HOW WE TEACH | Classroom and Laboratory Research Projects

Blended learning in basic medical laboratory courses improves medical students’ abilities in self-learning, understanding, and problem solving

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Chen J, Zhou J, Wang Y, Qi G, Xia C, Mo G, Zhang Z. Blended learning in basic medical laboratory courses improves medical students’ abilities in self-learning, understanding, and problem solving. Adv Physiol Educ 44: 9–14, 2020; doi:10.1152/advan.00076.2019.—Blended learning, is a teaching approach that integrates online self-learning and classroom teaching. When designed well, blended learning courses in medicine can facilitate students to improve themselves in self-learning, understanding, and problem solving, ultimately enhancing their learning efficiency. However, blended teaching methods are usually used only in a single course, so it is unclear whether these methods can work well in a variety of basic medical courses. The goal of this study is to explore students’ perceptions of whether blended laboratory courses are helpful for them in overcoming the difficulties they experience. Blended laboratory courses were taken by medical students at Guilin Medical University. Approximately 71.1% of the students agreed that online lecture courses improved their understanding of threshold concepts and the underlying theories. The majority of the students (63.01%) held the opinion that the blended laboratory courses were more effective than other types of courses in achieving the knowledge goals. The majority of the teachers believed that students’ interest in experimentation operations, hands-on abilities, confidence, and other factors were greatly improved compared with those of students taught using the traditional teaching model (face to face). In addition, the average scores for the quizzes of laboratory courses were significantly improved in the blended learning method compared with the traditional learning method. Blended laboratory courses are successful and welcomed by both students and teachers in undergraduate laboratory courses.

INTRODUCTION

Laboratory courses are believed to serve an important role in scientific theory courses, such as by providing opportunities for students to acquire experimental skills and collaborative learning skills (10). In addition, laboratory courses are expected to play a key role in providing opportunities for students to learn and reinforce knowledge, thus allowing them to apply these concepts in experimental curricula (6). Bradley et al. (3) suggested that laboratory courses can help students learn well if the classes are designed to address “threshold concepts.” Threshold concepts lead to a qualitatively different view of subject matter and are central to achieving mastery of a subject. They are transformative in that, once understood, they can result in a significant shift in a learner’s perception of a subject. They are integrative, inasmuch as connections that were previously hidden come into view (14, 15). However, if students do not learn these threshold concepts, students are unable to make progress in their learning and may even “get stuck” (11). Therefore, medical educators may have to grapple with threshold concepts related to teaching and learning.

Traditionally, basic medical laboratory courses begin with a short lecture given by teachers, which strictly complies with the Guilin Medical University laboratory manual. Students then follow the instructions in the manual to perform their medical exercise step by step. Experimental sessions are taught in a 40- to 50-student small class, which is divided into several smaller groups (of 4–5 students). Even so, many students finish their laboratory courses without fully understanding the principles behind the experiments (2).

Blended learning, which integrates online and face-to-face instruction, aims to lead students from a superficial to a deep and full understanding of the courses. It offers a promising way of transforming teaching methods in educational careers and has been reported to have good effects in many subjects (1, 9, 12, 13). With the spread of wireless fidelity on Chinese campuses and the increasing availability of online teaching systems or platforms, educators in Chinese universities are instigating a wave of blended learning reforms (16). The online portion of blended courses involves high-quality, open online courses that are intended to improve students’ study skills and motivation, as well as the teaching effectiveness of basic medical courses. Such blended learning is also used in on-campus courses that support “traditional” classes, such as lectures, tutorials, and/or laboratory-based classes. However, blended learning has only been used in a single course. Therefore, its effects lack confirmation in a variety of basic medical courses, and the majority of studies have focused on lectures and tutorials and have rarely examined blended learning in basic medical laboratory courses. Blended learning has been
used in a variety of basic medical laboratory courses, including anatomy, parasitology, physiology, and pathophysiology, providing proof of the effect of blended learning in basic medical laboratory courses.

Therefore, the goal of this study is to determine whether basic medical blended laboratory courses can help students better understand certain threshold concepts and improve their abilities of self-learning, understanding, and problem solving. Blended laboratory courses were taken by students of Guilin Medical University. Using online questionnaires and face-to-face investigation methods, we collected feedback from the students and instructors to quantitatively and qualitatively analyze the significance of practical laboratory programs in the teaching process.

MATERIALS AND METHODS

Study participants. The study was conducted by the School of Basic Medical Sciences at Guilin Medical University. The participating students were 5-yr undergraduate students majoring in Clinical Medicine (2015 class and 2016 class). The basic medical laboratory curriculum is part of the first- and second-year course. This project was conducted for 3 yr (2015–2017). All of the procedures in this study were approved by the Ethics Committee of Guilin Medical University, and informed consent was obtained from the students. The students were assured that the results would be treated confidentially (2).

Traditional laboratory courses. In traditional laboratory courses, students independently complete the same assigned reading before class (background and theoretical knowledge about the experiment, overview of the experiment, and step-by-step instructions). First, a quiz is administered by teachers. Then, according to the Guilin Medical University laboratory manual of basic medicine, a short lecture is given by the teachers in the first 20–30 min of class. The teachers summarize the key points from the reading materials and provide a detailed introduction to the equipment used in the following experiment. During this process, the teachers intermittently ask the students questions to determine whether they completely understand the key points. Finally, the students perform the medical exercise on their own while the teachers are available to assist them (7).

Construction of online blended laboratory courses platform. The blended laboratory courses reform was built on the School of Basic Medical Sciences of Guilin Medical University Education Online Teaching Platform. Microvideos, reading materials about the experiment, and online homework were arranged for medical students, according to the course syllabus of Guilin Medical University for the bachelor’s medical program. For threshold concepts, many related microvideos and reading materials are offered by teachers online. For example, homeostasis has been identified as a threshold concept and is likely to be problematic to teach and learn. For this concept, in addition to textbooks, we also offered students related class information online, such as physiology, biochemistry, and clinical disorders, to help students comprehend the concept properly (Table 1). In addition, online questionnaire surveys (five-point Likert scale questions) were conducted in this online teaching platform. Due to the popularity of WeChat and QQ among students, every class created WeChat and QQ groups for blended learning, which all students could join. The students posed questions (including question about threshold concepts), and the teachers answered these questions and provided feedback in time. The teachers also provided new papers or the latest information for the students. Course announcements were posted online in the WeChat and QQ groups.

Blended laboratory courses. In blended laboratory courses, students first read the overview of the experiment online before class, which provided detailed theoretical background information for the lecture and the key points of step-by-step instructions for performing the experiment. At the beginning of the class, a quiz of approximately 10 questions was administered by the instructors to determine whether the students fully understood the basic principle of the experiment. In the sequence, the students watched a series of microvideos, which replaced the teacher’s short lecture, extended the traditional prereading, and highlighted the necessary skills for the subsequent experiment (10–15 min) in the classroom. Then, during the video, the instructors 1) introduced how to use the laboratory equipment, 2) illustrated standard experimental protocol, and 3) pointed out aspects of equipment safety (7). Finally, the students performed the medical exercise on their own while the teachers were available to assist them.

Student evaluations. An anonymous questionnaire survey was conducted to collect feedback from students at the end of the blended laboratory courses. The questionnaire was based on previous peer instruction studies in medical education (4, 8). The students were asked about their learning experience through a questionnaire consisting of several points, including objectives, procedures, students’ attitudes, and recommended actions. In addition, the students rated the statements on a five-point Likert scale (1 strongly disagree to 5 strongly agree). Confirmatory factor analysis was used to assess the validity of the questionnaire. The internal consistency of the scale was measured by Cronbach’s coefficient (2).

Teacher survey questionnaire. To better assess this teaching method, using anonymous questionnaires, we also surveyed the 34 teachers of these lessons and the relevant 16 teachers who are engaged in teaching conducted in later courses.

Data analysis. For the results of the Likert scale-based questionnaires, significant deviations of participant responses to questions from the neutral score of 3 were analyzed using a one-sample Wilcoxon signed-rank test. The quiz score was expressed as the mean ± SD. To compare students’ quiz scores in the 2015 class with those in the 2016 class, SPSS 12.0 software (Chicago, IL) was used.

Table 1. Difference between 2015 without blended learning and 2016 with blended learning in learning the threshold concept of homeostasis

| Activity                                      | 2015 Without Blended Learning | 2016 With Blended Learning |
|-----------------------------------------------|-------------------------------|-----------------------------|
| Lecture about homeostasis                     | Yes                           | Yes                         |
| Textbook about homeostasis                    | Yes                           | Yes                         |
| Sources online about homeostasis (including physiology, biochemistry, and clinical disorders) | No                            | Yes                         |
| Free question about homeostasis online        | No                            | Yes                         |
| Small-group discussion about homeostasis by WeChat and QQ groups | No                            | Yes                         |
| Laboratory exercise about homeostasis (including hemorrhagic shock, respiration experiment) | Yes                           | Yes                         |
| Laboratory report                             | Yes                           | Yes                         |
| Report feedback                               | No                            | Yes                         |
| Quizzes                                       | Yes                           | Yes                         |
BLENDED LEARNING IMPROVES STUDENTS’ ABILITIES

RESULTS

Evaluation of the blended laboratory courses online. Table 2 shows the students’ responses to the questions investigating the practicability of blended laboratory courses online. Only 50.87% of the students in clinical medicine acknowledged that they initially made an effort to complete their blended laboratory courses online; however, after a semester of study, 100% of the students completed their blended laboratory courses online. Overall, positive results were obtained at ratings of ≥3.9, and 75.14% of the students agreed that blended laboratory online courses stimulated their enthusiasm for learning. Approximately 71.1% of the students agreed that blended courses improved their understanding of threshold concepts and the underlying theories, and 53.76% of the students agreed that their analytic abilities and critical thinking skills were developed via blended laboratory courses online (Table 2).

Student self-evaluation and satisfaction. The Wilcoxon test showed that the blended laboratory courses exhibited more positive scores on each of the five questions relative to the neutral response value (Table 3), suggesting that blended learning was more popular among students than traditional methods. The majority of the students (63.01%) held the opinion that the blended laboratory courses were better at fulfilling learning objectives, and the modified method helped most of the students (67.63%) better understand the threshold concepts and the underlying theory. Moreover, ~60.12% of the students considered blended learning more interesting than traditional learning, and 64.16% of the students believed that blended laboratory courses would encourage greater willingness to participate and to exert additional effort in laboratory courses compared with traditional methods. Therefore, the majority of the students (70.52%) reported that more blended laboratory courses should be established in the future. The students also commented that traditional lectures might require certain theoretical knowledge that was difficult to understand.

Teacher survey questionnaire results. The results of the feedback survey administered to the teachers who adopted the blended laboratory courses method in this teaching section showed (Table 4) that the teachers unanimously believed the students’ interests in surgical operations and the standardization of the operating process were significantly improved compared with the use of the traditional teaching model. In addition, most of the teachers expressed a willingness to continue using this teaching model and found that experimental teaching was more relaxed. In addition, the survey results of the teachers in later stage courses showed (Table 5) that the majority of the teachers believed that students’ interest in experimentation operations, hands-on abilities, confidence, and other areas were greatly improved compared with those of students taught under the traditional teaching model and expressed a willingness to adopt this teaching model in the future.

Students’ performance on the laboratory quizzes. The laboratory quizzes were mainly used to test the effectiveness of the

| Questionnaire Item                                                                 | Agree (Score: 5 and 4) | Neutral (Score: 3) | Disagree (Score: 2 and 1) |
|-----------------------------------------------------------------------------------|------------------------|--------------------|--------------------------|
|                                                                                  | n     | %     | n     | %     | n     | %     |
| The blended laboratory courses were                                                |        |       |        |       |        |       |
| better at fulfilling learning objectives.                                          | 109    | 63.01 | 43     | 24.86 | 21     | 12.13 |
| The blended laboratory courses enabled you to better understand concepts.          | 117    | 67.63 | 33     | 19.08 | 23     | 13.29 |
| The blended laboratory courses were more interesting than traditional laboratory courses. | 104    | 60.12 | 29     | 16.76 | 40     | 23.12 |
| The blended laboratory courses ensured greater student participation.              | 111    | 64.16 | 40     | 23.12 | 22     | 12.72 |
| More blended laboratory courses should be organized in the future.                | 122    | 70.52 | 35     | 20.23 | 16     | 9.25  |

Values are n, no. of students, and percentage of students. Responses were scored using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 2. Responses to questions evaluating student use of, and learning effects from, the blended laboratory courses online

Table 3. Responses from medical students regarding the blended laboratory courses

for statistical analyses with an independent sample t test. P < 0.05 was considered statistically significant.
blended laboratory courses in stimulating students’ interest and understanding of professional theory. The mean anatomy scores of the 2016 class (77.34 ± 13.59) were significantly higher than those of the 2015 class (65.92 ± 11.87) \( P < 0.001 \), indicating that there was an improvement in students’ learning effectiveness after they participated in the blended laboratory courses (Fig. 1). Additionally, an obvious change occurred in the parasitology (84.83 vs. 75.31) \( P < 0.001 \), physiology (90.33 vs. 84.23) \( P < 0.001 \), and pathophysiology (86.89 vs. 75.23) \( P < 0.001 \) scores between the groups with and without the modified method.

Furthermore, the percentage of students above the minimum score (set at 60) was higher in the 2016 class than in the 2015 class (Fig. 2).

**DISCUSSION**

The comprehensive coverage of wireless fidelity, which was once a privilege limited to a few universities in China, makes the wireless internet available from classrooms to dormitories. Currently, an increasing number of Chinese universities provide this universal resource, which greatly increases the speed of information flow across the web (16, 17). Furthermore, the widespread use of smartphones and personal computers on campus changes the manner in which teachers teach and students learn. Our college, Guilin Medical University, completed the campus wireless fidelity construction in 2016. The blended laboratory courses are pioneering university online courses that are open to all of the students majoring in Clinical Medicine at Guilin Medical University.

The construction of blended laboratory courses for medical students is currently well under way. The blended laboratory courses are now being transformed into online self-learning curricula that require self-discipline to learn about the theoretical courses before the laboratory courses, and the proportion of online self-learning is gradually increasing. In addition, the microvideos that we adopted were selected as the most helpful online self-learning materials by the students who attended the blended laboratory courses. With the rapid development of the internet, teachers can exploit and utilize online study resources to find the most economical and effective way to enhance students’ enthusiasm and improve teaching quality for blended laboratory courses. Among the students, 88% (Likert score: ≥3) agreed that online blended laboratory courses motivated them to learn (Table 2). Therefore, high-quality online resources will continue to be integrated into our blended laboratory courses at Guilin Medical University.

In this study, we compared students’ perceptions and performance between traditional and blended laboratory courses in an undergraduate basic medical laboratory. The results showed that, at the end of the blended laboratory courses, most students (75%) (Likert score: ≥3) held the opinion that the blended laboratory courses were more effective in accomplishing the skill and knowledge goals of laboratory courses (Table 2). Furthermore, the modified method helped the majority of the students (86%) (Likert score: ≥3) better understand the experimental theory and threshold concepts (Table 3). By watching many microvideos and reading materials on related lessons through the online platform, students thought they could better understand the threshold concepts. Meanwhile, many of the students thought that visualizing events and getting involved in a hands-on way also helped them to understand the threshold concepts. As one student said, “Seeing is believing.” This teaching method largely improved the positivity of the students toward experimental courses, and the students were much more confident in their operational capacity. Moreover, the students indicated that watching microlesson videos through the online laboratory courses platform before class significantly enhanced their interest in learning the theoretical material of the course compared with traditional preview lessons, suggesting that the blended laboratory courses were highly accepted among the students. Overall, these findings indicate that blended laboratory courses improved student performance more than tra-

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**Table 4. Responses from the classroom teachers regarding the blended laboratory courses**

| Questionnaire Item                                                                 | Agree (Score: 5 and 4) | Neutral (Score: 3) | Disagree (Score: 2 and 1) |
|-----------------------------------------------------------------------------------|------------------------|--------------------|--------------------------|
| The blended laboratory courses ensured the students’ basic operations in the experimentation class were more standardized and proactive. | 24                     | 8                  | 2                        |
| The blended laboratory courses ensured the students’ success rates in the experimentation class were higher. | 30                     | 2                  | 2                        |
| Compared with the traditional teaching model, I feel that the experimental teaching was more relaxed. | 19                     | 11                 | 4                        |
| I am willing to continue to adopt this teaching model in the experimentation class. | 22                     | 7                  | 5                        |

Values are no. of responses. Responses were scored using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

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**Table 5. Responses from the classroom teachers in later stage courses regarding the blended laboratory courses**

| Questionnaire Item                                                                 | Agree (Score: 5 and 4) | Neutral (Score: 3) | Disagree (Score: 2 and 1) |
|-----------------------------------------------------------------------------------|------------------------|--------------------|--------------------------|
| The blended laboratory courses ensured the students’ interest in surgical operations in the experimentation class improved. | 10                     | 3                  | 3                        |
| The blended laboratory courses ensured the students’ confidence in the surgical operating process in the experimentation class increased. | 12                     | 4                  | 0                        |
| The blended laboratory courses ensured the students’ basic operations in the experimentation class were more standardized. | 10                     | 5                  | 1                        |
| I am willing to try to adopt this model in teaching the experimentation class.    | 8                      | 4                  | 4                        |

Values are no. of responses. Responses were scored using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).
ditional anatomy, parasitology, physiology, and pathophysiology laboratory courses (5, 7).

The questionnaire survey results from the classroom teachers for subsequent courses showed that the teachers believed that students who participated in the new teaching model for the blended laboratory courses had increased hands-on abilities and initiative. Furthermore, 82% of the teachers expressed willingness to attempt to use this teaching model (Table 4).

Students’ performance on the laboratory quizzes was used to test the effectiveness of improving students’ attention and retention by linking the experiment with the theoretical knowledge (4). From the statistical results, we concluded that there was a significant difference in students’ performance; the quiz scores of the tested students were higher in the blended laboratory courses than in traditional courses. This significant difference may correlate with the specific features of the design of the courses, such as individual student responsibility, online homework preparation, and immediate feedback to correct learning errors in the experimental exercise. In addition, the changes in the score distribution further confirmed the effectiveness of the teaching method on the laboratory quizzes. Fewer students had scores <60 in the 2016 class than in the 2015 class, in which lectures were given in transitional laboratory courses.

In conclusion, blended laboratory courses are successful and welcomed by both students and teachers in undergraduate laboratory courses. During this process, teachers mainly focus on cultivating the autonomous learning ability of students rather than simply passing down theoretical knowledge. In addition, students become responsible for their own education, which effectively improves their self-discipline and self-control, as well as their abilities in self-learning, experimental skills, and understanding the threshold concept, leading to higher quiz scores in the blended laboratory course student group than in the traditional basic medical laboratory group. Furthermore, teachers find that these novel courses effectively stimulate the development of thinking methods and the problem-solving capability of students.

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DISCLOSURES
No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS
Z.Z. conceived and designed research; G.Q. and G.M. performed experiments; J.C. analyzed data; G.Q., C.X., and G.M. interpreted results of experiments; J.C., Y.W., and C.X. prepared figures; J.Z. drafted manuscript; J.C., J.Z., Y.W., and Z.Z. edited and revised manuscript; J.C. and Z.Z. approved final version of manuscript.
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