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ORIGINAL RESEARCH

Impact of a MOOC-Based Blended Learning Model on Performance, Satisfaction, and Perceptions in a Histology Course for Chinese Medical Students

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Background: While massive open online course (MOOC)-based blended learning has gained popularity across disciplines, its adoption in medical histology education is underexplored, and its educational benefits for undergraduate medical students have yet to be clearly established.

Objective: This study examined the relative effectiveness of traditional and blended learning methods in terms of academic performance, student perceptions, and learning satisfaction among first-year medical students in China enrolled in a histology course.

Methods: In this study, two groups with similar age, gender, and academic background were analyzed. The control group (n = 44) received traditional lecture-based teaching (LBT group), while the blended learning group (n = 45) received hybrid teaching, which combined traditional lecture-based teaching and MOOC (LBTM group).

Results: The final examination score of the blended learning participants was significantly higher than that of the control participants (LBTM 81.00 ± 10.84 vs LBT 75.34 ± 12.50, $P < 0.05$). The LBTM group demonstrated higher mean scores among the middle 30% (Mann–Whitney *U*-test, $P < 0.001$) and the lower 50% (Mann–Whitney *U*-test, $P < 0.01$) of students. Additionally, the final examination score was significantly correlated with the in-class quiz score (R = 0.420, $P < 0.01$). The implementation of blended learning was well-received by students in the LBTM group, who preferred the blended learning model (64.44%). Moreover, higher satisfaction was observed with blended learning (LBTM 21.87 ± 4.36 vs LBT 15.20 ± 4.15, $P < 0.001$).

Conclusion: Blended learning led to significant improvements in students' performance, satisfaction, and perception compared with traditional learning.

Keywords: academic outcomes, blended learning, traditional learning, human histology

Introduction

Histology is a prerequisite subject for understanding other basic medical sciences and higher clinical courses; hence, the subject is regarded as a valuable course in medical education.[1,2] Currently, histology is still based on rigid traditional teaching methods in China.[2] Traditional teacher-centered teaching strategy involves teachers transferring theoretical knowledge following the assigned syllabus and the students assimilating the knowledge passively.[3] One drawback of this method is the difficulty in understanding the abstract microstructures in histology, which reduces student engagement and interest in the subject.[4] Another drawback of the traditional teaching approach is that students spend a considerable amount of time on note-taking tasks and have limited opportunities to engage in classroom interaction.[5,6] This hinders the development of higher levels of thinking such as clinical reasoning, interpretation, or analysis.[5] Therefore, alternative

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methodologies are investigated to increase students' engagement and classroom interactions in the human histology course.

The rapid advancement of technology has driven significant shifts in teaching methods with digital tools. Online learning, including massive open online courses (MOOCs), provides alternative learning paradigms for many learners.[7–9] MOOCs have been applied in a variety of disciplines and laid the foundation for online education since the introduction of the MOOCs concept around 2008.[10,11] Students can access MOOCs anytime and from anywhere using digital devices. Therefore, MOOCs eliminate the barrier of space and time in traditional teaching mode, representing a major innovation in higher education.[12] MOOCs include educational resources such as videos, quizzes, forums, and other materials.[13] Students can get help by interacting with instructors and other peers taking the course on MOOC forums, facilitating personalized programs.[14] Therefore, MOOCs greatly promote students' enthusiasm for learning and encourage active learning.[15] Despite the various advantages, MOOCs also have some disadvantages, including low completion rates and a lack of personal contact with peers and tutors, suggesting that online learning alone is not the most effective strategy for teaching and learning.[16,17] However, these disadvantages of MOOCs can be supplemented by the traditional teaching. Therefore, a blended learning strategy combining the advantages of traditional teaching and digital resources may provide a more appropriate teaching strategy.

Blended learning integrates traditional face-to-face instruction with online or computer-mediated learning modalities, offering a flexible approach to education.[18] The face-to-face component allows instructors to implement various student-centered learning activities, promoting interaction and communication with students. This aspect aligns with educational communication theory, which emphasizes the importance of effective teacher-student interactions to achieve optimal teaching outcomes.[19] On the other hand, the online component of blended learning leverages the multiple intelligences theory, enabling individualized learning pathways where students can progress at their own pace, making the most of their unique strengths and preferences.[20] Additionally, constructivist theory underpins blended learning by emphasizing the importance of learner-generated knowledge through digital interactions and experiential tasks, fostering deeper learning.[21] These foundational theories have contributed significantly to the widespread adoption and application of blended learning in educational settings.

Although MOOC-based blended learning has been widely implemented across various medical disciplines, including physiology, pathophysiology, and oncology, its application in the field of medical histology remains relatively underexplored.[22–25] Histology, as a foundational component of medical education, is crucial for understanding clinical diagnosis and treatment.[26] However, the use of MOOCs models in histology education is still in its nascent stages.[27] This gap not only limits the progression of medical education but also restricts the full potential of MOOCs in transforming medical curricula. A previous review and meta-analysis by Andrew et al emphasized the importance of considering instructional design elements that impact student outcomes, which should be a key focus in future research.[28] This study seeks to address this gap by investigating the effectiveness of blended learning in medical histology education.

The primary objective of this study is to compare the effects of MOOC-based blended learning with traditional learning on the performance, perceptions, and satisfaction of Chinese medical students in a histology course. This blended program was hypothesized to enhance all three aspects compared to traditional learning.

Materials and Methods

Teaching Objects

The human histology course was delivered to first-year medical students at the Medical School Curriculum of Shandong University (SDU), China. The subjects were recruited following a presentation given a week before the beginning of the histology course, which lasted for one semester. All participants in both the control and experimental groups provided written informed consent. Students repeating the course were excluded from the study analyses. This study was approved by the Shandong University Medical School Ethics Review Committee (ECSBMSSDU2020-1-001). The study adhered to the principles of the Declaration of Helsinki regarding medical research involving human subjects. All methods were performed in accordance with the relevant guidelines and regulations.

Traditional Lecture-Based Learning Method

Students from the control group received traditional lecture-based teaching, as described below. One week before class, the teacher distributed learning materials, including human histology teaching materials, related clinical cases, and exercises. During class, the teacher gave a traditional lecture. After class, the teacher uploaded the PowerPoint slides used for the lecture to the mobile application. The students completed their homework after class.

Blended Learning Mode

The blended learning group was given a different set of learning activities, as presented below (Table 1).

Pre-Class Activities

Students were required to watch online videos for their pre-class learning (available from https://www.icourse163.org). The length of each video was about 10 min. The students could rewind, pause, and fast-forward a video lecture as they needed. The forum on the MOOCs platform created an interactive learning environment, where the instructor could solve students' doubts regarding the teaching contents and the students could communicate with their peers freely.

In-Class Activities

In-class activities consisted of the following components: the teacher lectures, exercises, quizzes, and classroom interactions. The teacher lectures consisted mainly of the key points, while easy knowledge points were accomplished

Table 1 Learning Activities Arranged in Blended Learning of Human Histology

Block	Pre-class Activities	Class Activities	Post-class Activities
Block 1 Introduction of histology	Microteaching videos 1. In *situ* hybridization 2. Cell culture and tissue engineering	Lecture on Block 1 Paraffin sectioning and HE staining* Light microscopy* Electron microscopy*	N/A
Block 2 Epithelial tissue	Microteaching videos andPPT 1. Classification of epithelial tissue 2. Glandular epithelium	Lecture on Block 2 Covering epithelium* Exercise Classroom interactions: How to divide the epithelial tissue into single cells?	Quiz based on Block 1-2
Block 3 Connective tissue	Microteaching videos andPPT 1. Dense connective tissue 3. Adipose tissue 4. Reticular tissue	Lecture on Block 3 Loose connective tissue* Exercise Classroom interactions: What cell types involved in immunity and what the related mechanisms are?	Quiz based on block 3
Block 4 Cartilage and bone	Microteaching videos andPPT 1. Elastic cartilage 2. The long bone 3. Endochondral ossification	Lecture on Block 4 osseous tissue* Exercise Classroom interactions: What do various bone cells do during fracture healing?	Quiz based on block 4
Block n	Microteaching videos andPPT	Lecture on Block n Key contents of block n* Exercise Classroom interactions	Quiz based on block n

Notes: N/A, not applicable; n, the number of the rest chapter; *represents the key contents of the corresponding block.

by students by watching MOOC videos before class. The histology exercises included multiple-choice questions and were carried out using the Rain-classroom application, which was jointly developed by Tsinghua University and Xuetang online.[29] The Rain-classroom application is a learning software that can be integrated into PowerPoint, enabling students to answer questions and complete in-class quizzes assigned by teachers. In each lecture session, teachers prepared an important question used for classroom interactions.

Post-Class Activities

The teachers asked students to complete multiple-choice questions after the class. These MOOC quizzes provided the students an opportunity to review the teaching contents and monitor progress in their knowledge.

Student Assessment

The final overall evaluation (total grade) for students included both formative and summative assessments. Students in the blended learning group were evaluated through MOOC quizzes (30%), homework (10%), and a final examination (60%). In contrast, students in the control group were assessed only through homework (10%) and a final examination (90%), as they did not participate in the MOOC component. The final examination was a closed-book test. The final examination administered to both groups had no difference in the amount and type of questions. Although the item number was identical, the questions differed slightly between both groups in the final examination. However, the final examination questions selected from our question bank had the same difficulty level for both groups. The final examination was held two weeks after the end of the histology course. For both groups, the course was taught by the same instructors using the same textbook and syllabus.

Student Perception of Blended Learning

A survey questionnaire was used to evaluate student's perceptions of the blended learning approach. The questionnaire consisted of 7 closed-ended questions scored by a 5-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The responses of the students were reported as frequencies with percentages.

Survey on Student Satisfaction

Students' satisfaction regarding the learning methods was assessed according to a previous study reported by Lozano-Lozano et al.[18] The content regarding learning satisfaction covered six areas, including (1) general satisfaction; (2) the clarity of instructions; (3) whether the final assessment reflected the course syllabus; (4) clarity with the use of the learning method; (5) whether there was enough time to complete the proposed exercises; and (6) improvement in the capacity to learn content. Again, a 5-point Likert scale was adopted (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). Following data collection, the sum scores were calculated for each area, and the appropriate statistical method was applied for analysis.

Statistical Method

Pearson chi-square tests were performed to evaluate categorical data expressed as percentages. The Mann–Whitney *U*-test was utilized to analyze the differences in student examination scores and student satisfaction between the control and blended learning groups. Evaluation data regarding the students' perception of the teaching method were presented descriptively. A Cronbach's alpha value ranging from 0.70 to 0.95 was considered appropriate.[30] Continuous data were expressed as means and standard deviations (SD). Statistical analyses were performed using Microsoft Excel (Microsoft Corp.) and GraphPad Prism, version 8 (GraphPad Software, San Diego, California). In this study, significance was set at $P < 0.05$.

Results

Demographic Characteristics

Students were divided into two groups. The control group (LBT) comprised 44 students enrolled in Autumn 2021. The experimental group (LBTM) comprised 45 students enrolled in Autumn 2022. To address the absence of randomization, the

Table 2 Characteristics of the Participants of the Groups

	LBT Group (n=44)	LBTM Group (n=45)	χ^2/U	*P* value
Age; years, (±SD)	18.4(±0.61)	18.6(±0.85)	884.5	0.31
Sex				
Female, n (%)	21(47.73)	24(53.33)	0.28	0.60
Male, n (%)	23(52.27)	21(46.67)		
The average scores*(mean ± SD)	617.20±35.71	610.64±31.46	859.5	0.29

Notes: *The average scores for national university entrance examination; n, sample size.
Abbreviations: LBT, traditional lecture-based teaching; LBTM, traditional lecture-based teaching and massive open online courses; SD, standard deviations; %, percentage.

age, gender, and academic ability of the groups were compared (Table 2). The age of students in the LBT and LBTM groups was 18.4 ± 0.61 and 18.6 ± 0.85, respectively (Mann–Whitney *U*-test, $P > 0.05$). The average scores for the national university entrance examination of the LBT and LBTM groups were 617.20 ± 35.71 and 610.64 ± 31.46, respectively (Mann–Whitney *U*-test, $P > 0.05$). The gender ratio in the LBT and LBTM groups was comparable ($\chi^2 = 0.28$, $P > 0.05$). No statistically significant differences in the students' gender, age, and average scores for the national university entrance examination were observed between the LBT and LBTM groups. Therefore, the participants in both groups were comparable.

Effects of Blended Learning Mode on Academic Performance

At the end of sessions, the performance of the two groups was evaluated. As shown in Table 3, the mean scores of the final examination in the LBT and LBTM groups were 75.34 ± 12.50 and 81.00 ± 10.84 out of 100, respectively (Mann–Whitney *U*-test, $P < 0.05$). The academic performance for the different student categories (top 20%, middle 30%, and bottom 50%) is shown in Table 3. The mean scores of the top 20% of students in the LBT group and LBTM group were 91.58±2.02 and 92.35±1.22, respectively, showing no statistically significant difference (Mann–Whitney *U*-test, $P > 0.05$). The mean score of the middle 30% of students in the LBTM group was significantly higher than that of the middle 30% of students of the LBT group (86.60 ± 3.44 vs 81.15 ± 2.66, respectively) (Mann–Whitney *U*-test, $P < 0.001$). For the bottom 50% of students, the LBTM group scored significantly higher than the LBT group, with mean scores of 72.79 ± 9.59 and 64.50 ± 8.25, respectively (Mann–Whitney *U*-test, $P < 0.01$). Moreover, the final exam score was significantly correlated with the in-class quiz score (Spearman correlation, $R = 0.420$, $P < 0.01$) (Figure 1).

Student Perception of Blended Learning Mode

Table 4 summarizes student perceptions regarding blended learning. The feedback generally indicated a positive perspective. Cronbach's α for the student perception questionnaire was 0.906. Most students agreed or were neutral (based on a five-point Likert scale) that the blended learning model enhanced their learning quality in several critical aspects: improving their confidence in examination (3.71 ± 1.05), a good approach for acquiring theoretical knowledge (3.64 ± 0.97), and timely

Table 3 Comparison of Students' Mean Scores of the Final Examination Between the LBT and LBTM Groups

Students	Mean Scores (mean±SD)	
	LBT Group (n=44)	LBTM Group (n=45)
Total students	75.34±12.50	81.00±10.84*
Top 20% students	91.58±2.02	92.35±1.22^{NS}
Middle 30% students	81.15±2.66	86.60±3.44***
Bottom 50% students	64.50±8.25	72.79±9.59**

Notes: *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$ vs LBT group; NS, non-significant; n, sample size.
Abbreviations: LBT, traditional lecture-based teaching; LBTM, traditional lecture-based teaching and massive open online courses; SD, standard deviations; %, percentage.

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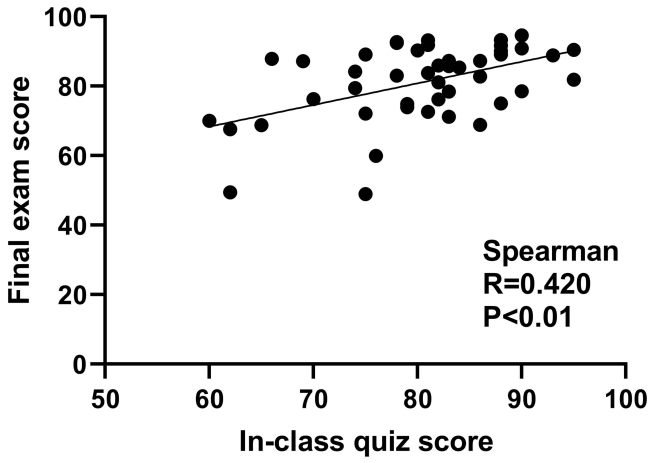

Figure 1 Correlation between the in-class quiz score and final exam score. Spearman's rank correlation coefficient was used to explore the relationships between the in-class quiz score and final exam score. Spearman correlation $R = 0.420$, $P < 0.01$.

response to MOOC questions (3.78 ± 0.89) and feedback on quizzes and assignments from teachers (3.71 ± 0.88). The majority of the respondents reported increased interactions with instructors (3.91 ± 0.86) or classmates (3.96 ± 0.84) using LBTM teaching method. Most students preferred the blended LBTM learning (3.76 ± 1.04) (see Supplementary File 1).

Satisfaction Survey Evaluation

Table 5 displays students' learning satisfaction with their respective learning methods. The satisfaction survey, detailed in the Methods section, encompassed six key areas. Each area was scored on a 5-point Likert scale (with 1 = strongly disagree to 5 = strongly agree), so the total possible score ranged from 6 to 30. Cronbach's α for the student satisfaction questionnaire was 0.72 in the LBT group and 0.73 in the LBTM group. The mean score of the LBTM group was 21.87 ± 4.36, while that of the LBT group was 15.20 ± 4.15 (Mann–Whitney *U*-test, $P < 0.001$). This suggested that the LBTM

Table 4 Results From Experimental Surveys Toward the LBTM Blended Learning Using a Five-Point Likert-Style Scale

Survey Questions	Mean ± SD
The quantity of my interactions with my instructors increased on LBTM	3.91±0.86
The quantity of my interactions with my classmates increased on LBTM	3.96±0.84
I am confident to sit exams after taking LBTM	3.71±1.05
LBTM is good for theoretical knowledge	3.64±0.97
Teachers' response to question is timely on MOOCs	3.78±0.89
Teachers provide feedback on quizzes and assignments on LBTM	3.71±0.88
I would prefer LBTM teaching	3.76±1.04

Abbreviations: LBTM, traditional lecture-based teaching and massive open online courses; MOOCs, massive open online courses; SD, standard deviations.

Table 5 Students' Satisfaction About Teaching Method in the LBT and LBTM Groups

Parameter	LBT Group (n=44)	LBTM Group (n=45)	U	*P* value	95% Confidence Interval
	Mean (SD)	Mean (SD)			
Learning satisfaction	15.20(4.15)	21.87(4.36)	287.5	<0.001	6.00–9.00

Abbreviations: LBT, traditional lecture-based teaching; LBTM, traditional lecture-based teaching and massive open online courses; SD, standard deviations; %, percentage.

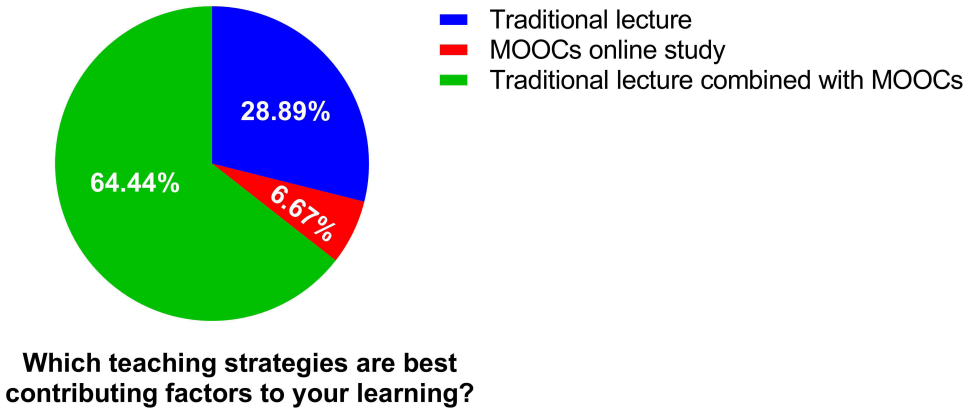

Figure 2 The results of questionnaire surveys on the students' preference of learning method. The best contributing factors responsible for your learning as rated by students.

group subjects were more satisfied than the members of the LBT group with the teaching methods received. The survey from the blended learning group showed that most students (64.44%) considered traditional lectures combined with MOOCs as the most effective way to study, whereas 28.89% chose traditional lectures and only 6.67% of the students elected purely MOOCs online study (Figure 2).

Discussion

In this study, student performance indicated that participants who received blended learning scored better than those taught using traditional lectures. In addition, the use of blended learning increased students' satisfaction and was positively perceived. Collectively, these findings strongly suggested that blended learning offers superior results in the human histology course compared to traditional learning.

The LBTM group scored significantly higher than the LBT group overall (81.00 ± 10.84 vs 75.34 ± 12.50; $P < 0.05$), as well as in both the middle 30% (86.60 ± 3.44 vs 81.15 ± 2.66; $P < 0.001$) and bottom 50% (72.79 ± 9.59 vs 64.50 ± 8.25; $P < 0.01$) of students. These improved learning outcomes in our study are in accordance with the findings of a systematic review that found improved gains using blended learning compared to traditional learning.[31] The higher performance of students from the blended learning group may be attributed to the articulation between MOOC-based pre-class learning and student-centered participation during class. Firstly, students prepared via pre-class learning (preview) by watching MOOC videos, which proved effective, especially for medical school freshmen, who are unfamiliar with introductory science courses like histology.[32,33] Previewing the course content allowed students to self-direct their learning experience, providing a general understanding of what teachers would teach in the classroom. Thus, the structured pre-class exposure through MOOCs may serve as a cognitive organizer, helping students build foundational mental models prior to deeper classroom engagement. Secondly, one of the points highlighted in this study was that MOOCs allow for abundant and valuable in-class time for quality discussions as lectures do not include simple knowledge points, which have already been covered by MOOCs before class. One of our in-class activities includes a question used for classroom interactions. These interactions stimulate students' interest and contribute to the development of students' core competencies, such as critical thinking skills and clinical reasoning ability. As expected, a majority of students reported that blended learning increased their interaction with peers and teachers in the blended learning group. This achieved a shift from traditional teacher-centered learning to student-centered learning. Consistent with our results, classroom interactions promoted mentally active learning and increased students' academic performance, as well as retention in science and other disciplines.[34,35] Importantly, the in-class quiz scores are positively correlated with the final exam results. Our findings align with previous research that identified a positive correlation between frequent quizzes and cumulative exam performance.[36] Additionally, easy accessibility for reviewing MOOC learning materials likely bolstered students' confidence in the histology course, particularly in the face of these pressures to reduce histology teaching hours due to innovations in medical education (eg, problem-based learning and integration of

disciplines).[37] Supporting this notion, most students agreed that blended learning facilitated the consolidation of knowledge and preparation for examinations. In conclusion, blended learning may partially account for the higher levels of academic performance and high satisfaction scores observed in the blended learning group.

While no significant difference in mean scores was observed among the top 20% of students between the LBTM and LBT groups, the LBTM group exhibited higher mean scores in the middle 30% and the lower 50% of students. These findings suggest that blended learning may be particularly beneficial for students with average or below-average academic performance in terms of knowledge acquisition compared to high achievers. Future studies are warranted to investigate the contributing factors, such as learning motivation and self-directed learning capabilities, in mediating the performance improvement among these student subgroups.

A meta-analysis and review by Andrew et al revealed that blended learning may lead to better learning outcomes than traditional teaching approaches in improving knowledge acquisition.[28] However, this analysis highlighted that future research should identify which elements of instructional design are beneficial for each outcome. Indeed, further data collection, particularly from pre-professional students such as medical students, would be beneficial. In this study, both MOOC-based online and in-class quizzes facilitated self-monitoring and enabled medical students to adjust their learning strategies in response to identified knowledge gaps. Our findings are consistent with a previous study, which reported that MOOCs improve the effectiveness of academic performance by facilitating the exchange of information and resources.[38] Our study provides evidence of the effects of blended learning in histology. Additionally, our results help to reduce the heterogeneity observed in the aforementioned meta-analysis.

The survey showed that 64.44% of students considered traditional lectures combined with MOOCs the most effective way to study, whereas only 28.89% still preferred traditional lectures and 6.67% of the students liked MOOCs online learning. These percentages justified the use of the blended learning mode of delivery rather than purely face-to-face traditional lecture or online-based learning alone. Our data are consistent with other studies, which showed that student learning was largely dependent on face-to-face classes in the blended learning mode.[39] In contrast, 28.89% of the students were in favor of the traditional lecture, which was primarily attributed to two reasons. First, the students have been used to attending class in the classroom and appreciate the sense of belonging provided by this teaching method. Second, they did not have enough discipline for online classes. Therefore, instructors need to focus on mobilizing students' enthusiasm for online study.

Limitations

The limitations of the present study should be acknowledged. First, non-randomized participant allocation may introduce selection bias. Although baseline characteristics (eg, University Entrance Scores, gender, age) were comparable between the two groups, pre-existing differences could still influence the outcomes. Second, the small sample size (n = 44/45) limits statistical power and increases the risk of Type II errors, which requires caution when interpreting the findings. Larger replication studies are needed. Third, despite controlling for exam quantity, format, and difficulty, minor variations in test items could affect assessment consistency.

Conclusion

This study addresses a critical gap in medical education by systematically evaluating the use of MOOC-based blended learning in histology—an area underexplored despite its widespread adoption in other medical disciplines. The results show that this approach significantly improves student learning outcomes. By presenting an evidence-based instructional model for histology, the study not only enriches the medical education literature but also offers practical guidance for integrating blended learning into undergraduate curricula.

Abbreviations

LBT, traditional lecture-based teaching; LBTM, traditional lecture-based teaching and massive open online courses (MOOCs); MOOCs, massive open online courses.

Data Sharing Statement

The original contributions presented in this study are included in the article, further inquiries can be directed to the corresponding author.

Ethics Statement

Prior to data collection, all participants provided written informed consent for both feedback provision and survey participation. This study has been approved by Shandong University Medical School Ethics Review Committee for ethics.

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Disclosure

The authors declare that they have no conflicts of interest for this work.

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