Effects of Virtual Reality-Based Teaching On Students' Learning Performance In Anatomy

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Abstract

Background: Students should become familiar with spatial relationships around anatomical structures, not just their appearance and function. This is a challenge in traditional classrooms where students use 2D images of books and descriptive articles as a reference. The aim of this study was to evaluate the effectiveness of VR training applied in anatomy training compared to conventional or 2D digital methods in the classroom.

Method: Our quasi-experimental method used pre-test and post-test to measure academic achievement and technology acceptance questionnaires. A total of 92 fourth-year medical students were from three classes. They were randomly divided into three groups: 1) Traditional education group and 2) Virtual Reality education group 3) E-learning group (based on Moodle). To examine learning performance, the measurement tools included pre-test and post-test of anatomy and technology acceptance questionnaire.

Result: The results showed that students who took anatomy courses in VR showed significantly higher academic achievement than those who taught through traditional methods. There was also a significant difference between E-learning and traditional groups and no significant difference was observed between E-learning and VR groups.

Conclusion: The present study provides empirical evidence for the use of VR in anatomy education. In addition, it explains how to create and implement a VR-based class for formal educational purposes.

Introduction

Anatomy is a visual science that is thought to be an important foundation for medical learning [1]. When studying anatomy, learners identify structures and their spatial relationships. However, medical students have difficulty in gaining a sufficient understanding of the three-dimensional anatomy of graphic images, such as those found in textbooks and PowerPoint. Despite the many teaching methods, many undergraduate and graduate students underestimate their descriptive knowledge. [2–3]. Many students are interested in using 3D images to learn anatomy [3–4]. Medical students' knowledge of human anatomy has an obvious erosion that must be evaluated and examined. Poor knowledge in human anatomy courses is thought to be one of the reasons for this problem, which is a major concern in medical education [5–8]. Students should become familiar with spatial relationships around anatomical structures, not just their appearance and function. This is a challenge in traditional classrooms where students use two-dimensional images from books and descriptive articles as a reference [7]. However, with the use of various tools and techniques for teaching anatomy, there is uncertainty about the methods of providing optimal education. With the rapid advancement of technology and e-learning, it is crucial to discover the potential of technology in providing tailored anatomical training [9–11]. Therefore, the development of modern strategies focused on teaching and learning anatomy efficiently as well as with high quality has become vital. With the development of new learning tools, the health and medical education system has begun to make greater use of interactive media and online content [12–13]. The use of computer-based 3D models in anatomy education has become popular in recent years. Notably, VR is a technology that allows you to explore and manipulate the multimedia environments produced by real or artificial 3D computers in real time [8, 14]. This enables an active first-person learning experience through different levels of immersion [15–16]. The advent of virtual reality technology can be traced back to the entertainment industry in the 1960s [17]. Virtual Reality (VR) promises to provide more engaging and engaging experiences with them [18]. Recently, the interest in VR has increased in the world of medical education, especially for the teaching of anatomy and resident surgery [10–11]. VR provides a simulation scene for students to quickly conceptualize three-dimensional physical communication [19]. Some studies have compared VR with other methods of teaching anatomy, such as dissection, lectures, 2D images, and combination instructions [17]. For example, in 2019, Maresky et al. [20] Tested the effectiveness of VR cardiac simulation in medical education. They found that students (n = 28) underwent virtual reality simulation in the final test performed much better than the control group (14 people). In 2015, a meta-analysis was conducted to evaluate the effectiveness of teaching the use of 3D visualization approaches in educational anatomy [21] The results showed that 3D visualization methods are better tools than 2D methods in obtaining real knowledge of anatomy and knowledge of spatial anatomy. However, there is not a high level of evidence on the effectiveness of these different VR methods compared to various other techniques in randomized controlled trials. Accordingly, the aim of this study was to evaluate the effectiveness of VR training applied in anatomy training compared to conventional or 2D digital methods in the classroom.

Method

Research design

A quasi-experimental method was used to investigate the effect of VR on students' anatomical learning performance. We assigned one class to the virtual reality education group, one class to the e-learning group (Moodle-based), and another class to the traditional education group after they determined that the three groups had prior knowledge levels. Prior to the test, all students signed the informed consent form and performed this pre-test. The virtual reality group took anatomy lessons in the VR group and E-learning (Moodle-based) that they learned through the model platform, while the traditional teaching group completed the same subjects through traditional teaching methods in a regular class. At the end of the experiment, post-test and questionnaire were administered to students.

Sample size

The study population consisted of 92 fourth year medical students of RAZI Medical School in Kermanshah, Iran, then they were randomly divided into three groups: 1) the traditional teaching group and 2) the virtual reality teaching group 3) the E-learning teaching group (Moodle-based). There were 31 students in the traditional education group, including 13 men and 18 women with a mean age of 21.11 ± 1.19 years. There were 30 students in the virtual reality education group, consisting of 16 men and 14 women, and their mean age was 20.11 ± 0.67 years. There were 31 students in the e-learning group consisting of 15 men and 16 women and their mean age was 20.11 ± 0.67 years. Also, there was no significant difference between the groups in terms of gender and age ($P > 0.05$).

Procedure

At the same time as teaching, the traditional teaching team combined literature-based learning with the teaching of text, images, animation, and film in a multimedia data set. While human anatomy modules on a 3D-VR software, operating systems installed on mobile phones (Table 1) were used for the VR group, and in the E-learning group, a Moodle-based online course was used. As shown in Fig. 1, the experiment's duration was 8 weeks, with seven 60-minute classes per week starting in early September 2019. In the first week, three groups of pre-test students completed. After that, we tested VR lessons and devices for optimal performance in VR. At the same time, the VR team needed to become familiar with the VR device and classroom settings, which helped reduce the new effects that might affect students' learning when using new technologies. From the second to the seventh week, the teacher held six science lessons each week. Each week, the VR group was introduced to the content and needs of the learning units for approximately 10 minutes. They then followed the teacher's instructions to gain scientific knowledge and experience virtual scenes. Because there were not enough VR devices for each student, the students were randomly divided into 10 subgroups of five students and used VR devices during the learning process. Each student experiences approximately 7 to 8 minutes of virtual scenes. After that, each subgroup engaged in face-to-face activities in which they discussed and completed a worksheet containing learning tasks (printed material). The E-learning group learned through the Moodle platform. In this context, 7 topics were designed for anatomy lessons in the form of 7 sessions. Students participated in an online class on a weekly basis. The teacher also provided students with homework, videos, chats and text in this room. The traditional teaching group, which was randomly divided into six subgroups of 5 students, studied the same subjects through traditional teaching methods in a regular classroom. Each week, the teacher used PowerPoint and regular videos to introduce the material. Then, each subgroup learned the units through science textbooks and worked together to complete the tasks on the activity page. Following this, the teacher summarized the answers after the students' discussion. The learning process, including participatory activities and study time, was the same in both groups except for the VR environment. In the eighth week, students completed post-test and comprehension scale in three groups.

Table 1
Applications used to teach content in VR group

session	Subject of education	Application used
1	General body anatomy and pre-test	Human body (male) educational VR 3D
2	Anatomy and physiology of the heart (1)	Living Heart for Cardboard VR
3	Anatomy and physiology of the heart (1)	Living Heart for Cardboard VR
4	Respiratory physiology (1)	Respiratory System Anatomy Pro
5	Respiratory physiology (2)	Respiratory System Anatomy Pro
6	Brain Anatomy (1)	Brain Anatomy Pro
7	Brain Anatomy (2)	Brain Anatomy Pro
8	Post -test	

Measurement tools

To examine learning performance, the measurement tools included pre-test and post-test, designed by two experienced anatomy teachers, as well as technology acceptance questionnaire. The pre-test and post-test content were designed differently to reduce the learning effect that could result from potential similarities between the two tests. The pre-test consisted of 25 items that focused on assessing that prior knowledge of pre-participation student anatomy was equivalent. This included 10 true or false cases and 10 single-choice cases (full score = 40). The post-test consisted of 24 items that measured anatomy knowledge and students' ability to understand knowledge related to learning units. These included eight single-choice items, eight true or false items, five vacancy fillers, and three short response items. Pre-test and post-test reliability were assessed using Cronbach's alpha values, both of which were greater than 0.80 and had acceptable internal consistency. A specialized group of three instructors confirmed the validity of the test content. Both the anatomy teachers and the expert group reviewed the final pre-test and post-test versions. We have fixed any problems to ensure high reliability and credibility. The language of both pre-test and post-test in this study was Persian. The Technology Acceptance Questionnaire developed by Chu et al. [22]. consisted of 13 items that were assessed through a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). This includes six items for perceived usefulness (for example, the learning system helped me get useful information when needed) and seven items for perceived ease of use (for example, it is not difficult for me to learn how the learning system works). Cronbach's alpha values for both dimensions were 0.84 and 0.86, respectively, which indicates the reliability of the questionnaire. questionnaire was translated into Persian to ensure that they correspond to the language culture in Iran. The researchers and two experienced teachers then validated the questionnaires to verify the accuracy of the items.

Statistical analysis

Descriptive quantitative analysis by comparison of the means and standard deviations of three groups was performed using SPSS 25. Moreover, to ensure that the data of the academic achievement test have the same scale, the perfect scores of the pre- and posttests were normalized using Min-Max Normalization during the data process.

Results

Academic achievement

The pre-test examined students' anatomy knowledge before learning activities. As shown in Table 2, the t-test result (e-learning and Traditional: t = 0.89, p = 0.2 > .05, VR and Traditional groups: t = 1, p = 0.8 > .05, VR and E-learning groups: t = 0.85, p = 0.9 > .05) shows no significant difference between the three groups, which indicates equivalent prior knowledge prior to learning activities. After learning activities, analysis of covariance (ANCOVA) test was used to test the difference between the three groups using pre-test scores as variable and post-test as dependent variables. The results of the homogeneity test showed that the post-test scores of the three groups are homogeneous (p = 0.73 > .0.05), which means that ANCOVA can be used. Table 3 summarizes the ANCOVA posttest results, in which a significant difference was found between VR and traditional groups (p = .001 < .05), indicating that students who have taken VR science courses have shown significantly higher academic achievement than those who teach through traditional methods .Also there was a significant difference were found between e-learning and Traditional groups (p = .001 < .05), indicating that the students who took the anatomy lessons in the e-learning showed significantly higher academic achievement than those learning through traditional teaching methods. also there was a no significant difference were found between e-learning and VR groups (p = 0.42 > .05).

Table 2
t-test result of pretest scores

	Group	N	Mean	SD	F	t
Pretest	Traditional	31	1.13	0.25	o.001	0.82
	E-learning	31	1.08	0.21		
	Traditional	31	1.13	0.25	0.22	0.88
	VR	30	1.07	0.20		
	E-learning	31	1.08	0.21	0.003	0.85
	VR	30	1.07	0.20		

Table 3
Descriptive data and ANCOVA of the posttest results

Group	N	Mean	SD	*F*
Traditional	31	3.78	1.30	10.28**
E-learning	31	4.69	.90	
Traditional	31	3.78	1.30	10.30**
VR	30	4.61	.50	
E-learning	31	4.69	.90	.10
VR	30	4.61	.50	

Technology acceptance

Regarding the VR group's assessment of the understanding and ease of use of the VR device, most students gave positive feedback regarding its effectiveness in learning anatomy. Mean values and standard deviation of perceived usefulness were 5.11 and 0.53 and mean and standard deviation of ease of use were 4.43 and 0.49. It can be concluded that students have a high score for technology acceptance, which means that they feel the benefits of using VR in the classroom in terms of its impact on their learning performance.

Discussion

In this study, we used VR using HMD and mobile containing a set of systematic VR anatomy lessons. To evaluate the effectiveness of the proposed method, we conducted an experiment in four anatomy learning units in a medical school. The results showed that students who practiced VR had significant academic achievement compared to those who learned through traditional teaching methods in a regular classroom. In addition, the VR group had a high degree of technology acceptance for using VR in the classroom. Regarding the academic achievement test, the findings are consistent with the results of similar studies, which show that VR has a positive effect on learning achievements [23–30]. In the present study, three specific reasons can illustrate the benefits of VR. First, the higher success of the VR group may be the result of positive VR features (immersion, interaction and immediate feedback). This is similar to previous studies in that effective VR interactions and communications allow users to focus more on learning, thus leading to better acquisition [31–35]. Second, face-to-face interactions are better for creative problem-solving and idea generation, while computer conferencing environments support better linking of ideas, interpretations, and integration of problems [36–37]. Therefore, face-to-face group learning activities combined with VR-supported interactive environments may provide a rich learning experience. In addition, visual descriptions of scientific content and instant feedback from the intelligent robot in the virtual scene may enhance the conceptual development of scientific knowledge [12]. The results also showed that students who worked in the e-learning group had a much higher academic achievement compared to students who learned through traditional teaching methods in a regular classroom. This means that e-learning enables students to engage with extracurricular science concepts by engaging in an e-learning environment. Inside the classroom, teachers used class time to discuss emerging ideas. This finding was supported by the study by Elfeky et al. [38], they concluded that there is a significant difference in the learning outcomes of learners during teaching with e-learning method. It could be that the e-learning classroom has created a deep learning environment that contributes to higher student performance. This is also buttressed by Mitra et al. [39] Which showed that the use of technological tools improves learning outcomes and encourages students to learn more actively. This function was better possible because e-learning is commensurate with the individual's learning speed and constantly provides tasks that accelerate learning outcomes. This brings both fast and slow learners to the same level of learning, and students are encouraged to frequently practice scientific concepts and experiments at home and at school. Convenience is also central to e-learning, allowing students to study at their own pace and thus improve performance. This strategy reduces the pressure on students and this gives them a better opportunity to practice and recall what they have learned. A study of Zipay et al. [40] showed that those who learn through e-learning performed better and retained more than their peers who use the conventional method of teaching. This is because today's students enjoy digital media because it allows them to read comfortably.

This study also showed that VR group students have a positive attitude towards accepting technology to use VR in the classroom. They found that VR is easy to use and improves their understanding of scientific knowledge. In addition, the high level of usefulness and ease of use shows that VR does not distract students during learning activities.

Implications, limitations and future research

Because there is so little information on this subject, one of the contributions of this research is due to its efforts to do more research on the use of VR in classrooms. The novelty of this study was that - in a classroom environment - a real virtual reality classroom consisting of 30 students and a teacher, who were in charge of the student learning process and class management through VR tools, was examined. This means that virtual reality tools have the ability to enhance classroom learning by providing visual knowledge and motivating young students with authentic learning experiences. For example, the mobile phone (VR education system) used in this study, which is used as a teaching tool, allows the teacher to interact directly with students by monitoring and managing their learning content in HMD. Slowly Therefore, the teacher can manage the classroom and learning content to perform learning activities more effectively. This study provides a reference for educators who wish to use this method in the classroom to perform similar learning activities on different topics.

This study also helps to identify and validate the empirical benefits (academic achievement) of using VR with HMD in the classroom. In addition, VR lessons can be integrated into existing anatomy curriculum as complementary resources. In this way, students have more opportunity to engage with scientific content and processes.

However, issues such as investing and teacher training are all important things to consider before successfully using VR with HMD in school classrooms. Schools and educators who want to use VR without investing may consider low-cost options. In addition, teachers may be challenged with the technical skills needed to design VR lessons or use VR technology for classroom practices. Because they need to spend more time and effort understanding the potential features of VR, participating in the design of virtual environments and classroom activities, and preparing for VR lessons.

This study also has several limitations. First, it was only proven that current VR is effective for fourth-year medical students, meaning that the results may not be generalizable to all age levels. Designing or implementing future VR for anatomy learning activities in the classroom should consider more of the learner's characteristics (age, gender, and perceived immersion). For example, as suggested by Cheng and Tsai [41], future studies could consider the immersion factors of basic attention and enjoyment. We also agree with Makransky and Lilleholt [42] that VR features, such as direct control, should be considered when designing VR environments. In addition, although the present study showed that VR can provide instant feedback for student learning, is this type of VR design, which includes elements of feedback, not as effective as many other online systems or traditional classroom conditions? Therefore, in the future, VR feedback elements should be educationally and technologically designed to improve anatomy learning. Moreover, since VR student groups had to use HMD during learning activities the student groups had to take turns using the HMDs during the learning activities, Future research should seek to prepare students for the effective use of HMD shared time and to explore how this group of students works in a VR environment. Finally, research into the long-term effects of using VR in classrooms is also needed to learn anatomy.

Conclusion

The results showed that students who practiced VR had significant academic achievement compared to those who learned through traditional teaching methods in a regular classroom. In addition, the VR group had a high degree of technology acceptance for using VR in the classroom. The present study provides empirical evidence for the use of VR in anatomy education. In addition, it explains how to create and implement a VR-based class for formal educational purposes. since in VR-based classroom student had to take turns using the HMDs during the learning activities, Future VR interventions should seek to prepare students for the effective use of HMD shared time and to explore how this group of students works in a VR environment.

Declarations

Abbreviations

Not applicable

Authors' contributions

BR and KA were involved in the conception and design of the work, managed the program; BR oversaw the program and contributed to the manuscript, analysis and interpretation of data, drafting and final approval the manuscript. BR, KA, and SPA collected data and participated in drafting the manuscript. The authors read and approved the final manuscript.

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Ethics approval

Ethical approval for this study has been obtained from Allameh Tabataba'i University Research Ethics Committee (approval number 1397.002).

Consent to participate

This study didn’t record any personal information and written consent was obtained from all participants. They were informed there is no risk involved in this study. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The datasets used and/or analyzed during the present study are available from the corresponding author upon request.

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References

1. McLachlan JC, Patten D. Anatomy teaching: ghosts of the past, present and future. Medical education. 2006 ,40(3):243-53. https://doi.org/10.1111/j.1365-2929.2006.02401.x.
2. Fitzgerald JE, White MJ, Tang SW, Maxwell-Armstrong CA, James DK. Are we teaching sufficient anatomy at medical school? The opinions of newly qualified doctors. Clinical Anatomy. 2008 ,21(7):718-24. https://doi.org/10.1002/ca.20662.
3. Triepels CP, Smeets CF, Notten KJ, Kruitwagen RF, Futterer JJ, Vergeldt TF, Van Kuijk SM. Does three-dimensional anatomy improve student understanding?. Clinical Anatomy. 2020,33(1):25-33. https://doi.org/10.1002/ca.23405.
4. - Bergman EM, Van Der Vleuten CP, Scherpbier AJ. Why don’t they know enough about anatomy? A narrative review. Medical Teacher. 2011,1;33(5):403-9.https://doi.org/10.3109/0142159X.2010.536276
5. Al-Mohrej OA, Al-Ayedh NK, Masuadi EM, Al-Kenani NS. Learning methods and strategies of anatomy among medical students in two different Institutions in Riyadh, Saudi Arabia. Medical teacher. 2017 ,16;39(1): 15-21. https://doi.org/10.1080/0142159X.2016.1254737.
6. Biasutto SN, Caussa LI, del Río LE. Teaching anatomy: cadavers vs. computers?. Annals of Anatomy-Anatomischer Anzeiger. 2006,1;188(2):187-90. https://doi.org/10.1016/j.aanat.2005.07.007.
7. Codd AM, Choudhury B. Virtual reality anatomy: Is it comparable with traditional methods in the teaching of human forearm musculoskeletal anatomy?. Anatomical sciences education. 2011,4(3):119-25. https://doi.org/10.1002/ase.214.
8. Davis CR, Bates AS, Ellis H, Roberts AM. Human anatomy: let the students tell us how to teach. Anatomical sciences education. 2014,8;7(4):262-72.https://doi.org/10.1002/ase.1424.
9. Dyer E, Swartzlander BJ, Gugliucci MR. Using virtual reality in medical education to teach empathy. Journal of the Medical Library Association: JMLA. 2018;106(4):498.https:doi.org/10.5195/jmla.2018.518.
10. Pilot A. Virtual Reality and Cardiac Anatomy: Exploring.2018.

11. Erolin C, Reid L, McDougall S. Using virtual reality to complement and enhance anatomy education. Journal of visual communication in medicine. 2019, 3;42(3):93-101. https://doi.org/10.1080/17453054.2019.1597626.
12. Liu R, Wang L, Lei J, Wang Q, Ren Y. Effects of an immersive virtual reality-based classroom on students' learning performance in science lessons. British Journal of Educational Technology. 2020;51(6):2034-49.https://doi.org/10.1111/bjet.13028.
13. Alharbi Y, Al-Mansour M, Al-Saffar R, Garman A, Alraddadi A. Three-dimensional Virtual Reality as an Innovative Teaching and Learning Tool for Human Anatomy Courses in Medical Education: A Mixed Methods Study. Cureus. 2020;12(2). https://doi.org/10.7759/cureus.7085
14. Jou M, Wang J. Investigation of effects of virtual reality environments on learning performance of technical skills. Computers in Human Behavior. 2013 1;29(2):433-8. https://doi.org/10.1016/j.chb.2012.04.020.
15. Rasouli B, Aliabadi K, Pourrosstai Aradkani S, Ahmady S, Asgari M. Development and Internal Validating of Medical Instructional Model Based on Virtual Reality. Iranian Journal of Medical Education. 2020 ,10;20:73-81. http://ijme.mui.ac.ir/article-1-4957-en.html
16. Labovitz J, Hubbard C. The Use of Virtual Reality in Podiatric Medical Education. Clinics in podiatric medicine and surgery. 2020 Jan 30;37(2):409-20. https://doi.org/10.1016/j.cpm.2019.12.008.
17. Zhao J, Xu X, Jiang H, Ding Y. The effectiveness of virtual reality-based technology on anatomy teaching: a meta-analysis of randomized controlled studies. BMC medical education. 2020 ,20(1):1-0. https://doi.org/10.1186/s12909-020-1994-z.
18. - Hawkins DG. Virtual reality and passive simulators: The future of fun. Communication in the age of virtual reality. 1995 ,1:159-89.
19. Petersen GB, Klingenberg S, Mayer RE, Makransky G. The virtual field trip: Investigating how to optimize immersive virtual learning in climate change education. British Journal of Educational Technology. 2020 Nov;51(6):2099-115. https://doi.org/10.1111/bjet.12991
20. Maresky HS, Oikonomou A, Ali I, Ditkofsky N, Pakkal M, Ballyk B. Virtual reality and cardiac anatomy: Exploring immersive three-dimensional cardiac imaging, a pilot study in undergraduate medical anatomy education. Clinical Anatomy. 2019,32(2):238-43. https://doi.org/10.1002/ca.23292.
21. Yammine K, Violato C. A meta-analysis of the educational effectiveness of three-dimensional visualization technologies in teaching anatomy. Anatomical sciences education. 2015, 12;8(6):525-38. https://doi.org/10.1002/ase.1510.
22. Chu HC, Hwang GJ, Tsai CC, Tseng JC. A two-tier test approach to developing location-aware mobile learning systems for natural science courses. Computers & Education. 2010,1;55(4):1618-27. https://doi.org/10.1016/j.compedu.2010.07.004.
23. Lochner L, Wieser H, Waldboth S, Mischo-Kelling M. Combining traditional anatomy lectures with e-learning activities: how do students perceive their learning experience?. International journal of medical education. 2016;7:69. doi: 10.5116/ijme.56b5.0369.

24. Moro C, Štromberga Z, Raikos A, Stirling A. The effectiveness of virtual and augmented reality in health sciences and medical anatomy. Anatomical sciences education. 2017 Nov;10(6):549-59.https://doi.org/10.1002/ase.1696.
25. - Parong J, Mayer RE. Learning science in immersive virtual reality. Journal of Educational Psychology. 2018 ,110(6):785. https://psycnet.apa.org/doi/10.1037/edu0000241.
26. - Shi A, Wang Y, Ding N. The effect of game–based immersive virtual reality learning environment on learning outcomes: Designing an intrinsic integrated educational game for pre–class learning. Interactive Learning Environments. 2019 ,30:1-4. https://doi.org/10.1080/10494820.2019.1681467.
27. Pandrangi VC, Gaston B, Appelbaum NP, Albuquerque Jr FC, Levy MM, Larson RA. The application of virtual reality in patient education. Annals of vascular surgery. 2019 Aug 1;59:184-9. https://doi.org/10.1016/j.avsg.2019.01.015.
28. Rourke S. How does virtual reality simulation compare to simulated practice in the acquisition of clinical psychomotor skills for pre-registration student nurses? A systematic review. International journal of nursing studies. 2020 Feb 1;102:103466. https://doi.org/10.1016/j.ijnurstu.2019.103466.
29. Wu B, Yu X, Gu X. Effectiveness of immersive virtual reality using head-mounted displays on learning performance: A meta-analysis. British Journal of Educational Technology. 2020 Nov;51(6):1991-2005.https://doi.org/10.1111/bjet.13023.
30. Zargaran A, Turki MA, Bhaskar J, Spiers HV, Zargaran D. The role of technology in anatomy teaching: striking the right balance. Advances in medical education and practice. 2020;11:259. https://doi.org/10.2147/AMEP.S240150.
31. Ragan ED, Bowman DA, Kopper R, Stinson C, Scerbo S, McMahan RP. Effects of field of view and visual complexity on virtual reality training effectiveness for a visual scanning task. IEEE transactions on visualization and computer graphics. 2015 ,13;21(7):794-807.DOI: 10.1109/TVCG.2015.2403312
32. Richert, A., Plumanns, L., Gross, K., Schuster, K., & Jeschke, S. 2015. Learning 4.0: Virtual immersive engineering education. *2015,*2(2)\: 51–66.
33. - Sattar MU, Palaniappan S, Lokman A, Hassan A, Shah N, Riaz Z. Effects of Virtual Reality training on medical students' learning motivation and competency. Pakistan journal of medical sciences. 2019 May;35(3):852.https:doi.org/ 10.12669/pjms.35.3.44.
34. Newman DR, Johnson C, Webb B, Cochrane C. Evaluating the quality of learning in computer supported co-operative learning. Journal of the American Society for Information science. 1997 ,48(6):484-95. https://doi.org/10.1002/(SICI)1097-4571(199706)48:6%3C484::AID-ASI2%3E3.0.CO;2-Q
35. Baniasadi T, Ayyoubzadeh SM, Mohammadzadeh N. Challenges and Practical Considerations in Applying Virtual Reality in Medical Education and Treatment. Oman Medical Journal. 2020 May;35(3):e125. .https:doi.org/10.5001/omj.2020.43.h.
36. Samosorn AB, Gilbert GE, Bauman EB, Khine J, McGonigle D. Teaching airway insertion skills to nursing faculty and students using virtual reality: A pilot study. Clinical Simulation in Nursing. 2020

Feb 1;39:18-26. https://doi.org/10.1016/j.ecns.2019.10.004.

37. Kidd TT, Keengwe J, editors. Adult Learning in the Digital Age: Perspectives on Online Technologies and Outcomes: Perspectives on Online Technologies and Outcomes. IGI Global; 2009.
38. Elfeky AI, Masadeh TS, Elbyaly MY. Advance organizers in flipped classroom via e-learning management system and the promotion of integrated science process skills. Thinking Skills and Creativity. 2020, 1;35:100622. https://doi.org/10.1016/j.tsc.2019.100622.
39. Mitra NK, Aung HH, Kumari M, Perera J, Sivakumar A, Singh A, Nadarajah VD. Improving the learning process in anatomy practical sessions of chiropractic program using e-learning tool. Translational Research in Anatomy. 2021 , 1;23:100100. https://doi.org/10.1016/j.tria.2020.100100.
40. Zipay NM, Roecker CB, Derby DC, Nightingale LM. The influence of online review videos on gross anatomy course performance among doctor of chiropractic students. Journal of Chiropractic Education. 2020,1;34(2):147-55. https://doi.org/10.7899/JCE-18-29.
41. Cheng KH, Tsai CC. Students' motivational beliefs and strategies, perceived immersion and attitudes towards science learning with immersive virtual reality: A partial least squares analysis. British Journal of Educational Technology. 2020 Nov;51(6):2140-59.https://doi.org/10.1111/bjet.12956.
42. -Makransky G, Lilleholt L. A structural equation modeling investigation of the emotional value of immersive virtual reality in education. Educational Technology Research and Development. 2018 ,66(5):1141-64. https://doi.org/10.1007/s11423-018-9581-2.

Figures

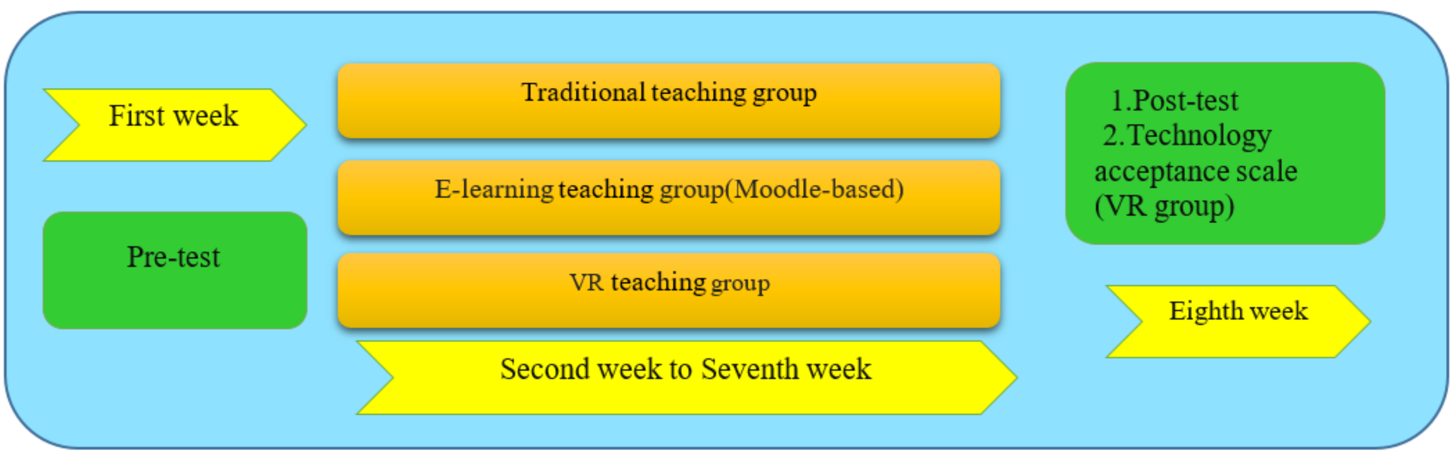

Figure 1

Procedure