EasyChair Preprint

№ 11929

The Use of Augmented Reality as a University Teaching Strategy in Health Sciences Programmes: a Scoping Review

Fabian Roman, Karina Lastre, Diva Licet Mendoza and Sonia Rodriguez Cano

March 13, 2024

Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 00 (2024) 000–000

Procedia Computer Science

www.elsevier.com/locate/procedia

The 15th International Conference on Ambient Systems, Networks and Technologies (ANT)
April 23-25, 2024, Hasselt, Belgium

The Use of Augmented Reality as a University Teaching Strategy in Health Sciences Programs: A Scoping Review

Fabian Roman[a], Karina Lastre Meza[b], Diva Mendoza [c,] Sonia Rodriguez Cano*

Universidad de la Costa[a], Barranquilla- Colombia, Universidad de Sucre [b],

Sincelejo-Sucre, Universidad de la Costa [c], Barranquilla-Colombia, Universidad de Burgos, Burgos-España

Abstract

The purpose of this systematic review of the literature is to identify, analyze and synthesize the findings found in the last 10 years regarding the issue of AR in academic health programs and to know the impact it has on students' learning. At the methodological level, the databases Scopus, PubMed, Web of Science and Science Direct were consulted, inclusion and exclusion criteria were established for the selection of the most relevant articles, methodological quality and relevance were analyzed. As a result, 16 articles suggest that AR has a positive impact on health disciplines, by fostering greater interactivity, motivation, understanding of concepts, acquisition of skills, retention of knowledge and personalization of learning. The systematic review concludes that further scientific evidence is needed to determine the effectiveness of AR in learning and its impact on the development of competences and learning outcomes in current education

*Keywords: Augmented Reality, Higher Education, Health, Education Technology, Teaching.*Introduction

1. Introduction

University teaching in the Health Sciences has been characterized throughout history by its traditional character, lectures, lessons led by the teacher, readings of articles, books, audio-visual aids and demonstrations are the most commonly used learning 2 Fabian Roman et al. / Procedia Computer Science 00 (2024) 000–000 methods for

imparting health knowledge (1), in general, are characterized because the student assumes a passive role in the teaching-learning process. The objective of learning and the fundamental component in the curricula of the Health Sciences programs, is disease education and its comprehensive approach, which requires the integration of different disciplines and the incorporation of new teaching methodologies involving the use of technology with active learning approaches that foster meaningful learning experiences. As a result, the use of emerging technologies or new information and communication technologies (ICT) in the educational field is growing in recent decades and the AR is an attractive technological resource for both students and teachers, for the particular case of the Health Sciences, is meant to be an active learning mode and the interactivity offered by the AR allows the student to build their own learning, promoting in the long term the retention of knowledge acquired (2). With this methodology, students can work in virtual environments that in the real world would be unattainable or dangerous, which causes an increase in the curiosity of learning, this emerging technology is also a useful means of arranging learning and the gain of knowledge, with a directly proportional relationship in which, the more enthusiasm and satisfaction, greater is the performance or memory of the information achieved(3), improving students' learning achievements and their motivation to learn(3).

This popularity of AR, in the field of education provides an opportunity to harness learning through technology (4) and to combine the real and virtual environment and interact with physical reality in real time, through different technological means such as smartphones, tablets or smart lenses, by integrating signals captured from the real world with signals generated by computers, makes them correspond in the construction of new coherent realities, which complement and coexist in the real and virtual world (5). AR, is a variation of virtual reality that enriches the real world with digital content in real time through different technological means such as smartphones, tablets or smart lenses and introduces students to immersive digital experiences that cannot be replicated through traditional teaching methods, is a technology that improves the real world environment around us by overlaying computer-generated content. (6) (7) (8). Among the advantages that the incorporation of RA within the University teaching process in Health Programs, (9) affirm that they improve the teaching-learning process by influencing it multidimensionality, it also reduces the cognitive load, it increases the motivation and satisfaction of the students, because it requires a very active involvement on the part of the participants, the student has the possibility to transfer what they have learned to the real world, and especially the environment created by the AR (10). Additionally, it is a support tool to better interact with complex material beyond lectures and textbooks (11) optimizes spatial understanding and promotes autonomous learning and provides greater realism to clinical simulation environments, the above, is useful in those courses with a large component 3D images and videos, which can help keep students interested in their teaching-learning process. (12) (13)

RA, supports teachers in customizing content for individual learning styles (14) and for designing immersive experiences such as simulations and virtual excursions without the physical implications of the trip allowing students to explore and interact with real world environments without leaving the classroom (15), this generates motivation to learn any content, studies have already pointed out that the inclusion of AR applications in education is relevant because they improve students' learning achievements and their motivation to learn.(16) The purpose of this review is to identify, evaluate and systematically summarize the literature of the last 10 years on the subject of AR in academic health programs and to know the impact it has on students' learning. This review aims to address the following research questions:

¿How are studies on the use of AR distributed in university health science programs, according to the methodology, year and country of publication, population and academic program?

What are the outcomes of effective implementation of IA in higher education programs in health sciences?

What innovative proposals for higher education in Health Sciences are currently being implemented?

2. Methodology

The scientific literature published on the subject of AR in higher education of health programs was systematically reviewed. The guidelines of the PRISMA Declaration and the checklist of 27 articles were assumed for its construction. (17) The elaboration process and each of its stages are described below. For the eligibility of the

review articles, inclusion criteria were raised, among them, that the results are within the last 10 years (2013-2023), published in English or Spanish, which are empirical research and not systematic reviews, of literature or narrative, that speak of the Higher Education of the programs of the area of the Health Sciences. Those researches that study the subject of RA were excluded, from academic programs other than health, that correspond to systematic reviews, proceedings of congresses, book chapters, expert opinions and letters to publishers. Studies without the full text available that did not work on the RA variable were considered irrelevant and therefore excluded from the review.

The initial search strategy was carried out using the electronic databases PubMed, Scopus, Web of Science and Science Direct, several search terms were included independently "augmented reality" and through combinations “augmented AND reality AND" technology" by supporting Boolean operators AND, OR to connect the words. Similarly, advanced systematic research was carried out using search strings from the identified terms. In Scopus: In PubMed: In Science Direct: In Web of Science". No methodological restrictions were imposed on the search strategy. After importing all recovered research to Mendeley and removing duplicate articles, a researcher performed on the stages of selecting potential articles to analyze. To do this, a preliminary search matrix was used with the following information: Doi, Article title, abstract, research purpose, classification or exclusion criteria. The studies selected as relevant in the preliminary search were revised in full text in the second stage according to the same criteria. The information from the studies selected as potential to analyze was recorded and organized in a Search and Analysis matrix, which included: query source, journal, journal quartile, citation, title, authors, year of publication, abstract, keywords, purpose, method, variable operationalization, study design, sampling method, characteristics of participants, a country where the research was carried out, main recommendations and limitations.

3. Results

An initial search of 283 articles was carried out, then the screening phase was carried out for the preliminary selection of manuscripts, here a total of 198 articles that did not meet the inclusion criteria were excluded: year of publication (n: 0), by themes that study augmented reality from another approach (n: 109), by database duplicity (n: 10), review articles (n: 64), editorial material (n: 4) books (n: 3) and conferences (n: 8). A total of 85 advanced search investigations were pre-selected as follows: in PubMed 24, in Scopus10, in Web OS Science 50, Science Direct, 1. In this phase was performed an extraction of information through a table of data in Excel that included: reference (journal, title, author, year of publication, etc.), study purpose, type of study, design, sample, results, conclusions and consulted database. Among the 85 articles evaluated through full-text re-view, 67 articles were excluded (32 wrong study designs, 8 wrong patient population, and 27 wrong environment) Finally, 18 articles met the inclusion and exclusion criteria for this review, however, 2 studies were excluded for not responding adequately to the study topic, leaving a total of 16 articles for the narrative synthesis.

3.1 Distribution of studies

Of the 16 papers reviewed, most were published in the last 5 years (n: 13) and only three of them between the years 2015-2018, prevailed Spain (n: 4), Australia (n: 4) countries with the highest number of publications on augmented reality followed by publications from countries such as Germany (n: 2) England (n: 1), the Netherlands (n: 2), Turkey (n: 1) and Latin America in Canada (n: 1) and Brazil (n: 1).

At the methodological level, the quantitative research approach (n: 11), mixed approaches (n: 5), the temporality of most of the studies was cross-sectional and as for the study types were found Quasi-experimental designs with study and experimental group, Pre – Pos test (n: 4), Experimental (n: 6), Randomized Controlled Trial (n: 1), Design-based research (n: 2) and Mixed (n: 3). Regarding the processing and analysis of the information, analysis of variance was evidenced, using the T-test procedure for independent samples from which the means of two groups of cases were compared, in the same way, the ANOVA procedure was used to generate an analysis of the variance of a factor for a quantitative dependent variable with respect to a single factor variable (the independent variable) and to contrast the hypothesis that several means are equal. As for the population, studies pre-dominated in the academic

programs of medicine and biomedical, as well as in other health careers, such as nursing, physiotherapy, psychology, nutrition.

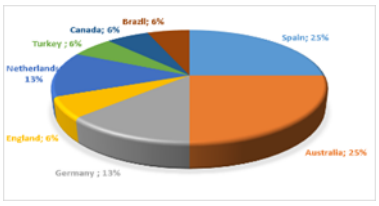

Figure 1. Distribution by countries

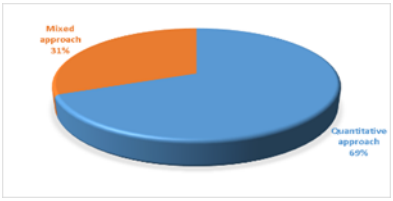

Figure 2. Methodologic approach

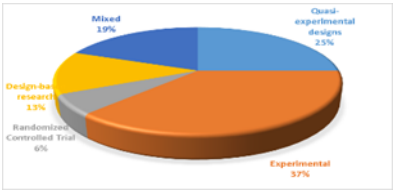

Figure 3. Study Design

.2 Effectiveness of Augmented Reality Implementation in Higher Education

10 studies that were oriented to test the effectiveness of methodologies based on AR in teaching-learning curricular contents included in the curricula of different health science programs and compare them with traditional teaching methods such as high, traditional notes and anatomy textbooks, as well as describing the influence of the use of AR on cognitive processes such as attention, autonomous learning, understanding and motivation of students. (12) (18) Two studies attempted to test whether AR provides a greater degree of learning than traditional videos and notes for the study of certain topics such as the anatomy of the human body, at the same time, whether autonomous learning with AR aids can be more valued in the metacognitive perception of students and whether the expectation of success in future learning of students using AR aids is higher. Overall, the authors conclude that, although technology has not been sufficiently developed for education, it can contribute to optimizing the student's autonomous work and academic training, they recognize that these methodologies favor learning and can complement the traditional teaching-learning model, enhancing the process of acquiring knowledge, developing new skills such as spatial abstraction and functional understanding. (19) (20) In addition to the above, two studies determined the effectiveness and potential of AR-based learning in terms of learning outcomes in a collaborative environment, in which team-focused interactive learning is encouraged, among the results found the students highlight as benefits the increase of the 3D understanding of the topographic anatomy, due to the high quality of the images that help to a greater discrimination of the anatomic structures, in the same way, a greater participation of the students , whose positive impact is given in the fun and the motivation(21). It is suggested that AR applications can play a role in future anatomical education as a complementary educational tool, especially in learning the three-dimensional relationships of anatomical structures.(22) Other studies, indicated as more significant findings, that the innovative methodology with Augmented Reality in groups results in better results in terms of motivation, participation, interaction with the content, the active role of participants and increased learning outcomes (23). In addition, the students affirmed that Mobile Augmented Reality (MAR), develops their motivation and also self-confidence and reduces their concerns.(24).

3.3 Innovative Augmented Reality Proposals for Higher Education in Health Sciences

Jamali (25) they developed a prototype mobile learning environment using mobile augmented reality called Human Anatomy in Mobile Augmented Reality or HuMAR, whose purpose was to help students potentially improve their learning process of the anatomical skeletal structures of the human body , using improved materials that stimulate their interest and contribute to the retention of information for longer. Birt et al.(26) and Bork et al. (27) used virtual reality through Samsung Gear and Oculus Rift and augmented reality through tablets to teach narrated anatomy lessons using 3D models for the brain, spinal cord and brain stem, its purpose was to achieve a learning experience in the hands of the participant, under a self-directed approach that allows an experiential learning and a greater commitment by the student, they used a Magic Mirror augmented reality system for teaching integrated courses in anatomy and radiology. The authors point out that years ago, virtual and augmented reality was expensive, cumbersome and exclusive to some educational institutions, and the pedagogy of simulation through

physical simulation trainers is very expensive, however, today, gaming engine platforms are available for free, such as Unity 3D, free augmented reality SDK software and mobile devices, such as tablets and smartphones with processors enabled for graphics processing unit and high quality displays, these are able to generate pleasant educational experiences within everyone's reach, which have demonstrated benefits for participatory, interactive and self-directed learning, while at the same time enabling new skills such as spatial understanding and orientation, particularly in students with low space capacity.

Reeves et al.(28) Mendez-Lopez et al. (29), Mellos and Probst (30) and Mcbain et al.(31) through mixed methodologies have tried to measure the impact of this technology on both academic performance and student perceptions, through surveys, questionnaires and focus group discussions, synthesized the attractive nature and interactivity of AR, the findings are positive because they confirm the value of this technology to facilitate immersive learning and the transfer of skills such as understanding complex 3D biological models in relation to their function, also that may be valid for students of any health program, therefore, there are no motivational or cognitive factors that could hinder its potential as an educational tool. Participants highlighted some negative aspects of the HR, among these practical problems pointed out that a good Internet connection should be available, adequate space, assistance or accompaniment of teachers and for their training position for the management of technological tools.

According to the systematic review carried out, the findings found claim that the number of studies on Augmented Reality is increasing, for this reason, it is usual to implement it as a meth-od of teaching technological innovation that attracts the modern and digital student (32). However, more studies are still needed in the area of health sciences to identify the factors that contribute to positive learning and the most effective way to combine this technology with current education. Of the 16 articles reviewed, 7 were oriented in working innovative proposals of AR, for the teaching -learning of academic contents of health, especially on human anatomy, in this regard, previous research has stated that when students graduate there are theoretical gaps in the knowledge of anatomic structures and a considerable loss of retention of anatomical knowledge, some key points of this situation, the decrease in the number of theoretical hours devoted to teaching anatomy in university education within the curricula, as well as the number of laboratory hours, limited availability of corpses and models(33). Some research suggests educational refinements, in other words, a multimodal approach to teaching-learning anatomy that includes effective interactive and immersive methodologies that pass the reading of textbooks or lecture-based instructions, a proposal to consider is the AR which has the potential to provide a greater understanding of the structures and functions of human organs in 3D space, while providing a more realistic representation of the human body compared to traditional means. (33) (34)

With respect to the most interesting AR tools, the use of multimedia technology, 3D modeling, real-time tracking and registration of objects, intelligent interaction, detection of images using mobile devices was evidenced, tablets portable, HoloLens 2 or Microsoft holographic lenses, these facilitate mixed reality scenarios, whose most distinctive feature is the ability to perceive an anatomical model in a real 3D plane without losing the user's own sense of environment. It was identified that three-dimensional anatomical models that allow stereoscopic viewing in AR can help optimize the acquisition of anatomical knowledge in students with lower visual and spatial skills. (18). This variety of AR applications and technologies provide in the educational field new alternatives to improve educational environments, which gives better learning outcomes evidenced by higher content retention (35) better academic performance (36) in solving tasks. (37) (38) and a greater capacity to interact and contextualize the biological structures observed in nature, while encouraging dialogical learning through peer interaction. (38)

However, it is interesting to discuss the effectiveness of RA in teaching-learning processes in academic programs in the area of health, the systematic review showed 6 papers indicating a statistically significant relationship in the use of RA compared to traditional teaching-learning methodologies, AR is an aid for the student to learn better and more, in turn to have a greater theoretical understanding and metacognitive perception in terms of attention, retention and motivation to achieve autonomous learning (19), AR enables the development of new skills such as spatial ability through three-dimensional visual stimuli combining experiences of physical words with virtual environments.(20) In line with these results, other studies have already indicated that RA increases self-confidence, motivation, attention and interest, which enables a productive study environment (39) and gives the student the

opportunity to make active observations and see the material repeatedly (39), so young people claim that their fears as well as their feeling of frustration diminish.(40) On the motivation towards AR, the results of other studies comparing various teaching methods revealed significant statistical differences(41) and others that have not (42). However, they agree that motivation is a substantial component of learning and preserving it is a major challenge for educators, although not everyone is ready to adopt such advanced technologies (10) et al., 2021) they require adapting, updating and quickly altering the content in a way that is not possible with a prescribed textbook, such as introducing AR games and alternative, very attractive activities. (43)

These investigations show in the first instance that the educational materials or applications that promote the mobile reality increase, admit that students have an active role in the learning process, the student has the opportunity to access information and applications repeatedly through their mobile devices whenever and wherever they want, can manipulate and interact and carry out a practical procedure using three-dimensional animations and videos as often as they wish, they receive immediate feedback that leads to easier learning and understanding (44) (24) (45) (46), as a second, contribute to the promotion of collaborative learning and the interaction of contents , being more effective with respect to the use of traditional methodologies based on the reproduction of contents by the teacher (23) as a third, they allow you to keep your focus on curricular goals, creating immersive and interactive learning environments that support visualizations that would otherwise not be possible (12) and finally, they encourage the development of skills, there are studies that claim that mobile AR training practices have a positive effect on the progress of psychomotor (47) through experience, and interaction with the various created objects (48) (44) they also improve memory at a structural level and functional .(49).I do not know can leave aside, the 3 studies that showed no statistically significant differences, in fact, these studies con-sider that RA should be considered as a complementary educational tool, especially in learning the three-dimensional relation-ships of anatomical structures (22), These new methods promote intrinsic benefits, such as greater immersion and student participation. Although compared with different computer-based learning techniques (augmented, virtual and mixed reality) show no differences, AR has been endorsed as an effective learning tool in anatomical education compared to virtual reality and mobile-based instructional methods. (43) (50). These findings are similar to previous works that characterized the RA as a complementary teaching modality, which is not intended to replace existing ones, but allows a multimodal and self-directed learning. Interactive 3D techniques have the potential to improve anatomy knowledge and are increasingly demanded by medical students. (51) . The systematic review reported 7 promising studies on AR content innovation, these were oriented to the development of application prototypes that use AR technology as learning tools, designed to improve the learning environments of different disciplines of the Health Sciences, promote student motivation, increase learning outcomes and build their capacity to engage passionately in self-learning. (25)

The incorporation of AR-based applications for teaching and learning of different topics such as the 3D visualization of the morphology of brain regions and the search for their function-al information, the teaching of radiology and macroscopic anatomy, estimating food portions, teaching nursing injection practices, not only do they improve the development of physical skills in students, but they are also welcomed as an inclusive teaching tool in the curricula given their practical and useful effect on medical procedures and practices, reducing the likelihood of error while increasing competition, motivation and learning(21) (31). How-ever, despite the imperative that the RA has many advantages, is still a logistical and pedagogical challenge because it requires specialized equipment for its execution that may not be available to all educational institutions. (28) From this systematic review concluded in the first instance that the type of research that predominates is quantitative, with the use of experimental, quasi-experimental designs and mixed de-signs that combine quantitative and qualitative techniques, as well as the academic program with the highest number of research exercises is Medicine. As for the AR Technology Tools most used in Higher Education for the programmatic contents of the health sciences area are the use of multimedia technology, 3D modeling, real-time tracking and registration of objects, intelligent interaction, Image detection, using mobile devices and portable tablets.

References

1. Chouvarda I, Mountford N, Trajkovik V, Loncar-Turukalo T, Cusack T. Leveraging Interdisciplinary Education Toward Securing the Future of Connected Health Research in Europe: Qualitative Study. J Med Internet Res. 13 November 2019;21(11): e14020. Doi: 10.2196/14020
2. Meng X, Yang L, Sun H, Du X, Yang B, Guo H. Using a Novel Student-centered Teaching Method to Improve Pharmacy Student Learning. Am J Pharm Educ [Internet]. 1 March 2019 [cited June 5, 2023];83(2). Available in: https://www.ajpe.org/content/83/2/6505
3. Garzón J, Kinshuk, Baldiris S, Gutiérrez J, Pavón J. How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis. Educ Res Rev. 1 November 2020; 31:100334. https://doi.org/10.1016/j.edurev.2020.100334
4. Tan Y, Xu W, Li S, Chen K. Augmented and Virtual Reality (AR/VR) for Education and Training in the AEC Industry: A Systematic Review of Research and Applications. Buildings. October 2022;12(10):1529. https://doi.org/10.3390/buildings12101529
5. Mendez KJW, Piasecki RJ, Hudson K, Renda S, Mollen-kopf N, Nettles BS, et al. Virtual and augmented reality: Implications for the future of nursing education. Nurse Educ Today. 1 October 2020; 93:104531. https://doi.org/10.1016/j.nedt.2020.104531
6. Phakamach P, Senarith P, Wachirawongpaisarn S. The Metaverse in education: The future of immersive teaching & learning. RICE J Creat Entrep Manag. 2022;3(2):75-88. 75-88. chrome-exten-si-on://efaidnbmnnnibpcajpcglclefindmkaj/https://dergipark.org.tr/en/download/article-file/2574111
7. Seidametova ZS, Abduramanov ZS, Seydametov GS. Using augmented reality for architecture artifacts visualizations. In CEUR Workshop Proceedings; 2021. https://doi.org/10.31812/123456789/4626
8. Hantono BS, Nugroho LE, Santosa PI. Meta-Review of Augmented Reality in Education. In: 2018 10th International Conference on Information Technology and Electrical Engineering (ICITEE). 2018. p. 312-5. https://doi.org/10.1109/ICITEED.2018.8534888
9. Rodríguez-Abad C, Fernandez de la Iglesia J del C, Martínez-Santos AE, Rodríguez-González R. A Systematic Re-view of Augmented Reality in Health Sciences: A Guide to Decision-Making in Higher Education. Int J Environ Res Public Health. January 2021;18(8):4262. https://doi.org/10.3390/ijerph18084262
10. Díaz-Agea JL, Pujalte-Jesús MJ, Leal-Costa C, García-Méndez JA, Adánez-Martínez MG, Jiménez-Rodríguez D. Motivation: bringing up the rear in nursing education. Motivational elements in simulation. The participants' perspective. Nurse Educ Today. 1 August 2021; 103:104925. https://doi.org/10.1016/j.nedt.2021.104925
11. Sun G, Xie H, Liu Y, Chen Y, Hou X, Zhang D. Impact of brain injury on processing of emotional prosodies in neonates. Front Pediatr. 2019;7(MAY). https://doi.org/10.1007/s10956-022-10001-4
12. Rodríguez-Abad C, Rodríguez-González R, Martínez-Santos AE, Fernández-de-la-Iglesia J del C. Effectiveness of augmented reality in learning about leg ulcer care: A quasi-experimental study in nursing students. Nurse Educ Today. 1 December 2022; 119:105565. https://doi.org/10.1016/j.nedt.2022.105565
13. Gargrish S, Mantri A, Kaur DP. Augmented reality-based learning environment to enhance teaching-learning experience in geometry education. Procedia Comput Sci. 2020;172:1039-46. https://doi.org/10.1016/j.procs.2020.05.152
14. Childs E, Mohammad F, Stevens L, Burbelo H, Awoke A, Rewkowski N, et al. An Overview of Enhancing Distance Learning Through Augmented and Virtual Reality Technologies [Internet]. arXiv; 2023 [cited June 25, 2023]. Available in: http://arxiv.org/abs/2101.11000. https://doi.org/10.48550/arXiv.2101.11000
15. Young GW, Stehle S, Walsh BY, Tiri E. Exploring virtual reality in the higher education classroom: Using VR to build knowledge and understanding. J Univers Comput Sci. 2020;(8):904-28. https://eprints.teachingandlearning.ie/id/eprint/5668/
16. Kugelmann D, Stratmann L, Nühlen N, Bork F, Hoffmann S, Samarbarksh G, et al. An Augmented Reality magic mirror as additive teaching device for gross anatomy. Ann Anat - Anat Anz. January 1, 2018;215:71-7. https://doi.org/10.1016/j.aanat.2017.09.011
17. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020: an updated guide for the publication of systematic reviews. Rev Esp Cardiol. 1 September 2021;74(9):790-9. https://doi.org/10.1016/j.recesp.2021.06.016
18. Bogomolova K, van der Ham IJ, Dankbaar ME, van den Broek WW, Hovius SE, van der Hage JA, et al. The effect of stereoscopic augmented reality visualization on learning anatomy and the modifying effect of visual-spatial abilities: A double-center randomized controlled trial. Anat Sci Educ. 2020;13(5):558-67. https://doi.org/10.1002/ase.1941
19. Ferrer-Torregrosa J, Jiménez-Rodríguez MÁ, Torralba-Estelles J, Garzón-Farinós F, Pérez-Bermejo M, Fernández-Ehrling N. Distance learning ects and flipped classroom in the anatomy learning: comparative study of the use of augmented reality, video and notes. BMC Med Educ. 2016;16(1):1-9. https://doi.org/10.1186/s12909-016-0757-3
20. Fernandes J, Teles A, Teixeira S. An augmented reality-based mobile application facilitates the learning about the spinal cord. Educ Sci. 2020;10(12):376. https://doi.org/10.3390/educsci10120376
21. Bork F, Lehner A, Eck U, Navab N, Waschke J, Kugelmann D. The effectiveness of collaborative augmented reality in gross anatomy teaching: A quantitative and qualitative pilot study. Anat Sci Educ. 2021;14(5):590-604. https://doi.org/10.1002/ase.2016
22. Henssen DJ, van den Heuvel L, De Jong G, Vorstenbosch MA, van Cappellen van Walsum AM, Van den Hurk MM, et al. Neuroanatomy learning: Augmented reality vs. cross-sections. Anat Sci Educ. 2020;13(3):353-65. https://doi.org/10.1002/ase.1912
23. López-Belmonte J, Pozo-Sánchez S, Fuentes-Cabrera A, Rodríguez-García AM. Eficacia contrastada de la Realidad Aumentada en el aprendizaje de la reanimación cardiopulmonar. Educ Médica Super. 2021;35(1). http://scielo.sld.cu/scielo.php?pid=S0864-21412021000100004&script=sci_arttext&tlng=pt

24. Kurt Y, Öztürk H. The effect of mobile augmented reality application developed for injections on the knowledge and skill levels of nursing students: An experimental controlled study. Nurse Educ Today. 1 de agosto de 2021; 103:104955. https://doi.org/10.1016/j.nedt.2021.104955
25. Jamali SS, Shiratuddin MF, Wong KW, Oskam CL. Utilising mobile-augmented reality for learning human anatomy. Procedia-Soc Behav Sci. 2015; 197:659-68. https://doi.org/10.1016/j.sbspro.2015.07.054
26. Birt J, Stromberga Z, Cowling M, Moro C. Mobile mixed reality for experiential learning and simulation in medical and health sciences education. Information. 2018;9(2):31. https://doi.org/10.3390/info902003
27. Azher S, Cervantes A, Marchionni C, Grewal K, Marchand H, Harley JM. Virtual Simulation in Nursing Education: Headset Virtual Reality and Screen-based Virtual Simulation Offer A Comparable Experience. Clin Simul Nurs. 1 June 2023; 79:61-74. https://doi.org/10.1016/j.ecns.2023.02.009
28. Reeves LE, Bolton E, Bulpitt M, Scott A, Tomey I, Gates M, et al. Use of augmented reality (AR) to aid bioscience education and enrich student experience. Res Learn Technol. 2021; 29:2572. doi:10.25304/rlt. v29.2572
29. Mendez-Lopez M, Juan MC, Molla R, Fidalgo C. Evaluation of an augmented reality application for learning neuro-anatomy in psychology. Anat Sci Educ. 2022;15(3):535-51. https://doi.org/10.1002/ase.2089
30. Mellos I, Probst Y. Evaluating augmented reality for 'real life 'teaching of food portion concepts. J Hum Nutr Diet. 2022;35(6):1245-54. https://doi.org/10.1111/jhn.13016
31. McBain K, Chen L, Lee A, O'Brien J, Ventura NM, Noël GP. Evaluating the integration of body donor imaging into anatomical dissection using augmented reality. Anat Sci Educ. 2023;16(1):71-86. https://doi.org/10.1002/ase.2157
32. Arantes M, Arantes J, Ferreira MA. Tools and resources for neuroanatomy education: a systematic review. BMC Med Educ. 2018; 18:1-15. . https://doi.org/10.1186/s12909-018-1210-6
33. Sutherland J, Belec J, Sheikh A, Chepelev L, Althobaity W, Chow BJ, et al. Applying modern virtual and augmented reality technologies to medical images and models. J Digit Imaging. 2019; 32:38-53. https://doi.org/10.1007/s10278-018-0122-7
34. Latiff AA, Kamarzaman S, Manan NA, Rampal KG, Muniandy BK. Students' Perception on Anatomy Education in Cyberjaya University College of Medical Sciences, Malaysia. J Anat Soc India. June 2019;68(2):163. 10.4103/JASI.JASI_46_19
35. Meng X, Yang L, Sun H, Du X, Yang B, Guo H. Using a novel student-centered teaching method to improve pharma-cy student learning. Am J Pharm Educ. 2019;83(2). https://doi.org/10.5688/ajpe6505
36. Wu H, Li S, Zheng J, Guo J. Medical students' motivation and academic performance: the mediating roles of self-efficacy and learning engagement. Med Educ Online. 1 January 2020;25(1):1742964. https://doi.org/10.1080/10872981.2020.1742964
37. Mitrousias V, Varitimidis SE, Hantes ME, Malizos KN, Arvanitis DL, Zibis AH. Anatomy learning from prosected cadaveric specimens versus three-dimensional software: A comparative study of upper limb anatomy. Ann Anat-Anat Anz. 2018; 218:156-64. https://doi.org/10.1016/j.aanat.2018.02.015
38. García-Carrión R, López de Aguileta G, Padrós M, Ramis-Salas M. Implications for social impact of dialogic teaching and learning. Front Psychol. 2020; 11:140. https://doi.org/10.3389/fpsyg.2020.00140
39. Gümbür Y, Avaroğullari M. The effect of using augmented reality applications on social studies education. Araşt Ve Deneyim Derg. 31 December 2020;5(2):72-87. https://doi.org/10.47214/adeder.835927
40. Khan T, Johnston K, Ophoff J. The impact of an augmented reality application on learning motivation of students. Adv Hum-Comput Interact. 2019. https://doi.org/10.1155/2019/7208494
41. Cabero-Almenara J, Roig-Vila R. The motivation of techno-logical scenarios in augmented reality (AR): Results of different experiments. Appl Sci. 2019;9(14):2907. https://doi.org/10.3390/app9142907
42. Nørgård C, O'Neill LD, Chemnitz J, Majgaard G. Learning Anatomy with Augmented Reality: Learning design and app design for optimal learning. Tidsskr Læring Og Medier LOM. 2019;12(20): https://doi.org/10.7146/lom.v12i20.109569
43. Moro C, Smith J, Finch E. Improving stroke education with augmented reality: A randomized control trial. Comput Educ Open. 2021; 2:100032. https://doi.org/10.1016/j.caeo.2021.100032
44. Aebersold M, Voepel-Lewis T, Cherara L, Weber M, Khou-ri C, Levine R, et al. Interactive Anatomy-Augmented Virtual Simulation Training. Clin Simul Nurs. 1 February 2018; 15:34-41. https://doi.org/10.1016/j.ecns.2017.09.008
45. Alismail A, Thomas J, Daher NS, Cohen A, Almutairi W, Terry MH, et al. Augmented reality glasses improve adherence to evidence-based intubation practice. Adv Med Educ Pract. 31 December 2019; 10:279-86. https://doi.org/10.2147/AMEP.S201640
46. Logishetty K, Western L, Morgan R, Iranpour F, Cobb JP, Auvinet E. Can an augmented reality headset improve accuracy of acetabular cup orientation in simulated THA? A randomized trial. Clin Orthop. 2019;477(5):1190.
47. Martli Ep, Dincer Nu. Technology in nursing education: Augmented reality. Pamukkale Üniversitesi Mühendis Bilim Derg. 2021;27(5):627-37. doi: 10.5505/pajes.2020.38228
48. Taçgin Z, Tacgin E. A smart multimodal augmented reality application skill training for preoperative procedures. Bilişim Teknol Derg. 2020;13(1):57-63. https://doi.org/10.17671/gazibtd.642130
49. Lewis Jr JB, Mulligan R, Kraus N. The importance of medical mnemonics in medicine. Pharos. 2018:30-5. chro-me-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.alphaomegaalpha.org/wp-content/uploads/2021/03/2018-1-Lewis.pdf
50. Moro C, Phelps C, Stromberga Z. Utilizing serious games for physiology and anatomy learning and revision. Adv Physiol Educ. 2020;44(3):505-7. https://doi.org/10.1016/j.caeo.2021.100032
51. Triepels CPR, Koppes DM, Van Kuijk SMJ, Popeijus HE, Lamers WH, Van Gorp T, et al. Medical students' perspective on training in anatomy. Ann Anat-Anat Anz. 2018; 217:60-5. https://doi.org/10.1016/j.aanat.2018.01.006