Investigating the Effectiveness of Blended Learning as a New Strategy for Teaching Anatomy to Medical Students: A Systematic Review

Zahra Karbasi[1,2*] , Parisa Eslami[3], Maryam Zahmatkeshan[4,5], Sadrieh Hajesmaeel Gohari[1]

[1]Assistant Professor of Health Information Management, Medical Informatics Research Center, Institute for Futures Studies in Health, Kerman University of Medical Sciences, Kerman, Iran

[2]Assistant Professor of Health Information Management, Department of Health Information Sciences, Faculty of Management and Medical Information Sciences, Kerman University of Medical Sciences, Kerman, Iran

[3]Ph.D. in Medical Informatics, Department of Health Information Management, School of Allied Medical Sciences, Tehran University of Medical Sciences, Tehran, Iran

[4]Assistant Professor of Health Information Management, Noncommunicable Diseases Research Center, Fasa University of Medical Sciences, Fasa, Iran

[5]Assistant Professor of Health Information Management, School of Allied Medical Sciences, Fasa University of Medical Sciences, Fasa, Iran

Abstract

Background: The combined use of electronic and traditional education is called blended learning. Anatomy is a major in medical education. Using this method creates flexible learning environments and more interaction in learning.

Objectives: The present study was conducted to investigate the effect of blended learning on teaching anatomy to medical students.

Methods: This comprehensive literature review was conducted on December 3, 2022. Our research was conducted by adhering to the PRISMA guidelines. Online databases PubMed, Eric, and Web of Science were systematically searched for relevant articles using predefined keywords. Using EndNote, all relevant literature published within the past five years was retrieved and further analyzed.

Results: Our comprehensive search strategy resulted in the retrieval of 351 articles. After screening the articles and selecting the articles based on the inclusion criteria, 22 articles were eligible and included in the study. Most of the studies were conducted in India (n = 5), China (n = 2), United Kingdom (n = 2), and Portugal (n = 2). The majority of studies were conducted in 2022 (n = 7). The most important finding of all reviewed articles was the effectiveness of blended learning, which is mentioned as an effective method for teaching anatomy.

Conclusion: Blended learning can improve performance and increase satisfaction and motivation in students. Identifying suitable learning resources with medical students' abilities improves learners' knowledge. Applying new learning methods can be very effective as some conditions, such as the COVID-19 crisis, limit access to corpses and physical presence.

Keywords: Blended Learning, Anatomy, Medical Education, E-Learning

Background

Medical education provides information in the medical sciences and clinical practice (1). Various methods are used for medical education, including traditional face-to-face instruction, e-learning, and blended learning. Teaching medical students in the clinical setting with real patients is a time-honored tradition. This technique is a crucial component of clinical training. The traditional method allows medical students to engage in clinical activities and practice and become acquainted with the cultural and social aspects of the clinical environment. Direct observation and receiving feedback are two important factors in the successful education of medical students (2).

E-learning aims to provide distance health education using Information and Communication Technologies

(ICT) (3). With the outbreak of the Coronavirus Disease in 2019 (COVID-19), using this method of education has become more popular, particularly in medical education. However, practical issues, including unstable internet connectivity, a lack of computer laboratories, and the shortage of PCs and laptops, make it difficult to employ e-learning effectively (4).

The combined use of electronic and traditional education is called blended learning (5). Using this method creates flexible learning environments and more interaction in learning (6). Blended learning has different forms, which have a high potential to transfer content (7). Nowadays, various types of combined learning models, such as hybrid and flipped models, are among the most widely used educational methods in education and provide continuous and effective learning (8).

A study demonstrated that mobile applications could improve the performance of medical student learners (9). Another study showed that 3-dimensional (3-D) anatomical models could improve medical students' knowledge of ear anatomy more than traditional teaching methods (10). Although numerous studies have reported the benefits of e-learning in medical education, others have indicated that it cannot replace the traditional method. For instance, a study conducted in Greece revealed that traditional anatomy teaching is a more preferred and effective teaching method than e-learning. Remote learning cannot replace the conventional method of anatomy instruction, but it can be used as part of a blended learning approach (11).

According to the literature, blended learning can replace two other methods in medical education because it enhances the learning experience and the satisfaction of both students and teachers (12). It also enhances students' commitment by involving them in learning (13).

Anatomy is a major in medical education. Numerous studies have been conducted on the effectiveness of blended learning in anatomy courses (14-16). Based on our knowledge and investigations, despite various studies in this field, no study has examined the effect of blended learning on anatomy education.

Objectives

The present study was conducted to investigate the effect of blended learning on teaching anatomy to medical students.

Methods

This comprehensive literature review was conducted on December 3, 2022. Our research was conducted by adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Sources of Data: Online databases PubMed, Eric, and Web of Science were systematically searched for relevant articles using predefined keywords. Using EndNote, all relevant literature published within the past five years was retrieved and further analyzed. Table 1 summarizes the search strategy.

Table 1. Details of search strategy by databases

Databases	Search strategy
Web of Science	Blended learning (All Fields) or blended program (All Fields) or blended education (All Fields) or blended course (All Fields) or blended training (All Fields) or hybrid learning (All Fields) or hybrid program (All Fields) or hybrid education (All Fields) or hybrid course (All Fields) or hybrid training (All Fields) or computer-aided learning (All Fields) or Computer-assisted learning (All Fields) AND Anatomy (All Fields)
PubMed	(((((((((((((Blended learning) OR (blended program)) OR (blended education)) OR (blended course)) OR (blended training)) OR (hybrid learning)) OR (hybrid program)) OR (hybrid education)) OR (hybrid course)) OR (hybrid training)) OR (Computer-aided learning)) OR (Computer-assisted learning)) AND ("Anatomy"[Mesh])
Eric	(Blended learning) OR (blended program) OR (blended education) OR (blended course) OR (blended training) OR (hybrid learning) OR (hybrid program) OR (hybrid education) OR (hybrid course) OR (hybrid training) OR (Computer-aided learning) OR (Computer-assisted learning) AND Anatomy

Goals of Study: This study's primary objective was to investigate the effect of blended learning on teaching anatomy to medical students.

Inclusion criteria

- English studies.

- Studies reported the efficacy of using blended learning to teach anatomy to medical students.

Exclusion Criteria

- Lack of access to the article's full text.
- Non-English language articles.

- Articles that were not original, such as review articles, systematic reviews, letters to the editor, short communication, books, and commentaries.

Process of Study Selection: Related studies were reviewed through title and abstract screening by two authors independently.

Disagreements were mentioned and resolved through consensus in a joint meeting with the third reviewer. Then, the authors checked the full text of the articles based on the eligibility criteria, and finally, the information was extracted from the articles and collected in the relevant tables.

Data Extraction: Two investigators independently summarized and extracted the following data from the included publications: author, year, country, study aim, population, domain, intervention, study design, sample size, and main outcomes. The collected information is organized in the relevant tables.

Results

Our comprehensive search strategy resulted in the retrieval of 351 articles. After screening the articles and selecting the articles based on the inclusion criteria, 22 articles were eligible and included in the study. The details of the study selection process are presented in Figure 1. Most of the studies were conducted in India (n = 5), China (n = 2), United Kingdom (n = 2), and Portugal (n = 2). The distribution of articles in each country is presented in Figure 2 and Table 2.

Table 2. Frequency of reviewed articles per country

Country	Number of studies
India	5
China	2
Portugal	2
UK	2
Oman	1
France	1
Netherlands	1
Saudi Arabia	1
Germany	1
Georgia	1
Pakistan	1
Taiwan	1
Greece	1
South Carolina	1
New Zealand	1

According to the results obtained, the highest peak of the use of blended learning was in 2022. The frequency of articles published in different years is presented in Figure 3.

Also, most of the studies were experimental, the details of which are presented in Table 3. Since the study aimed to confirm the blended learning method in anatomy education, the investigated sub-branches of anatomy included histology, knee and shoulder anatomy, brainstem anatomy, gross anatomy, musculoskeletal and cardiovascular anatomy, anatomy pathology, nerve and head, and face radiology.

In the reviewed studies, different learning methods have been used, such as the flipped classroom, a variety of hybrid methods, online platforms, and electronic learning modules. The details of the learning models are presented in Figure 4.
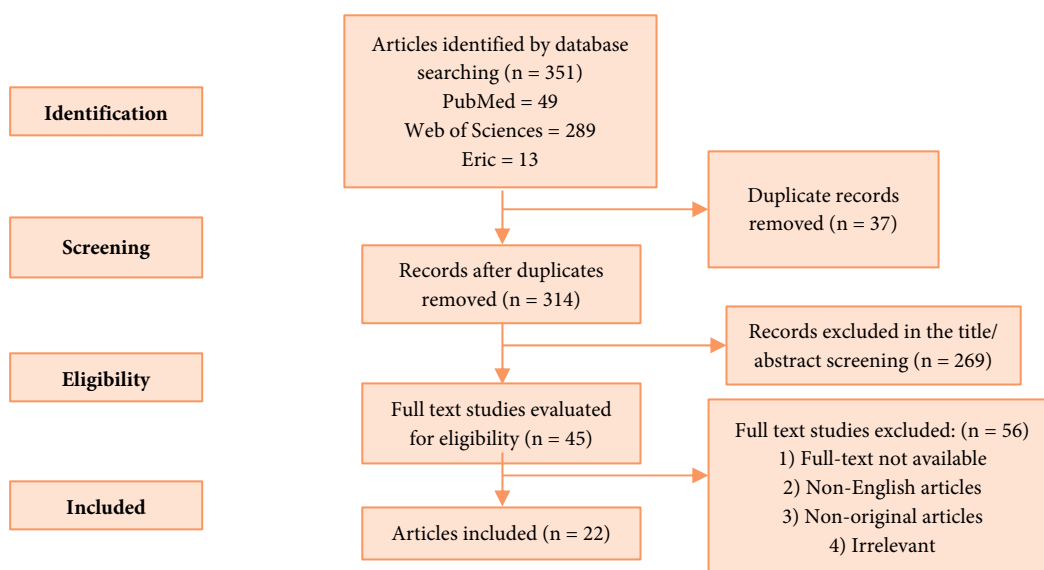
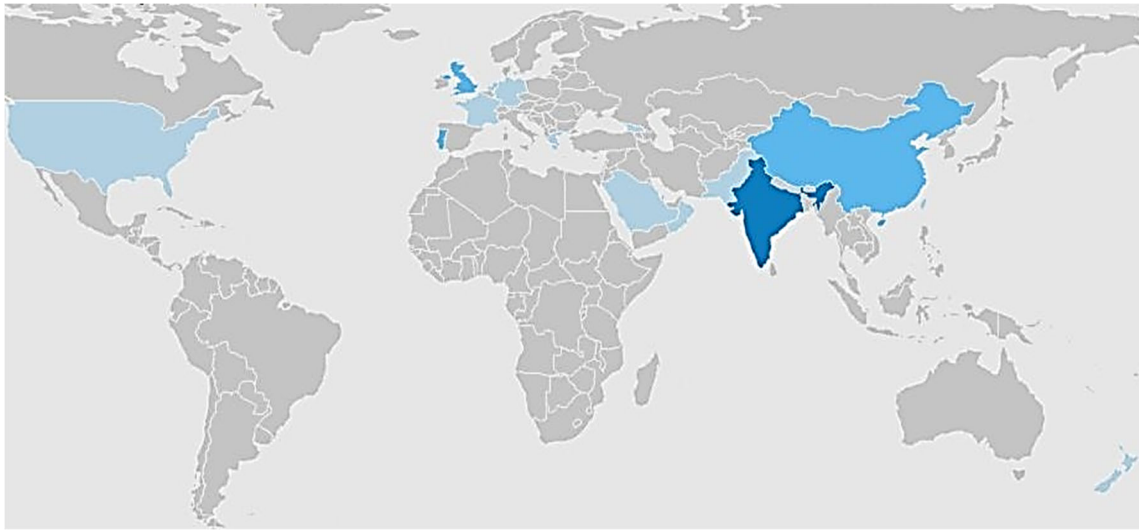

Figure 1. The process of selecting articles

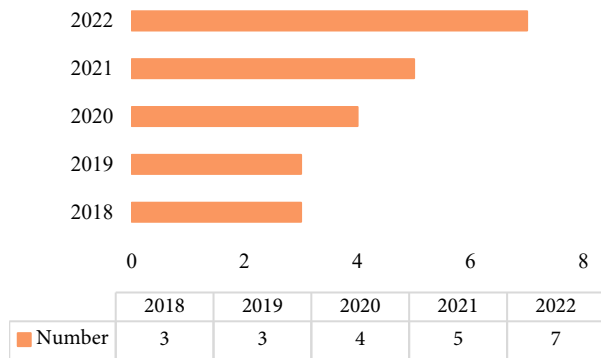**Figure 2.** Distribution of articles per country

	2018	2019	2020	2021	2022
Number	3	3	4	5	7

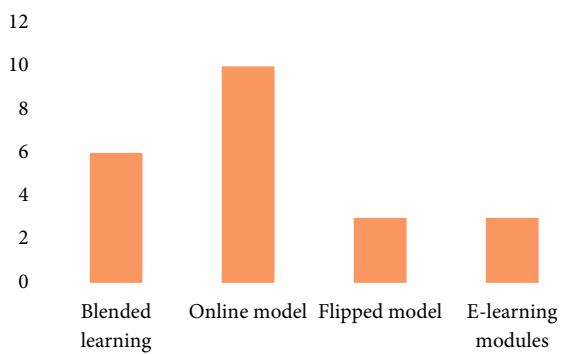**Figure 3.** Frequency of articles by publication year

Figure 4. Frequency of blended learning models used in studies

Table 3. Summary of characteristics of the included studies

Author	Year	Country	Aim of study	Population	Domain	Intervention	Study design	Sample size	Main outcome
Albalushi et al. (17)	2022	Oman	To distinguish the effectiveness of on-line anatomy evaluation in contrast to face-to-face assessment.	Doctor of medicine and biomedical science students	Anatomy	Face-to-face & online	Retrospective study	Doctor of medicine (n = 465) and biomedical sciences students (n = 88)	Online evaluation of anatomy is considered as one of the good methods like traditional evaluation.
Aristotle et al. (18)	2021	India	To consider the effectiveness of flipped classroom in histology classes.	Medicine and bachelor of surgery students	Histology	Flipped classroom	Interventional study	One hundred fifty students of the 1st-year medicine and bachelor of surgery students	Flipped classroom methodology of instructing histology had a very stunning effect.
Bhat et al. (19)	2022	India	Designing an electronic module for teaching anatomy and evaluating it.	Bachelor of medicine, and bachelor of surgery students	Anatomy	E-learning module	Prospective, randomized, interventional study	N/A	The satisfactory effect of the blended learning method was one of the results of this study.
Bretagne et al. (20)	2022	France	Examining the effectiveness of simulators in improving students' performance.	Medical students	Shoulder and knee anatomy	Procedural simulators	Randomized controlled study	Thirty medical students	The students' self-assurance stage in arthrocentesis accelerated.
Cappellen van Walsum & Henssen (21)	2022	Netherlands	Evaluating the impact of brainstem anatomy e-learning.	Medical students	Brainstem anatomy	Three-dimensional	Cross-sectional	Thirty-eight medical students	Learning anatomy using three- dimensional modules was a valuable study method.
Chen & et al. (22)	2020	China	To discover students' perceptions of whether or not blended laboratory learning are useful.	Undergraduate medical students	Anatomy	Online blended courses	Experimental study	N/A	Blended laboratory learning was profitable.
Cheng & et al. (23)	2021	China	To consider the gross anatomy training in China all through the pandemic.	Teachers of medical schools	Gross anatomy	Online	Cross-sectional	Three hundred fifty-nine participants	A complete of 36.2% of respondents desired to put into effect online instructing of theoretical classes after the pandemic.

Chimmalgi & Hortsch (24)	2022	India	To decide the effectiveness of self-directed learning modules	First-year medical students	Histology	Online self-directed learning modules	Experimental study	One hundred fifty medical students	The use of self-directed learning was positively received by learners.
El Sadik, & Al Abdulmonem (25)	2020	Saudi Arabia	To decide the consequence of the flipped class room based totally on the student's degree of understanding.	First-year medical students	Anatomy	Flipped classroom	Experimental study	First group (n = 49) and second group (n = 46)	The findings of this study presented the benefits of the flipped classroom.
Golenhofen et al. (26)	2019	Germany	Evaluating the impact of using mobile learning for anatomy education.	First-year medical students	Anatomy	Mobile learning tool	Observational study	Three hundred twenty medical students	Superior students were more motivated to use the mobile learning.
Greene. (27)	2020	Georgia	Using dissection videos and checking its effectiveness in teaching anatomy.	First-year medical students	Anatomy	Online learning screencasts	Experimental study	Two hundred one first-year medical students	Medical students found the use of screencasts useful.
Guimaraes et al. (28)	2019	Portugal	Evaluating the impact of computer-assisted learning on anatomy education.	Medical students	Musculoskeletal and cardiovascular anatomy	Computer-assisted learning	Prospective cohort study	Six hundred seventy-one medical students	Computer-assisted learning increased students' competencies in anatomy.
Jamil et al. (29)	2018	Pakistan	Investigating the impact of three-dimensional software in teaching anatomy.	First year undergraduate medical students	Anatomy	Three-dimensional software	Experimental study	Sixty-seven medical students	Software program based on 3D technologies was effective tool.
Lee et al. (30)	2019	Taiwan	Investigating the effect of using a virtual platform to improve students' laboratory performance.	Medical students	Histology and pathology	Web-based virtual platform	Pilot study	Six hundred sixty-two third-year students	Using the virtual platform improved students' performance and showed a positive effect.
Mitrousias et al. (31)	2018	Greece	To investigate performance using three-dimensional software in education.	Undergraduate, first-year medical students	Anatomy	Three-dimensional software	Comparative study	Seventy-two medical students	The three-dimensional software program was a favorite among students as an educational tool.
Nagaraj et al. (15)	2020	India	Investigating the impact of blended learning on radiology anatomy education.	First year undergraduate medical students	Radiological anatomy	E-learning modules	Prospective study	One hundred fifty undergraduates' medical students	The level of students' satisfaction with the modules was high.

Nathaniel et al. (32)	2021	South Carolina	Investigating differences in traditional and blended learning methods for neuroscience education.	Medical students	Neuroanatomy	Blended online course	Experimental study	One hundred two medical students	The blended learning method was effective in improving the performance of medical students.
Perumal. (33)	2018	New Zealand	Development and analysis of a web-based anatomy teaching tool.	Third-year medical students	Anatomy	Online anatomy learning	Experimental study	Two hundred eighty-two medical students	Online anatomy learning enhanced the learning experience and academic performance of students.
Rajan & Pandit (34)	2022	UK	Examining the application of a neuroscience electronic module.	Medical students	Neuroanatomy	E-module	Randomized control trial	Thirty-two medical students	Electronic modules helped motivate learners and overcome problems related to neuroscience.
Santos et al. (35)	2021	Portugal	Examining students' performance in the anatomy course using computer- assisted learning tools.	Medical students	Anatomy	Computer-assisted learning	Experimental study	611 medical students	Computer-assisted learning use has a positive effect on anatomy performance.
Sarkar et al. (36)	2021	India	Inventing a new model of blended learning and checking its effectiveness.	First year medical students.	Head, face and neck	Lectures and videos	Cross-sectional descriptive study	125 medical students	Blended learning promotes increased engagement and deeper educational learning.
Stone et al. (37)	2022	The UK and Ireland	Examining students' experiences of learning anatomy online.	Medical students	Anatomy	Online learning	Experimental study	224 medical students	Students reported that online methods were effective.

One of the criteria that can be used to measure the quality and effectiveness of teaching and learning is the satisfaction of learners (38). In this study, the effectiveness is the subjective understanding that students have about the desired results of blended learning programs, that if they are successful in the blended learning program, they will be more satisfied than others (39). In some studies (15, 20, 25, 34), students' use of blended learning method has satisfied them significantly. In addition, in several studies (22, 31), a large proportion of students (more than half) participating were satisfied with blended learning methods.

Another criterion for evaluating the effectiveness of learning methods is improving learners' performance (40). Researchers used different methods to investigate performance improvement. The noteworthy point is that in the studies (15, 19, 21, 22, 24, 25, 27-29, 31-33, 35), performance improvement when working with a blended learning environment has been reported, indicating the correlation of performance with blended learning methods.

According to the review of articles in the last 5 years, several studies (17, 21, 23, 24, 32, 37) investigated the use of blended learning during the outbreak of COVID-19, all of which reported the positive effect of using this method. The most important finding of all reviewed articles was the effectiveness of blended learning, which is mentioned as an effective method for teaching anatomy.

Discussion

This study aimed to investigate the effectiveness of blended learning methods on the learning level of medical anatomy students. To this end, we focused on different learning methods and their impact on anatomy learning.

The search conducted yielded 351 results, of which we identified and included 22 unique papers. Overall, the studies sought to describe the development of hybrid e-learning interventions (19, 33), compare the efficacy of such interventions to traditional learning (17, 18, 32), and validate students' perceptions of hybrid e-learning (19, 22, 26, 37). These studies and the increasing number of papers published over the past five years indicate that the blended learning field is still evolving, with the primary emphasis on intervention efficacy and acceptability evaluation (17, 18, 20, 24, 35, 36). Because anatomy is a fundamental medical science course and anatomy learning programs are typically taught to medical students in their first and second years of study,

most reviewed interventions were primarily designed to educate first-year medical students (17, 18, 27). Interactive electronic modules were the most prevalent form of blended learning in the studies (15,19,21,24,34).

There were many functional similarities between the reviewed interactive e-modules, including the collection of clinical cases to aid student learning, the provision of interactive questions to encourage active participation, the recording of student progress for tracking student progress and performance, and the provision of individualized feedback to prevent students from making possible mistakes. However, developed interventions do not seem the same in different medical areas. For example, in neuroscience and surgery fields, more sophisticated features such as virtual reality and augmented reality have been introduced compared to other fields. This could be due to the more complicated nature of those fields in terms of domain and user-specific requirements (34, 41, 42).

Based on our study, two studies (32, 37) investigated the effect of blended learning in the COVID-19 crisis, pointing out the favorable effect of the blended learning method. According to the obtained results, it is inferred that the blended learning method is a practical and promising approach for the post-corona era (43). Restrictions on access to cadavers during the pandemic may affect the teaching and learning of anatomy. Therefore, digital learning may replace real cadavers shortly (44).

Blended learning has been used in various areas of anatomy education, such as histology, shoulder and knee anatomy, brainstem anatomy, gross anatomy, musculoskeletal and cardiovascular anatomy, radiological anatomy, head, face, and neck. In most cases, the results have been reported to be favorable. These results suggest that in addition to face-to-face training, using blended learning may promote active learning in different educational fields. Blended learning had an overall positive effect. Various techniques were used to teach anatomy, such as flipped classrooms, e-Learning modules, simulators, online blended courses, mobile learning, videos, computer-assisted learning, and three-dimensional software. All these techniques somehow improved the skills of medical students. According to Karbasi and Niakan, new educational methods are very effective in this field, considering the importance of medical education. New technologies have provided new opportunities for anatomy education (45).

Therefore, it can be claimed that blended learning is an effective process to increase the motivation of students to learn and participate, thereby improving the effectiveness of medical education.

Limitation: Based on the review and knowledge of the authors, this is the first systematic review of the effect of blended learning methods on anatomy learning for medical students. Hence, it is challenging to compare the results between studies. Since we investigated the effectiveness of anatomy on medical students, it limited the search results based on the keywords of combined learning and synonyms.

Conclusion

Blended learning can improve performance and increase satisfaction and motivation in students. Identifying suitable learning resources with medical students' abilities improves learners' knowledge. Applying new learning methods can be very effective as some conditions, such as the COVID-19 crisis, limit access to corpses and physical presence. Using the face-to-face method and new teaching methods and their combination can positively affect learning due to its high flexibility. It is suggested to conduct other studies to deal with various blended learning methods and compare them in another discipline.

Conflict of interests: The authors declare that they have no conflict of interests.

Ethical approval: The code of ethics approved under the number (IR.KMU.REC.1401.235) was obtained from the Ethics Committee of Kerman University of Medical Sciences.

References

1. The Free Dictionary. Medical education. 2005. Available from: https://medical-dictionary.thefreedictionary.com/medical+education.
2. Burgess A, van Diggele C, Roberts C, Mellis C. Key tips for teaching in the clinical setting. BMC Med Educ. 2020 Dec 3;20(Suppl 2): 463. doi: 10.1186/s12909-020-02283-2. [PMID: 33272257] [PMCID: PMC7712575]
3. Masic I. E-learning as new method of medical education. Acta Inform Med.2008;16(2):102-17.doi:10.5455/aim.2008.16.102-117. [PMID: 24109154] [PMCID: PMC3789161]
4. Zalat MM, Hamed MS, Bolbol SA. The experiences, challenges, and acceptance of e-learning as a tool for teaching during the COVID-19 pandemic among university medical staff. PLoS One. 2021 Mar 26;16(3):e0248758. doi: 10.1371/journal.pone.0248758. [PMID: 33770079] [PMCID: PMC7997029]
5. Hege I, Tolks D, Adler M, Härtl A. Blended learning: ten tips on how to implement it into a curriculum in healthcare education. GMS J Med Educ. 2020 Sep 15;37(5):Doc45. doi: 10.3205/zma001338. [PMID: 32984504] [PMCID: PMC7499465]
6. Lai C-L, Hwang G-J. A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. Computers & Education. 2016;100:126-40. doi: 10.1016/j.compedu.2016.05.006.
7. Demirer V, Sahin I. Effect of blended learning environment on transfer of learning: An experimental study. Journal of Computer Assisted Learning. 2013;29(6):518-29. doi:10.1111/jcal.12009.
8. Rasheed RA, Kamsin A, Abdullah NA. Challenges in the online component of blended learning: A systematic review. Computers & Education. 2020;144:103701. doi: 10.1016/j.compedu.2019.103701.
9. Briz-Ponce L, Juanes-Méndez JA, García-Peñalvo FJ, Pereira A. Effects of mobile learning in medical education: a counterfactual evaluation. J Med Syst. 2016 Jun; 40(6): 136. doi: 10.1007/s10916-016-0487-4. [PMID: 27098779]
10. 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 Nov; 40(11): 1081-7. doi: 10.1111/j.1365-2929.2006.02611.x. [PMID: 17054617]
11. Totlis T, Tishukov M, Piagkou M, Kostares M, Natsis K. Online educational methods vs. traditional teaching of anatomy during the COVID-19 pandemic. Anat Cell Biol. 2021 Sep30;54(3):332-9. doi: 10.5115/acb.21.006. [PMID:34031272] [PMCID: PMC8493018]
12. Kharb P, Samanta PP. Blended learning approach for teaching and learning anatomy: Students' and teachers' perspective. Journal of the Anatomical Society of India. 2016;65(1):43-7. doi:10.1016/j.jasi.2016.06.001.
13. López-Pérez MV, Pérez-López MC, Rodríguez-Ariza L. Blended learning in higher education: Students' perceptions and their relation to outcomes. Computers & education. 2011;56(3):818-26. doi:10.1016/j.compedu.2010.10.023.
14. Grønlien HK, Christoffersen TE, Ringstad Ø, Andreassen M, Lugo RG. A blended learning teaching strategy strengthens the nursing students' performance and self-reported learning outcome achievement in an anatomy, physiology and biochemistry course–A quasi-experimental study. Nurse Educ Pract. 2021 Mar:52:103046. doi: 10.1016/j.nepr.2021.103046. [PMID: 33853032]
15. Nagaraj C, Yadurappa SB, Anantharaman LT, Ravindranath Y, Shankar N. Effectiveness of blended learning in radiological anatomy for first year undergraduate medical students. Surg Radiol Anat. 2021 Apr; 43(4): 489-496. doi: 10.1007/s00276-020-02572-x. [PMID: 32964270]
16. Wardana ING. Effectiveness Of Blended Learning In Human Anatomy Courses. Jurnal Pendidikan Indonesia. 2021;2(02): 209-19. doi:10.36418/japendi.v2i2.102.
17. Albalushi H, Al Mushaiqri M, Sirasanagandla SR, Das S. Students' Performance in Face-to-Face, Online, and Hybrid Methods of

Teaching and Assessment in Anatomy. Int J Environ Res Public Health. 2022 Oct 15;19(20):13318. doi: 10.3390/ijerph192013318. [PMID: 36293903] [PMCID: PMC9602488]

18. Aristotle S, Subramanian S, Jayakumar S. Effectiveness of flipped classroom model in teaching histology for first-year MBBS students based on competency-based blended learning: An interventional study. J Educ Health Promot. 2021 May 20:10:152. doi: 10.4103/jehp.jehp_467_20. [PMID: 34222527] [PMCID: PMC8224505]

19. Bhat GM, Bhat IH, Shahdad S, Rashid S, Khan MA, Patloo AA. Analysis of feasibility and acceptability of an e-learning module in anatomy. Anat Sci Educ. 2022 Mar;15(2):376-391. doi: 10.1002/ase.2096. [PMID: 33914418]

20. Bretagne V, Delapierre A, Cerasuolo D, Bellot A, Marcelli C, Guillois B. Randomized Controlled Study of a Training Program for Knee and Shoulder Arthrocentesis on Procedural Simulators with Assessment on Cadavers. ACR Open Rheumatol. 2022 Apr;4(4):312-321. doi: 10.1002/acr2.11400. [PMID: 34989181] [PMCID: PMC8992473]

21. Cappellen van Walsum AMv, Henssen DJ. E-Learning Three-Dimensional Anatomy of the Brainstem: Impact of Different Microscopy Techniques and Spatial Ability. Anat Sci Educ. 2022 Mar;15(2):317-329. doi: 10.1002/ase.2056. [PMID: 33507593] [PMCID: PMC9292761]

22. Chen J, Zhou J, Wang Y, Qi G, Xia C, Mo G, et al. Blended learning in basic medical laboratory courses improves medical students' abilities in self-learning, understanding, and problem solving. Adv Physiol Educ. 2020 Mar 1;44(1):9-14. doi: 10.1152/advan.00076.2019. [PMID: 31821032]

23. Cheng X, Chan LK, Pan SQ, Cai H, Li YQ, Yang X. Gross anatomy education in China during the Covid-19 pandemic: A national survey. Anat Sci Educ. 2021 Jan;14(1):8-18. doi: 10.1002/ase.2036. [PMID: 33217164]

24. Chimmalgi M, Hortsch M. Teaching Histology Using Self-Directed Learning Modules (SDLMs) in a Blended Approach. Med Sci Educ. 2022 Nov 7; 32(6): 1455-1464. doi: 10.1007/s40670-022-01669-9. [PMID: 36407816] [PMCID: PMC9640883]

25. El Sadik A, Al Abdulmonem W. Improvement in student performance and perceptions through a flipped anatomy classroom: Shifting from passive traditional to active blended learning. Anat Sci Educ. 2021 Jul;14(4):482-490. doi: 10.1002/ase.2015. [PMID: 32881423]

26. Golenhofen N, Heindl F, Grab-Kroll C, Messerer DA, Böckers TM, Böckers A. The use of a mobile learning tool by medical students in undergraduate anatomy and its effects on assessment outcomes. Anat Sci Educ. 2020 Jan;13(1):8-18. doi: 10.1002/ase.1878. [PMID: 30913369]

27. Greene SJ. The use and effectiveness of interactive progressive drawing in anatomy education. Anat Sci Educ. 2018 Sep;11(5):445-460. doi: 10.1002/ase.1784. [PMID: 29624896] [PMCID: PMC6314192]

28. Guimarães B, Firmino-Machado J, Tsisar S, Viana B, Pinto-Sousa M, Vieira-Marques P, et al. The role of anatomy computer-assisted learning on spatial abilities of medical students. Anat Sci Educ. 2019 Mar;12(2):138-153. doi: 10.1002/ase.1795. [PMID: 29762903]

29. Jamil Z, Saeed AA, Madhani S, Baig S, Cheema Z, Fatima SS. Three-dimensional visualization software assists learning in students with diverse spatial intelligence in medical education. Anat Sci Educ. 2019 Sep;12(5):550-560. doi: 10.1002/ase.1828. [PMID: 30376698]

30. Lee BC, Hsieh ST, Chang YL, Tseng FY, Lin YJ, Chen YL, et al. A web-based virtual microscopy platform for improving academic performance in histology and pathology laboratory courses: A pilot study. Anat Sci Educ. 2020 Nov;13(6):743-758. doi: 10.1002/ase.1940. [PMID: 31883209]

31. 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. 2018 Jul:218:156-164. doi: 10.1016/j.aanat.2018.02.015. [PMID: 29669259]

32. Nathaniel TI, Goodwin RL, Fowler L, McPhail B, Black AC, Black Jr AC. An Adaptive Blended Learning Model for the Implementation of an Integrated Medical Neuroscience Course During the Covid-19 Pandemic. Anat Sci Educ. 2021 Nov;14(6):699-710. doi: 10.1002/ase.2097. [PMID: 33915035] [PMCID: PMC8239699]

33. Perumal V. A sectional anatomy learning tool for medical students: development and user–usage analytics. Surg Radiol Anat. 2018 Nov;40(11):1293-300.doi:10.1007/s00276-018-2082-5. [PMID: 30116840]

34. Rajan KK, Pandit AS. Comparing computer-assisted learning activities for learning clinical neuroscience: a randomized control trial. BMC Med Educ. 2022 Jul 3; 22(1): 522. doi: 10.1186/s12909-022-03578-2. [PMID: 35780115] [PMCID: PMC9250740]

35. Santos RS, Carvalho AC, Tsisar S, Bastos AR, Ferreira D, Ferreira MA, et al. How computer-assisted learning influences medical Students' performance in anatomy courses. Anat Sci Educ. 2021 Mar;14(2):210-220. doi: 10.1002/ase.1997. [PMID: 32564474]

36. Sarkar S, Sharma S, Raheja S. Implementation of blended learning approach for improving anatomy lectures of phase i MBBS students–learner satisfaction survey. Adv Med Educ Pract. 2021 Apr 23:12:413-420. doi: 10.2147/AMEP.S301634. [PMID: 33935527] [PMCID: PMC8079801]

37. Stone D, Longhurst GJ, Dulohery K, Campbell T, Richards A, O'Brien D, et al. A Multicentre Analysis of Approaches to Learning and Student Experiences of Learning Anatomy Online. Med Sci Educ. 2022 Sep 19; 32(5): 1117-1130. doi: 10.1007/s40670-022-01633-7. [PMID: 36160292] [PMCID: PMC9483883]

38. Halverson LR, Graham CR, Spring KJ, Drysdale JS, Henrie CR. A thematic analysis of the most highly cited scholarship in the first decade of blended learning research. The internet and higher education. 2014;20:20-34. doi:10.1016/j.iheduc.2013.09.004.

39. Lo CC. How student satisfaction factors affect perceived learning. Journal of the Scholarship of Teaching and Learning. 2010; 10(1):47-54.

40. Min W, Yu Z. A Systematic Review of Critical Success Factors in Blended Learning. Education Sciences. 2023;13(5):469. doi: 10.3390/educsci13050469.

41. 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. 2018 Jan:215:71-77.doi:10.1016/j.aanat.2017.09.011.[PMID: 29017852]

42. Svirko E, Mellanby J. Teaching neuroanatomy using computer-aided learning: What makes for successful outcomes? Anat Sci Educ. 2017 Nov;10(6):560-569. doi: 10.1002/ase.1694. [PMID: 28431201]

43. Atwa H, Shehata MH, Al-Ansari A, Kumar A, Jaradat A, Ahmed J, et al. Online, Face-to-Face, or Blended Learning? Faculty and Medical Students' Perceptions During the COVID-19 Pandemic: A Mixed-Method Study. Front Med (Lausanne). 2022 Feb

3:9:791352. doi: 10.3389/fmed.2022.791352. [PMID: 35186989] [PMCID: PMC8850343]

44. Singal A, Bansal A, Chaudhary P. Cadaverless anatomy: Darkness in the times of pandemic Covid-19. Morphologie. 2020 Sep;104(346):147-150. doi: 10.1016/j.morpho.2020.05.003. [PMID: 32518047] [PMCID: PMC7254017]

45. Karbasi Z, Niakan Kalhori SR. Application and evaluation of virtual technologies for anatomy education to medical students: A review. Med J Islam Repub Iran. 2020 Dec 3:34: 163. doi: 10.47176/mjiri.34.163. [PMID: 33816362] [PMCID: PMC8004573]