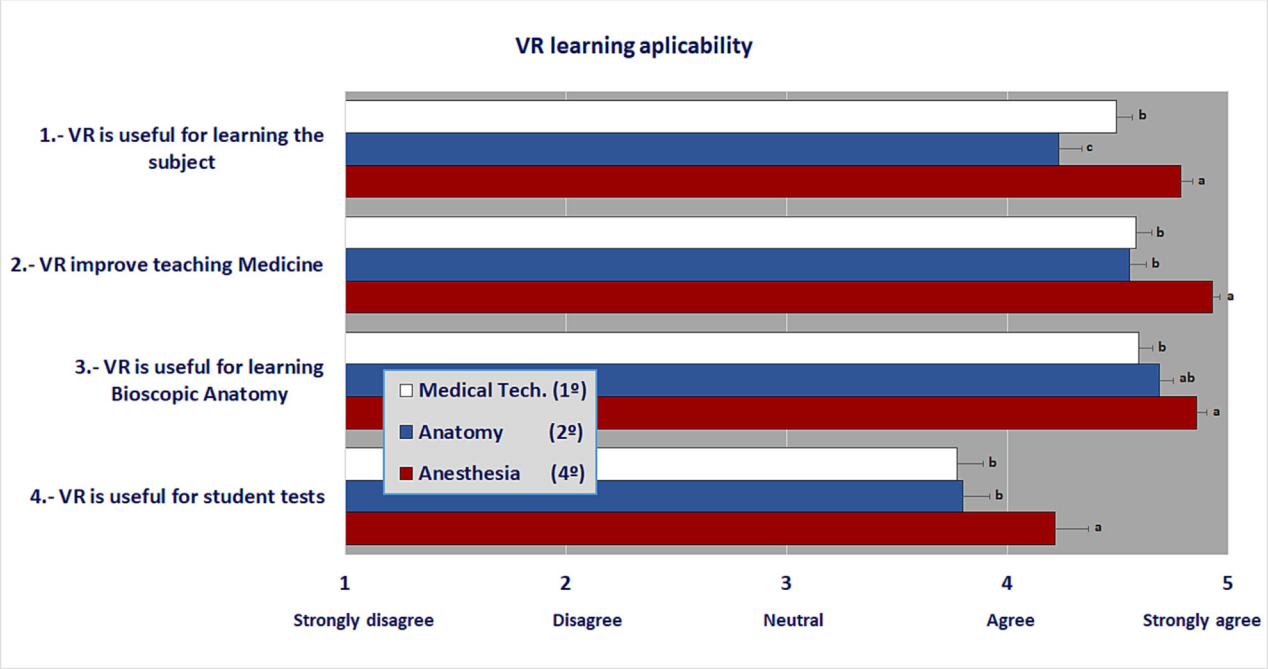

Figure 1 Satisfaction survey with the VR tool related to the learning applicability.

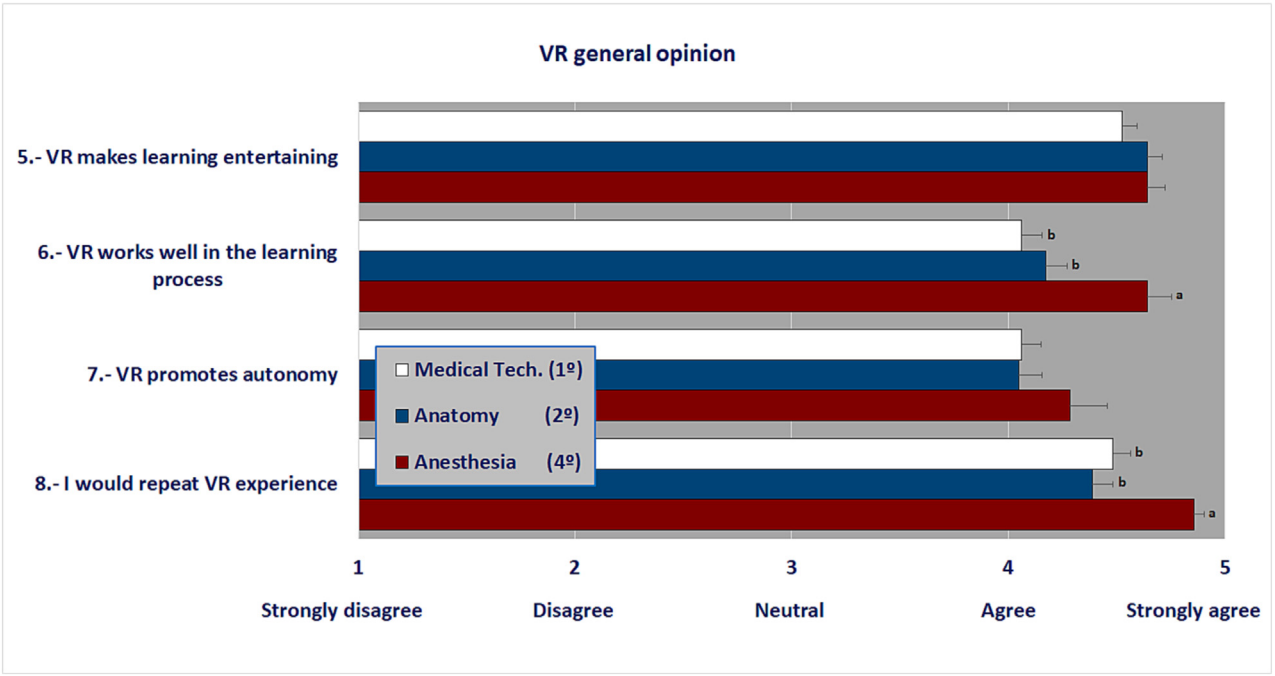

Figure 2 Satisfaction survey related to student general opinion.

Table 3 Level of significance (*P* value) of the comparison of means of the different subjects.

Question n°	1	2	3	4	5	6	7	8
p- value	.000	.002	.034	.004	.418	.001	.371	.002

The students of Medical Tech. participated in the experience, and 74% answered all the survey questions voluntarily (Table 1). In general, these first-year (first term) students had intermediate scores with less statistically significant enthusiastic answers than fourth-year students. The freshmen enjoyed the experience, and considered VR beneficial, with

pedagogical relevance for improving medical subjects, including bioscopic anatomy (Figure 1). Moreover, they considered that VR is a firm candidate to have a role in making study more entertaining and promote autonomous learning. They also indicated that having more virtual experiences would facilitate learning and were prone to repeat the experience (Figure 2). The students, however, were less satisfied with the use of the application for exams (Figure 1).

The second-year students (first term) experienced VR in Anatomy III and contributed with satisfaction surveys of 68% (Table 1). The students considered the activity decidedly positive, with a similar level of approval as the freshmen (Figure 1 and 2). However, they were less eager than the first-year students in questions such as number 1, focused on the applicability of the tool. Compared with 4th year students', significant differences were found (P <0.05) (Table 2). Like their first-year counterparts, they were positive, but not fully persuaded by the applicability of the tool for exams.

Anesthesia is a fourth-year optional subject. The level of contribution on the survey was the highest of all the participants, 84%. The students' scores stood out on practically all items, both connected with the learning process, or those about general opinion. Anesthesia students benefit from exploring the basics of anatomy while focusing on clinical procedures. The students have found the VR tools to be of practical use regarding approaches because they enhanced mere anatomical learning, which was a topic the students had studied in previous courses and had already passed. Independently of the difference of age comparing experimental students' groups, these fourth-year students objected to using the App for exams and awarded the lowest scores to the fourth question.

Discussion

The Medical Tech. subject included the youngest students of the study, which meant newly incorporated students. First-year (first term) students in our university have limited contact with organography; first year Anatomy (Anatomy I and II) is devoted only to embryology, osteology, and muscular structure. This subject combines the conventional contents of medical physics with the main technologies used in medical practices. Accordingly, this experience was incorporated as extracurricular content as classroom training. The syllabus of Medical Tech. encompasses a wide available spectrum of medical technology, including radiology, ultrasound, or robotics, beyond the use of VR, which could have determined the answers. This group of students experimented with the application on anatomic systems not yet studied. However, despite this apparent indifference, freshman medical students found the potential to promote further improvement.

Human Anatomy III comprises basic structural anatomy. These students obtain the most benefit by using the tool. Nevertheless, in those questions connected with VR academic use throughout the term, the students show slightly less enthusiasm, not significantly different from their first-year counterparts. Because the students were aware that they were the main recipients of the experience, they could have perceived the proposal as a new burden added to the classroom work, practical laboratory sessions, and personal study. Their perceptions about the tool improved when they perceived the tool exclusively as a complement to their training. Second-year students were more aware of the potential of the tool.

The senior students (Anesthesia) belonged to an elective subject. These students have a different relationship with anatomical systems, switching their interest to a clinical application to fortify and lay down the anatomical bases.[12] The anatomy of the respiratory system was especially rehearsed, which represented an important visual and spatial reinforcement associated with the teaching of airway management. They can witness, be taught, and practice anatomy related to airway control, tracheal intubation, and manual ventilation of the lungs. Also, cannulation of veins and arteries, cardiopulmonary resuscitation, lumbar puncture, the performance of blocks with local anesthetics, which are useful tools for learning protocols with even better results than classic textbooks. Seimour et al., (2002),[13] showed that 16 surgical residents, those trained using VR techniques, perform operations 29% faster than those who used traditional techniques. Another use for VR related to Anesthesiology and Pain Control was reported to provide anxiety-reducing benefits and sedation-sparing effects.[14]

The aim of this study was to identify and compare the perceptions of immersive VR on learning different aspects of Anatomy during the undergraduate university experience. In the present study, the experience was educationally rewarding and thus it was reflected in the scores, oscillating globally over 4. This finding suggests that the resource could be an effective tool in helping students learn different anatomic systems. The hypothesis that VR technology promotes learning is consistent with findings from other studies where VR use[15] significantly improved anatomical knowledge test scores.[2,16] Students from different courses agree that VR applications can help improve the learning process, encouraging us to look for new ways of capturing a student's attention. However, the level of commitment was not accompanied by a relevant interest in its use for tests. Currently, the App does not implement an "assessment," a performance evaluation system. The students cannot gauge whether a questionnaire would be useful in advance. A mode specifically designed to test performance based on anatomy knowledge quizzes and extensive use throughout the semester could have qualified the opinion of the students.

In another vein, paradoxically the question connected with autonomous learning obtained lower agreement than expected, considering that it was thought to be one of the tool's strengths. The students can experience the subject according to his or her own path (learning in first person) without a fixed class timetable, can repeat the process as many times as desired with no need to access the practical laboratories. The training carried out in groups in a recreational framework has not put them in the context of individual use. Use of the tool continued beyond a demo mode circumscribed to a 2 hours' experience would develop its full potential with continuous access to the glasses throughout the semester. Running technological tools, such as immersive VR, allows students to manage their knowledge and practical skills developing new forms of learning innovation and raising the quality of the academic process.[17] All the groups showed a

positive navigation guesstimate. The lack of prior preparation did not make navigation clumsy with the head-mounted displays that block visual cues from the physical environment. Medical students learn to interact with this technology, acquiring a set of skills that predispose them to an increasingly common technological field in the medical work environment.[18] VR offers benefits for learners and educators, delivering cost-effective, repeatable, standardized learning and clinical training on demand.[19]

As compared to cadavers and dissection, VR are less preferable, and the lack of tactile experience is regarded as a disadvantage.[20] VR can be used both as didactic and experiential educational tools, allowing a deeper understanding of the interrelationship of anatomical structures that cannot be achieved by any other means, including cadaver dissection.[21] Although the results are encouraging, it is not our recommendation that such Apps could replace traditional tools to teach anatomy. VR is a useful adjunct to reinforce the traditional teaching of anatomy. Where possible, practical laboratory sessions allow the student to observe the structures of the body in situ, studying their relations to other structures and allowing the student to gain familiarity with the textures, strength, and other physical characteristics of the bodies' numerous different tissues.[26] However, as a complement, with this approach, universities, healthcare institutions or under or postgraduate medical student could increase formative delivery at a reduced cost, while ensuring training quality. The proposed concept of VR also helps to provide a useful learning environment in the COVID-19 scenario.[22] The practical lesson has been compromised for the social distance issues and VR can be an add-on throughout this menace. VR technologies are accessible and easier to incorporate into anatomy related teaching. The improvement in VR and virtual learning resources quality in general, alongside the enhanced ability of students to interact with virtual worlds, will make VR simulation continue to expand.[23,24]

Virtual reality used in an immersive approach has turned out to be a powerful tool to teach Anatomy or for the training of practical procedures resting on an anatomic/anatomy skill. Medical students of different subjects or academic levels evaluated the immersive VR positively, especially in areas related to teaching applicability and overall satisfaction, showing engagement, enjoyment, and learner motivation. Among the advantages of the tool, we consider that it is a transportable and easy-to-use system with the students' own devices. Also, its low cost and easy installation and handling for any type of user. On the other hand, as disadvantages from a technical point of view, progress should be made in its limited computing capacity, which requires that the contents (3D models) be optimized for versatile use. The use of VR glasses versus integrated systems such as Oculus Quest2 makes the immersive sensation, while sufficient, not the best possible. The average scores obtained were significantly higher, which gives strong evidence that the resource could be a valid complementary method for teaching anatomy. Students can practice anywhere allowing continual improvement to suit learner needs, which is especially important under social distancing situations and difficulties in achieving technical competence. From the methodological point of view, these elements can be translated into a useful teaching strategy for learning anatomy or medical procedures, with high potential to transform anatomy education.

Funding

The project was developed within the call for educational innovation projects, PIE 2019-39 and PIE 2020-39 from the Vice Rectorate for Degrees and Permanent Training of the University of Las Palmas of Gran Canaria. The present study was awarded by the Cátedra Fundación MAPFRE Guanarteme of Technology and Education (TecnoEdu 2020) from the University of La Laguna.

Conflicts of interest

The authors report no conflict of interest. The authors alone are responsible for the content and writing of this article.

Ethical approval

This study follows the ethical practices of the Institutional Board of the University of Las Palmas de Gran Canaria and carried out in accordance with the Declaration of Helsinki, including the anonymity and consent of participants.

Contributors

Pedro L. Castro M.A., Rodriguez-Florido and Blanca Mompeó study conception and design. Rafael Ginés analysis of data. Juan A. Ramírez, Luis Domínguez and Manuel Maynar interpretation of data. Aurelio Rodríguez interpretation of data and drafting of the article. All authors contributed to the revision of the manuscript and all authors approved the final version of the manuscript. All authors are accountable for all aspects of the work.

References

1. Castro Alonso PL. Introducción al uso de imágenes digitales en formato web en el aprendizaje de la histología humana. Educ Médica. 2019;20:280–3.
2. Nicholson DT, Chalk C, Funnell WRJ, Daniel SJ. Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model. Med Educ. 2006;40:1081–7.
3. Salinas Ibáñez J. Innovación docente y uso de las TIC en la enseñanza universitaria. RUSC Univ Knowl Soc J. 2004;1:3.
4. Shuler C, Winters N, West M. The future of mobile learning - Implications for policy makers and planners. UNESCO - United Natl Educ. 2013:1–44.
5. Collins A, Halverson R. Rethinking education in the age of technology: The digital revolution and schooling in America. Teachers College Press; 2018.
6. Stepan K, Zeiger J, Hanchuk S, Del Signore A, Shrivastava R, Govindaraj S, et al. Immersive virtual reality as a teaching tool for neuroanatomy. Int Forum Allergy Rhinol. 2017;7:1006–13 Wiley Online Library.
7. Ekstrand C, Jamal A, Nguyen R, Kudryk A, Mann J, Mendez I. Immersive and interactive virtual reality to improve learning and retention of neuroanatomy in medical students: a randomized controlled study. C Open. 2018;6:E103–9.

8. Alfalah SFM. Perceptions toward adopting virtual reality as a teaching aid in information technology. Educ Inf Technol. 2018;23:2633–53.
9. Izard SG, Juanes Méndez JA, Palomera PR. Virtual reality educational tool for human anatomy. J Med Syst. 2017;41:76.
10. Jang S, Vitale JM, Jyung RW, Black JB. Direct manipulation is better than passive viewing for learning anatomy in a three-dimensional virtual reality environment. Comput Educ. 2017;106:150–65.
11. Likert R. A technique for the measurement of attitudes. Arch Psychol. 1932;140:1–55.
12. Kulcsár Z, O'Mahony E, Lövquist E, Aboulafia A, Šabova D, Ghori K, et al. Preliminary evaluation of a virtual reality-based simulator for learning spinal anesthesia. J Clin Anesth. 2013;25:98–105.
13. Seymour NE, Gallagher AG, Roman SA, O'Brien MK, Bansal VK, Andersen DK, et al. Virtual reality training improves operating room performance results of a randomized, double-blinded study. Ann Surg. 2002;236:458–64.
14. Alaterre C, Duceau B, Sung Tsai E, Zriouel S, Bonnet F, Lescot T, et al. Virtual reality for peripheral regional anesthesia (VR-PERLA Study). J Clin Med. 2020;9:215.
15. Fairén M, Moyés J, Insa E. VR4Health: personalized teaching and learning anatomy using VR. J Med Syst. 2020;44:1–11.
16. De Faria JWV, Teixeira MJ, De Moura Sousa Júnior L, Otoch JP, Figueiredo EG. Virtual and stereoscopic anatomy: when virtual reality meets medical education. J Neurosurg. 2016;125:1105–11.
17. Izard SG, Juanes JA, Peñalvo FJG, Estella JMG, Ledesma MJS, Ruisoto P. Virtual reality as an educational and training tool for medicine. J Med Syst. 2018;42:1–5.
18. Costello E, Corcoran M, Barnett JS, Birkmeier M, Cohn R, Ekmekci O, et al. Information and communication technology to facilitate learning for students in the health professions: current uses, gaps, and future directions. J Asynchr Learn Netw. 2014:18.
19. Pottle J. Virtual reality and the transformation of medical education. Futur Healthc J. 2019;6:181–5.
20. Petersson H, Sinkvist D, Wang C, Smedby Ö. Web-based interactive 3D visualization as a tool for improved anatomy learning. Anat Sci Educ. 2009;2:61–8.
21. Pensieri C, Pennacchini M. Virtual reality in medicine.Handb. 3D3C Platforms. Springer; 2016. p. 353–401.
22. Singh RP, Javaid M, Kataria R, Tyagi M, Haleem A, Suman R. Significant applications of virtual reality for COVID-19 pandemic. Diabetes Metab Syndr Clin Res Rev. 2020;14:661–4.
23. Li Z, Li Z, Peng C, Zhao M, He Q. A bibliometric analysis of virtual reality in anatomy teaching between 1999 and 2022. Front Educ. 2022;7, 874406. https://doi.org/10.3389/feduc.2022.874406.
24. Banerjee S, Pham T, Eastaway A, Auffermann WF, Quigley III EP. The use of virtual reality in teaching three-dimensional anatomy and pathology on CT. J Digit Imaging. 2023:1–6.