

Exploration and evaluation of reporting quality of randomised controlled trials on blended learning in medical education

Xiaoli Zhang¹

Guanran Zhang¹

Yanru Chen²

Fuwu Wang¹

Yuji Guo¹

Xiaorui Li¹

Jianming Zhang¹

Author details can be found at the end of this article

Correspondence to:

Jianming Zhang

(1050733897@qq.com)

Xiaorui Li (2947291621@

qq.com)

Abstract

Aims/Background Blended learning has been a commonly adopted teaching mode in the medical education community in recent years. Many studies have shown that the blended learning mode is superior to the traditional teaching mode. Nonetheless, pinpointing the specific advantages provided by blended teaching methods is challenging, since multiple elements influence their effectiveness. This study aimed to investigate the reliability of the conclusions of published randomised controlled trials (RCTs) on blended learning in medical education by assessing their quality, and to provide suggestions for future related studies.

Methods Two investigators searched PUBMED and EMBASE, and assessed RCTs related to medical blended learning published from January 1, 2010 to December 31, 2021. The analysis of the overall quality of each report was based on the 2010 consolidated standard of reporting trials (CONSORT) Statement applying a 28-point overall quality score. We also conducted a multivariate assessment including year of publication, region of the trial, journal, impact factor, sample size, and the primary outcome.

Results A total of 22 RCTs closely relevant to medical blended learning were eventually selected for study. The results demonstrated that half of the studies failed to explicitly describe at least 34% of the items in the 2010 CONSORT Statement. Medical blended learning is an emerging new teaching mode, with 95.45% of RCTs published since 2010. However, many issues that we consider crucial were not satisfactorily addressed in the selected RCTs.

Conclusion Although the 2010 CONSORT Statement was published more than a decade ago, the quality of RCTs remains unsatisfactory. Some important items were inadequately reported in many RCTs such as sample size, blinding, and concealment. We encourage researchers who focus on the effects of blended learning in medical education to incorporate the guidelines in the 2010 CONSORT Statement when designing and conducting relevant research. Researchers, reviewers, and editors also need to work together to improve the quality of relevant RCTs in accordance with the requirements of the 2010 CONSORT Statement.

Key words: Blended learning; CONSORT Statement; Medical education; Randomised controlled trials; Report quality

Submitted: 01 April 2024; Revised: 09 May 2024; Accepted: 15 May 2024

Introduction

Randomised controlled trials (RCTs) are generally considered the gold standard of evidence-based medicine. High-quality RCTs should convey all critical information to the readers clearly and transparently (Moher et al, 2010). However, many RCTs fail to ensure the integrity and clarity of their methods and results, which may lead researchers to draw biased or even wrong conclusions, and eventually result in a significant waste of human, material, and financial resources (Dickinson et al, 2000; Jüni et al, 2001). In order to improve the quality of RCTs conducted by researchers, the consolidated standard of reporting trials (CONSORT) Statement was first published in 1996 (Begg et al, 1996), and was revised in 2001 (Moher et al, 2001) and 2010 (Schulz et al, 2010). The 2010 CONSORT Statement

How to cite this article:

Zhang X, Zhang G, Chen Y, Wang F, Guo Y, Li X, Zhang J. Exploration and evaluation of reporting quality of randomised controlled trials on blended learning in medical education. *Br J Hosp Med.* 2024. <https://doi.org/10.12968/hmed.2024.0166>

contains a 28-item checklist and a flow diagram, providing guidance for researchers to comprehend and evaluate the RCT quality (Moher et al, 2010). Previous studies indicated significant improvements in the quality of RCTs after the appearance of the CONSORT (Kane et al, 2007).

As the cornerstone of medical education, anatomy is significant for medical students (Turney, 2007). Cadaver-based teaching has been the main method for hundreds of years; however, it has many limitations, including issues related to cost and time investment (Drake et al, 2009; Estai and Bunt, 2016). During the Corona Virus Disease 2019 (COVID-19) pandemic, the traditional cadaver-based teaching method was limited and some colleges adopted online teaching methods (Saverino et al, 2022). In recent years, many questions about the best anatomy teaching method have been raised. The traditional teaching methods require costly resources, and the amount of time committed by students to learning anatomy is on the decline (Lockwood and Roberts, 2007; Drake et al, 2009). Therefore, more and more researchers are trying to discover up-to-date and time-saving medical learning methods (Biasutto et al, 2006; Singh et al, 2019).

Blended learning usually refers to a teaching mode that combines face-to-face and online instruction or learning (Hrastinski, 2019). Blended learning is a thoughtful integration of both methods. Face-to-face teaching refers to traditional classroom teaching, group discussions, flipped classrooms, and other teaching methods. Online teaching includes online lectures, massive open online courses (MOOCs), and remote communication via the internet. Educators around the world have advocated and promoted the blended learning model since it maximises the advantages of traditional offline teaching models and emerging online learning models (Lam, 2014). Compared with traditional teacher-centred offline learning, the online aspect of blended learning can benefit students in many ways. Online learning, for instance, makes learning resources more accessible (Mooney and Bligh, 1997) and allows learners to freely decide when and where to study, which makes blended learning a good complement to traditional offline learning modes (Ruiz et al, 2006; Dhawan, 2020). With the development of information technology, the blended learning mode combining offline and online learning is more widely used globally (Garrison and Kanuka, 2004). It plays an important role in the promotion of higher education, especially in today's era when the COVID-19 pandemic continues to disrupt face-to-face learning. In the field of medical education, online learning plays an increasingly vital role (Ruiz et al, 2006).

However, to date, there is no clear evidence that blended learning significantly improves outcomes in medical education. The results of some RCTs showed that blended learning was more effective for medical learners than traditional learning (Arroyo-Morales et al, 2012; Maloney et al, 2015; Chen et al, 2020; Wang et al, 2022). On the other hand, there were also RCTs that showed no significant difference in performance between students using blended learning and those using face-to-face learning (Péron et al, 2012). In addition, blended learning is complex and its effectiveness is influenced by many factors. However, the selection of these factors can be subjective, and most RCTs have focused on only a few. RCTs on pedagogy research should be conducted and published in accordance with the corresponding normative guidelines, and it is critical to know whether the findings of these RCTs are meaningful or not. Therefore, it is necessary to further explore and evaluate the quality of RCTs related to blended learning in medical education. Although the CONSORT Statement was originally designed for medical intervention RCTs, it can also be a useful tool for evaluating other types of RCTs (Zhang et al, 2022). In the current study, based on the 2010 CONSORT Statement, the overall reporting quality of published RCTs related to blended learning in medical education was assessed to provide some insights into the effects of blended learning.

Methods

PUBMED and EMBASE were searched for RCTs about blended learning published from January 1, 2010 to December 31, 2020. We used the following combined text and MeSH terms: 'blended learning' and 'Education, Medical'. The complete search conditions were:

((‘Education, Medical’ [MeSH]) OR (Medical Education [Title/Abstract])) AND (blended learning [Title/Abstract]).

The following studies were eligible for inclusion: (a) RCTs related to blended learning and applied in medical education; (b) The use of blended learning was set as the experimental group; (c) All papers were published in English.

The following studies were excluded: (a) non-RCTs; (b) Lack of integrated or valid data; (c) Unrelated to medical teaching; (d) Secondary reports of previously published studies or repeated published studies. If multiple publications were found to report the same RCT, the publication with the most comprehensive data was selected.

Relevant data were collected and analysed by two well-trained researchers. SPSS Statistics 25.0 (IBM SPSS Statistics, Chicago, IL, USA) was used to analyse the data. The two researchers independently analysed the data and then reached a consensus through discussion if there were any differences. The overall quality score (OQS) including 28 items based on the 2010 CONSORT Statement was used to identify the overall reporting quality of the RCTs (Lai et al, 2006; Péron et al, 2012; Toulmonde et al, 2011). The 28-item, 2010 standardised CONSORT checklist splits some items of 2010 CONSORT Statement to make it more available for comprehensive assessment. Some items like ‘Adverse event’ are not suitable for blended learning were excluded from the research. Each item from the CONSORT Statement was scored ‘1’ when reported and ‘0’ when not mentioned. The OQS for each trial is calculated by summing the scores of each item, ranging from 0 to 28 points. Cohen’s κ statistic was calculated for each item assessed by the OQS to check the agreement between the two investigators in assigning scores to each item. Consistency was considered slight if $\kappa \leq 0.2$; fair if $0.2 < \kappa \leq 0.4$; moderate if $0.4 < \kappa \leq 0.6$; substantial if $0.6 < \kappa \leq 0.8$, and almost perfect if $0.8 < \kappa \leq 1$. The percentage of positive trials and 95% CIs were also calculated.

The characteristics of the RCTs including year of publication, region of the trial, journal, impact factor, sample size, and the primary outcomes were also analysed. The region of the RCTs was designated according to the location of the research. The impact factors were determined by the latest 2020 science index. The primary outcome of the RCT was defined as ‘positive’ if the outcome of the experimental group was better than that of the control group. Otherwise, the result was defined as ‘negative’.

Results

As shown in [Figure 1](#), our initial search in various databases returned 54 related studies, of which 22 RCTs were ultimately selected for further analysis (Moeller et al, 2010; Hsu and Hsieh, 2011; Shaw et al, 2011; Arroyo-Morales et al, 2012; Albrecht et al, 2013; Ilic

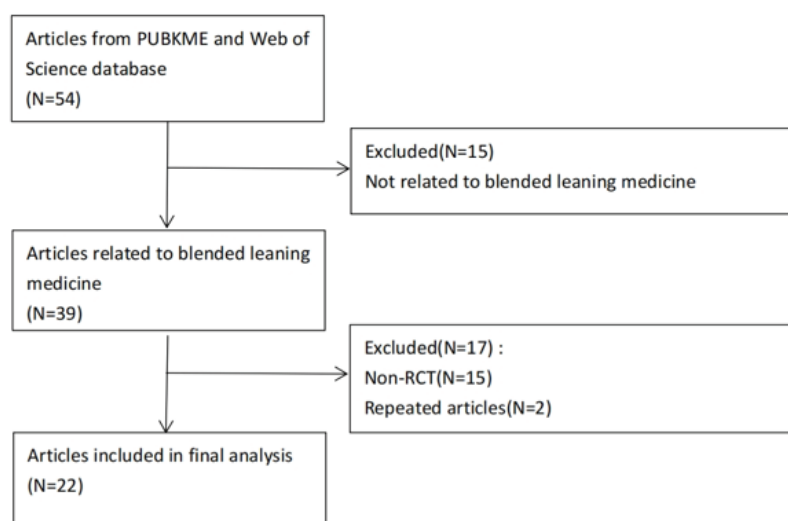


Figure 1. Flowchart of the selection process of randomised controlled trials.

et al, 2013a; Ilic et al, 2013b; Stewart et al, 2013; Ilic et al, 2015; Maloney et al, 2015; Stockwell et al, 2015; Langenau et al, 2017; Coret et al, 2018; McCutcheon et al, 2018; Chen et al, 2020; Madou and Iserbyt, 2020; Goolsby et al, 2021; McCall et al, 2021; Sonne et al, 2021; Yaylaci and Guven, 2021; Yu et al, 2021; Zeng et al, 2021). Among the excluded papers, there were 15 non-RCTs, 2 duplicate papers, and 15 papers unrelated to blended learning. The final 22 RCTs were analysed in greater detail. **Table 1** shows the results of the quality assessment of selected RCTs based on the 2010 CONSORT Statement. **Table 2** lists their characteristics, such as sample size and journal impact factors, etc.

As shown in **Table 3**, the median OQS score was 18.5 (range 9–24), indicating that half of the studies did not explicitly describe at least 34% of the items in the, 2010 CONSORT Statement. Most studies presented abstracts of the RCTs (77.27%, n=17) at the beginning of the paper. However, only half of the studies indicated that they were RCTs in the title. In the introduction section, most studies adequately described the background and presented the purpose or hypothesis of the RCTs. Experimental methods are core contents of RCTs. In this section, most RCTs clearly described the trial design, participant criteria, setting and location, results, and statistical methods. However, only 4 of these RCTs (18.18%) described sample size calculations, and only 5 studies (22.73%) accurately detailed who delivered the intervention. More than half of the RCTs (54.55%, n=12) did not explicitly describe the method of sequence generation, the mechanism of allocation concealment, and the measures of blinded intervention. In addition, most of the 22 RCTs did not conduct additional analysis and did not specify the completeness of the trial method and the limitations of the RCTs.

More than half of the RCTs presented detailed and scientific results and data analysis, except for adverse events that were not available for medical research on blended learning. Only 13 of the 22 RCTs provided flowcharts showing the selection process for participants, as recommended by the, 2010 CONSORT Statement. Since trial registration does not apply to pedagogy research, we focused on the ethics approval section of the reports. However, across all 22 RCTs, only 9 (40.91%) mentioned the ethics approval and access to the full trial protocol. Additionally, few RCTs mentioned funding or other support for the trial (63.64%, n=14).

As can be seen from **Table 2**, most of the RCTs were published after, 2010 (95.45%, n=21). Of the 22 RCTs, 5 were performed in Asia (22.73%), 12 in Europe and North America (54.55%), and 5 elsewhere. More than half of the RCTs were published in journals with an impact factor less than 4 (72.73%, n=16), and only one RCT was published in a journal with an impact factor more than 10 (4.55%). In terms of sample size, there were 15 RCTs (68.81%) with less than 200 participants and there was only 1 RCT with more than 400 participants (4.55%). The primary outcomes of most RCT studies were positive (77.27%, n=17), which provided favourable evidence for the popularisation and application of blended learning in the field of medical education.

Discussion

Despite the fact that the CONSORT Statement was first published several decades ago, the overall quality of RCTs of blended learning in the medical field still needs to be improved. We found that interventions in both the experimental and control groups were generally described in detail. However, bias in methodological reporting was found. Some important items such as blinding, concealment, and sample size calculation are missing in most RCTs. These defects might lead to incomplete descriptions of the results and even biased conclusions. From the perspective of teaching in China, most RCTs in blended teaching can only be grouped according to class, which may make randomisation difficult to achieve and cause significant bias. In addition, most of the reports miss the principle of blinding, especially in the preparation of examination questions and final assessments. This absence can lead to artificial bias or even produce the exact opposite result. Likewise, the sample size was unsatisfactory, with most RCTs having a sample size of less than 200 people, and some with even less than 100 people. We thought that this was most likely due to

Table 1. Overall quality of reporting: rating using items based on the 2010 consolidated standard of reporting trials Statement (n=22)

Item	Criteria	Description	No. of positive trials	Percentage of positive trials (%)	95%CI	Cohen's κ coefficient
1	Title	Identification as a randomised trial in the title	11	50.00	(29, 71)	0.909
2	Abstract structure	Structured summary of trial design, methods, results and conclusions	17	77.27	(60, 95)	0.699
3	Background	Adequate description of the scientific background and explanation of rationale	22	100.00		NA*
4	Objectives	Description of the specific objectives or the scientific hypotheses in the introduction	18	81.82	(66, 98)	0.703
5	Trial design	Description of trial design, including allocation ratio	19	86.36	(72, 101)	1
6	Participants	Description of the eligibility criteria for participants	20	90.91	(78, 103)	0.645
7	Settings and location	Description of the settings and locations where the data were collected	20	90.91	(78, 103)	1
8	Interventions	Details of the interventions intended for each group	20	90.91	(78, 103)	0.645
9	Outcomes	Definition of primary and secondary outcome measures, including how and when they were assessed	17	77.27	(60, 95)	0.466
10	Sample size	Description of sample size calculation	4	18.18	(2, 34)	0.861
11	Randomisation, sequence generation	Definition of the method used to generate the random allocation sequence	10	45.45	(25, 66)	0.639
12	Randomisation, restriction	Description of the type of randomisation; details of any restriction	12	54.55	(34, 75)	0.590
13	Allocation concealment	Description of the mechanism used to implement the random allocation sequence to assure concealment until interventions were assigned	10	45.45	(25, 66)	0.988
14	Implementation	Description of who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	5	22.73	(5, 40)	0.897
15	Blinding	Whether or not participants, those administering the interventions, or those assessing the outcomes were blinded to group assignment; if relevant, description of the similarity of interventions	10	45.45	(25, 66)	0.645

Table 1. (Continued)						
16	Statistical methods	Description of the statistical methods used to compare groups for primary and secondary outcomes	20	90.91	(78, 103)	0.621
17	Ancillary analysis, method	Description of the methods for additional analyses, such as subgroup analyses and adjusted analyses	7	31.82	(12, 51)	0.984
18	Diagram	A CONSORT diagram was presented to show the flow of participants	13	59.09	(39, 80)	0.818
19	Participant flow	Details on the flow of participants through each stage of the trials (number of patients randomly assigned, receiving intended treatment, and were analysed for the primary outcome)	19	86.36	(72, 101)	0.776
20	Recruitment	Dates defining the periods of recruitment and follow-up	16	72.73	(54, 91)	0.744
21	Baseline data	A table showing baseline demographic and clinical characteristics for each group	17	77.27	(60, 95)	0.542
22	Intent-to-treat analysis	Number of patients in each group included in each analysis and whether patients were analysed according to the group to which they were randomly assigned	19	86.36	(72, 101)	0.614
23	Outcomes measures	For each primary and secondary outcome, a summary of results for each group, the estimated effect size and its precision (e.g. 95% CI) are provided	21	95.45	(87, 104)	0.645
24	Ancillary analyses	Results of subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	10	45.45	(25, 66)	0.421
25	Adverse event classification	Description of all important adverse events in each group, with classification	0	0.00		NA*
26	Registration	Presentation of the registration number and name of trial registry	9	40.91	(20, 62)	0.553
27	Protocol	Where the full trial protocol can be accessed	9	40.91	(20, 62)	0.732
28	Funding	Sources of funding and other support	14	63.64	(44, 84)	0.732

CI: confidence interval; CONSORT: consolidated standards of reporting trials; NA: not available.

*Cohen's κ coefficient couldn't be calculated because the positive rates awarded by two investigators were both 100% for these items.

the limited educational resources and the difficulty of conducting large-scale educational trials. Additionally, there also might be a subjective assumption that the blended learning should be better than the traditional classroom. All of these factors may obscure the true effects of blended learning in medical education. At the same time, due to the complexity

Table 2. Trial characteristics

Characteristic		No. of studies (n=22)	Percentage of studies (%)
Year of publication	1976–2000	0	0.00
	2001–2010	1	4.55
	2011–2021	21	95.45
Region in which trials were conducted	Asia	5	22.73
	Europe and North America	12	54.55
	Others	5	22.73
Journal	BMC Medical Education	5	22.73
	Journal of Medical Internet Research	2	9.09
	Other journals	15	68.18
Journal impact factor	<4	16	72.73
	4–10	5	22.73
	>10	1	4.55
Primary outcome	Positive	17	77.27
	Negative	5	22.73
Sample size (range)	<200	15	68.81
	200–400	6	27.27
	>400	1	4.55

of interventions, the lack of basic items in the reports, such as abstracts and intervention flowcharts, might also create barriers for readers. Therefore, researchers need to make a greater effort to ensure more comprehensive and objective reporting on the practical effects of blended learning in the medical field. In addition, subgroup analysis and adverse events are too complex to perform in teaching research and may not be suitable for teaching research RCTs. Therefore, there is a great need for statisticians to formulate a brand new RCT reporting standard more suitable for teaching research, or to optimise the existing CONSORT Statement to make it more suitable for teaching research. For instance, enhancing the description of assessment methods is essential. Since there are no gold standards for pedagogical research, various assessment methods such as subjective evaluation and process-based assessment exist. Therefore, comprehensive method descriptions and related bias analysis are crucial. Moreover, items that do not conform to pedagogical research, such as subgroup analysis and adverse events, can be appropriately removed. The registration number item is not available for pedagogical research and can be replaced with appropriate alternatives, such as ethics approval.

The characteristic analysis indicated that there are significant regional differences in the application of blended learning. According to the number of published articles, blended learning, as a gradually popularised teaching mode, is more widely applied in Europe and America than in Asia because of differences in traditional educational concepts and evaluation modes. At the same time, the results of most RCTs prove that blended learning is effective in improving students' comprehension. These results suggest that more colleges should incorporate blended learning to meet the needs of students in the new era.

The traditional concept of medical blended learning refers to online learning combined with classroom teaching (Kim et al, 2008). However, when we searched the databases with 'medical blended learning' as the keyword and RCT as the restriction, the results

Table 3. Trial overall quality score scores

No.	Author	OQS Score
1	Aiyuan Guo	14
2	Manuel Arroyo-Morales	17
3	Stephen Maloney	10
4	Dragan Llic	23
5	Alice Stewart	20
6	Dragan Llic	16
7	Jian Chen	15
8	Brent R. Stockwell	19
9	Alon Coret	18
10	Rong Hu	19
11	Rusli Bin Nordin	18
12	Urs-Vito Albrecht	19
13	Stefan Moeller	18
14	Craig Goolsby	19
15	Erik E. Langenau	9
16	Li-Ling Hsu	21
17	Tom Madou	16
18	Marcy C McCall	20
19	Karen McCutcheon	24
20	Timothy Shaw	19
21	Carolin Sonne	16
22	Serpil Yaylaci	19

OQS, overall quality score.

were extensive. There are more and more innovative attempts to apply blended learning not only in the teaching of medical students, but also in clinical disease treatment and clinical staff retraining (van Houten-Schat et al, 2018; Klein et al, 2019). Evidence-based medicine was the main application area of this new teaching model in most of the articles we search. However, more observational and manipulative disciplines, such as anatomy and morphology, still have great prospects for exploration (Shaffer and Small, 2004; Nagaraj et al, 2021). The cultivation of clinical operation skills by blended learning also deserves further research. These results indicate that both the forms of blended learning applications and future research directions are increasingly diverse.

When comparing the quality of RCT studies on blended learning with traditional RCT studies (such as otolaryngology, stomatology, traditional Chinese medicine, etc.) (Huang et al, 2018; Li et al, 2020; Qin et al, 2021), it is clear that there is significant room for improvement in the quality of both types of RCT reports. This indicates the necessity of overall improvement in the quality of RCT research. Methodological aspects such as randomisation and blinding are of insufficient quality in both areas. However, compared to clinical RCT studies, the inadequacy in sample size calculation in blended learning research stands out prominently. Methodology is key to reproducible research, thus requiring more attention and standardisation.

This study has several limitations. First, as a relatively new teaching mode, blended learning has only begun to attract the attention of teaching staff in recent years (Ruiz et al,

2006; Hrastinski, 2019), so there are relatively few related teaching studies and even fewer RCTs. This study only identified 22 published RCTs after screening. In addition, most of the RCTs were conducted only in class and ignored the performance of participants in the hospital; thus, a lack of sufficient information may lead to biased results. Another limitation of the study was that the OQS was calculated on the basis that each item in the 2010 CONSORT Statement was equally important. Although many previous studies have given the same weight to each item in the 2010 CONSORT Statement (Guo and Iribarren, 2014; Ghimire et al, 2014; Hua et al, 2015), we believe that this calculation method is not very reasonable and needs further improvement. At the same time, the CONSORT Statement is a standard for the reporting of the trials and evaluating studies from a reporting perspective might help to identify their limitations. Further research is still needed from the implementation aspect of experiments.

We suggest that there are several ways to improve the quality of RCTs reporting: More adequate training of researchers; consensus among journals, editors, and reviewers on the approval of the CONSORT Statement; and improvement of the CONSORT Statement itself to make it more suitable for pedagogy research. Most importantly, researchers should make every effort to adhere to the criteria for educational RCTs. The core aspects of RCTs, such as randomisation and blinding, should not be neglected. Therefore, we believe that researchers must be reasonably familiar with the CONSORT Statement in order to conduct RCTs. Journal editors and peer reviewers are also obliged to encourage researchers to adhere more strictly to the CONSORT Statement. Although the CONSORT Statement has become a useful tool for evaluating RCTs, it still has room for further improvement.

Conclusion

In conclusion, the reporting quality of RCTs on blended learning in medical education is unsatisfactory. Therefore, it is recommended that both researchers, journal editors, and peer reviewers should place more emphasis on the CONSORT Statement when designing, conducting, supervising and reviewing RCT research. Meanwhile, we also expect statisticians to develop new CONSORT Statements or optimise the existing CONSORT Statements to make them more suitable for guiding or evaluating RCTs in teaching research.

Key Points

- This study evaluated 22 selected RCTs on blended learning in medical education based on the 2010 CONSORT Statement.
- The results showed that the reporting quality of RCTs on blended learning in medical education was still unsatisfactory.
- The characteristic analysis also revealed inadequate sample size and discrepancies in the application between Eastern and Western regions.
- It is recommended that more emphasis be placed on the CONSORT Statement during the research and that the existing CONSORT Statement should be optimised to make it more suitable for pedagogical research.

Author details

¹Key Laboratory for Experimental Teratology of Ministry of Education, Department of Histology and Embryology, School of Basic Medical Sciences, Shandong University, Jinan, Shandong, China

²Liver Transplantation Center, National Clinical Research Center for Digestive Diseases, Beijing Friendship Hospital, Capital Medical University, Beijing, China

Availability of data and materials

The data used and analysed during the current study are within the manuscript.

Author contributions

XLZ conceived and designed this project and gave critical revision of the manuscript. YJG, FWW, GRZ and YRC helped with the analysis of data. YRC, FWW and YJG helped to review and revise the draft. FWW also provided financial support; XRL and JMZ contributed equally to the collection and analysis of data and the manuscript draft. All authors contributed to important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics approval and consent to participate

Not applicable.

Acknowledgement

Not applicable.

Funding

This study was funded by the National Natural Science Foundation of China (Grant No. 81672861); Research on education and teaching reform of undergraduates at Shandong University (Grant No. 2023Y153); Research on Teaching Reform of Undergraduate in Cheeloo Medical College of Shandong University (Grant/Award Numbers: qlyxjy-202374, qlyxjy-202018).

Conflict of interest

The authors declare no conflict of interest.

References

- Albrecht UV, Folta-Schoofs K, Behrends M, von Jan U. Effects of mobile augmented reality learning compared to textbook learning on medical students: randomized controlled pilot study. *J Med Internet Res*. 2013;15(8):e182. <https://doi.org/10.2196/jmir.2497>
- Arroyo-Morales M, Cantarero-Villanueva I, Fernández-Lao C et al. A blended learning approach to palpation and ultrasound imaging skills through supplementation of traditional classroom teaching with an e-learning package. *Man Ther*. 2012;17(5):474–478. <https://doi.org/10.1016/j.math.2012.04.002>
- Begg C, Cho M, Eastwood S et al. Improving the quality of reporting of randomized controlled trials. The CONSORT statement. *JAMA*. 1996;276(8):637–639. <https://doi.org/10.1001/jama.276.8.637>
- Biasutto SN, Caussa LI, Criado del Río LE. Teaching anatomy: cadavers vs. computers? *Ann Anat*. 2006;188(2):187–190. <https://doi.org/10.1016/j.aanat.2005.07.007>
- Chen J, Zhou J, Wang Y et al. Blended learning in basic medical laboratory courses improves medical students' abilities in self-learning, understanding, and problem solving. *Adv Physiol Educ*. 2020;44(1):9–14. <https://doi.org/10.1152/advan.00076.2019>
- Coret A, Boyd K, Hobbs K, Zazulak J, McConnell M. Patient narratives as a teaching tool: a pilot study of first-year medical students and patient educators affected by intellectual/developmental disabilities. *Teach Learn Med*. 2018;30(3):317–327. <https://doi.org/10.1080/10401334.2017.1398653>
- Dhawan S. Online learning: a panacea in the time of COVID-19 crisis. *J Educ Technol Syst*. 2020;49(1):5–22. <https://doi.org/10.1177/0047239520934018>
- Dickinson K, Bunn F, Wentz R, Edwards P, Roberts I. Size and quality of randomised controlled trials in head injury: review of published studies. *BMJ*. 2000;320(7245):1308–1311. <https://doi.org/10.1136/bmj.320.7245.1308>
- Drake RL, McBride JM, Lachman N, Pawlina W. Medical education in the anatomical sciences: the winds of change continue to blow. *Anatomical Sci Ed*. 2009;2(6):253–259. <https://doi.org/10.1002/ase.117>
- Estai M, Bunt S. Best teaching practices in anatomy education: a critical review. *Ann Anat*. 2016;208:151–157. <https://doi.org/10.1016/j.aanat.2016.02.010>

- Garrison DR, Kanuka H. Blended learning: uncovering its transformative potential in higher education. *Internet Higher Educ.* 2004;7(2):95–105. <https://doi.org/10.1016/j.iheduc.2004.02.001>
- Ghimire S, Kyung E, Lee H, Kim E. Oncology trial abstracts showed suboptimal improvement in reporting: a comparative before-and-after evaluation using CONSORT for abstract guidelines. *J Clin Epidemiol.* 2014;67(6):658–666. <https://doi.org/10.1016/j.jclinepi.2013.10.012>
- Goolsby C, Rojas LE, Rodzik RH et al. High-school students can stop the bleed: a randomized, controlled educational trial. *Acad Pediatr.* 2021;21(2):321–328. <https://doi.org/10.1016/j.acap.2020.05.012>
- Guo JW, Iribarren SJ. Reporting quality for abstracts of randomized controlled trials in cancer nursing research. *Cancer Nurs.* 2014;37(6):436–444. <https://doi.org/10.1097/NCC.0000000000000112>
- Hrastinski S. What do we mean by blended learning? *TechTrends.* 2019;63(5):564–569. <https://doi.org/10.1007/s11528-019-00375-5>
- Hsu LL, Hsieh SI. Effects of a blended learning module on self-reported learning performances in baccalaureate nursing students. *J Adv Nurs.* 2011;67(11):2435–2444. <https://doi.org/10.1111/j.1365-2648.2011.05684.x>
- Hua F, Deng L, Kau CH et al. Reporting quality of randomized controlled trial abstracts: survey of leading general dental journals. *J Am Dent Assoc.* 2015;146(9):669–678.e1. <https://doi.org/10.1016/j.adaj.2015.03.020>
- Huang YQ, Traore K, Ibrahim B, Sewitch MJ, Nguyen LHP. Reporting quality of randomized controlled trials in otolaryngology: review of adherence to the CONSORT statement. *J Otolaryngol Head Neck Surg.* 2018;47(1):34. <https://doi.org/10.1186/s40463-018-0277-8>
- Ilic D, Bin Nordin R, Glasziou P, Tilson JK, Villanueva E. Implementation of a blended learning approach to teaching evidence based practice: a protocol for a mixed methods study. *BMC Med Educ.* 2013a;13(1):170. <https://doi.org/10.1186/1472-6920-13-170>
- Ilic D, Hart W, Fiddes P, Misso M, Villanueva E. Adopting a blended learning approach to teaching evidence based medicine: a mixed methods study. *BMC Med Educ.* 2013b;13(1):169. <https://doi.org/10.1186/1472-6920-13-169>
- Ilic D, Nordin R, Glasziou P, Tilson JK, Villanueva E. A randomised controlled trial of a blended learning education intervention for teaching evidence-based medicine. *BMC Med Educ.* 2015;15(1):1–10. <https://doi.org/10.1186/s12909-015-0321-6>
- Jüni P, Altman DG, Egger M. Systematic reviews in health care: assessing the quality of controlled clinical trials. *BMJ.* 2001;323(7303):42–46. <https://doi.org/10.1136/bmj.323.7303.42>
- Kane RL, Wang J, Garrard J. Reporting in randomized clinical trials improved after adoption of the CONSORT statement. *J Clin Epidemiol.* 2007;60(3):241–249. <https://doi.org/10.1016/j.jclinepi.2006.06.016>
- Kim K, Bonk CJ, Oh E. The present and future state of blended learning in workplace learning settings in the United States. *Perf Improv.* 2008;47(8):5–16. <https://doi.org/10.1002/pfi.20018>
- Klein M, Otto B, Fischer MR, Stark R. Fostering medical students' clinical reasoning by learning from errors in clinical case vignettes: effects and conditions of additional prompting procedures to foster self-explanations. *Adv Health Sci Educ.* 2019;24(2):331–351. <https://doi.org/10.1007/s10459-018-09870-5>
- Lai R, Chu R, Fraumeni M, Thabane L. Quality of randomized controlled trials reporting in the primary treatment of brain tumors. *J Clin Oncol.* 2006;24(7):1136–1144. <https://doi.org/10.1200/JCO.2005.03.1179>
- Lam J. The Context of Blended Learning: The TIPS Blended Learning Model. Paper presented at: Hybrid Learning. Theory and Practice. ICHL 2014; August 8–10, 2014; Shanghai, China. https://doi.org/10.1007/978-3-319-08961-4_9
- Langenau EE, Lee R, Fults M. Blended learning educational format for third-year pediatrics clinical rotation. *J Am Osteopath Assoc.* 2017;117(4):234–243. <https://doi.org/10.7556/jaoa.2017.041>
- Li M, Zhou B, Zhou L, Li L. Reporting quality of randomized controlled trials for the treatment of eczema with Chinese patent medicine based on the CONSORT-CHM formulas 2017. *Evid Based Complement Alternat Med.* 2020;2020:1–9. <https://doi.org/10.1155/2020/2949125>
- Lockwood AM, Roberts AM. The anatomy demonstrator of the future: an examination of the role of the medically-qualified anatomy demonstrator in the context of tomorrow's doctors and modernizing medical careers. *Clin Anat.* 2007;20(4):455–459. <https://doi.org/10.1002/ca.20427>
- Madou T, Iserbyt P. Mastery versus self-directed blended learning in basic life support: a randomised controlled trial. *Acta Cardiol.* 2020;75(8):760–766. <https://doi.org/10.1080/00015385.2019.1677374>
- Maloney S, Nicklen P, Rivers G et al. A cost-effectiveness analysis of blended versus face-to-face delivery of evidence-based medicine to medical students. *J Med Internet Res.* 2015;17(7):e182. <https://doi.org/10.2196/jmir.4346>

- McCall MC, Fanshawe TR, McCartney D et al. Online supplementation for teaching evidence-based medicine: feasibility of a randomised-controlled trial. *BMJ Evid-Based Med*. 2021;26(5):254. <https://doi.org/10.1136/bmjebm-2020-111372>
- McCutcheon K, O'Halloran P, Lohan M. Online learning versus blended learning of clinical supervisee skills with pre-registration nursing students: a randomised controlled trial. *Int J Nurs Stud*. 2018;82:30–39. <https://doi.org/10.1016/j.ijnurstu.2018.02.005>
- Moeller S, Spitzer K, Spreckelsen C. How to configure blended problem-based learning-results of a randomized trial. *Med Teach*. 2010;32(8):e328–e346. <https://doi.org/10.3109/0142159X.2010.490860>
- Moher D, Hopewell S, Schulz KF et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *J Clin Epidemiol*. 2010;63(8):e1–e37. <https://doi.org/10.1016/j.jclinepi.2010.03.004>
- Moher D, Schulz KF, Altman DG, CONSORT GROUP (Consolidated Standards of Reporting Trials). The CONSORT statement: revised recommendations for improving the quality of reports of parallel-group randomized trials. *Ann Intern Med*. 2001;134(8):657–662. <https://doi.org/10.7326/0003-4819-134-8-200104170-00011>
- Mooney GA, Bligh JG. Information technology in medical education: current and future applications. *Postgrad Med J*. 1997;73(865):701–704. <https://doi.org/10.1136/pgmj.73.865.701>
- 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;43(4):489–496. <https://doi.org/10.1007/s00276-020-02572-x>
- Péron J, Pond GR, Gan HK et al. Quality of reporting of modern randomized controlled trials in medical oncology: a systematic review. *J Natl Cancer Inst*. 2012;104(13):982–989. <https://doi.org/10.1093/jnci/djs259>
- Qin D, Hua F, Liang S, Worthington H, He H. The reporting quality of split-mouth trials in orthodontics according to CONSORT guidelines: 2015–19. *Eur J Orthod*. 2021;43(5):557–566. <https://doi.org/10.1093/ejo/cjaa085>
- Ruiz JG, Mintzer MJ, Leipzig RM. The impact of E-learning in medical education. *Acad Med*. 2006;81(3):207–212. <https://doi.org/10.1097/00001888-200603000-00002>
- Saverino D, Marcenaro E, Zarcone D. Teaching histology and anatomy online during the COVID-19 pandemic. *Clin Anat*. 2022;35(1):129–134. <https://doi.org/10.1002/ca.23806>
- Schulz KF, Altman DG, Moher D. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. *J Pharmacol Pharmacother*. 2010;1(2):100–107. <https://doi.org/10.4103/0976-500X.72352>
- Shaffer K, Small JE. Blended learning in medical education: use of an integrated approach with web-based small group modules and didactic instruction for teaching radiologic anatomy. *Acad Radiol*. 2004;11(9):1059–1070. <https://doi.org/10.1016/j.acra.2004.05.018>
- Shaw T, Long A, Chopra S, Kerfoot BP. Impact on clinical behavior of face-to-face continuing medical education blended with online spaced education: a randomized controlled trial. *J Contin Educ Health Prof*. 2011;31(2):103–108. <https://doi.org/10.1002/chp.20113>
- Singh K, Bharatha A, Sa B, Adams OP, Majumder MAA. Teaching anatomy using an active and engaging learning strategy. *BMC Med Educ*. 2019;19(1):149. <https://doi.org/10.1186/s12909-019-1590-2>
- Sonne C, Persch H, Rosner S et al. Significant differences in written assessments as a result of a blended learning approach used in a clinical examination course in internal medicine: a randomized controlled pilot study. *GMS J Med Educ*. 2021;38(2):Doc42. <https://doi.org/10.3205/zma001438>
- Stewart A, Inglis G, Jardine L, Koorts P, Davies MW. A randomized controlled trial of blended learning to improve the newborn examination skills of medical students. *Arch Dis Child Fetal Neonatal Ed*. 2013;98(2):F141–F144. <https://doi.org/10.1136/archdischild-2011-301252>
- Stockwell BR, Stockwell MS, Cennamo M, Jiang E. Blended learning improves science education. *Cell*. 2015;162(5):933–936. <https://doi.org/10.1016/j.cell.2015.08.009>
- Toulmonde M, Bellera C, Mathoulin-Pelissier S et al. Quality of randomized controlled trials reporting in the treatment of sarcomas. *J Clin Oncol*. 2011;29(9):1204–1209. <https://doi.org/10.1200/JCO.2010.30.9369>
- Turney BW. Anatomy in a modern medical curriculum. *Ann R Coll Surg Engl*. 2007;89(2):104–107. <https://doi.org/10.1308/003588407X168244>
- van Houten-Schat MA, Berkhout JJ, van Dijk N et al. Self-regulated learning in the clinical context: a systematic review. *Med Educ*. 2018;52(10):1008–1015. <https://doi.org/10.1111/medu.13615>
- Wang D, Zhou J, Wu Q et al. Enhancement of medical students' performance and motivation in pathophysiology courses: shifting from traditional instruction to blended learning. *Front Public Health*. 2022;9:813577. <https://doi.org/10.3389/fpubh.2021.813577>

- Yaylaci S, Guven F. The effectiveness of different E-learning modalities in enhancing neonatal cardiopulmonary resuscitation: principles, knowledge, and communication skills of undergraduate paramedic students. *Prehosp Disaster Med.* 2021;36(5):576–585. <https://doi.org/10.1017/S1049023X21000832>
- Yu Z, Hu R, Ling S et al. Effects of blended versus offline case-centred learning on the academic performance and critical thinking ability of undergraduate nursing students: a cluster randomised controlled trial. *Nurse Educ Pract.* 2021;53:103080. <https://doi.org/10.1016/j.nepr.2021.103080>
- Zeng J, Liu L, Tong X et al. Application of blended teaching model based on SPOC and TBL in dermatology and venereology. *BMC Med Educ.* 2021;21(1):606. <https://doi.org/10.1186/s12909-021-03042-7>
- Zhang X, Zhang G, Yuan Y, Zhang Y. Study on the reporting quality of randomized controlled trials of flipped classroom in medical education. *Clin Anat.* 2022;35(5):592–597. <https://doi.org/10.1002/ca.23871>