A new approach for laboratory exercise of pathophysiology in China based on student-centered learning

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Although pathophysiology is an important subject bridging basic and clinical medicine, it has long been recognized to be a subject that is difficult for students to master (3). The Chinese pathophysiology course is very dense, putting a high strain on students who want to complete their studies within the officially planned fifth semester. Therefore, the paradigm of university teaching in pathophysiology is still traditional teacher-centered learning. Namely, during a lecture, the teacher transmits knowledge (what the teacher believes is important) to the students, who passively absorb and then use the knowledge as needed. The teaching activity of the pathophysiology laboratory course consists of formal lectures, laboratory exercises, and small-group discussion. However, many students battle to link the theory with laboratory exercise, with the teacher and textbook structuring the whole course (3). For them, many times, the laboratory manual was turned into a “cookbook,” where students blindly follow the step-by-step protocol without any real opportunity to think critically about the task at hand (2). Thus, it’s not surprising that undergraduate students were unable to correctly explain the pathophysiological mechanisms after completing a semester of laboratory exercise (10). The student-centered instructional strategy purportedly engages students in active learning and critical thinking (3, 9). In student-centered courses, students come prepared with information learned from completing the preparatory assignment in predetermined work teams, in which the problems were solved through good communication between team members (1a). The student-centered study has several advantages, such as providing an informal environment for better linking the theory with the exercise, improving communication skills and critical thinking, increasing intrinsic motivation, and facilitating cooperation among students via learning to respect their partner’s views. The goal of the present study was to improve students’ overall understanding, critical thinking, and application of pathophysiological concepts. The attempt to achieve this goal was started by instituting voluntary learning activities, including a “small-group discussion,” an “oral research presentation,” and a “free response question” session. These activities aimed to engage students by giving them the opportunity to express themselves, verbally and in writing, and offer feedback as part of a formative assessment. This approach aimed to help students to document their strengths and weaknesses, improve their ability to combine theory with laboratory data, and reinforce their independent learning.

MATERIALS AND METHODS

Traditional Learning

Traditionally, pathophysiological laboratory exercises began with a 30-min lecture given by teachers. The short lecture was based on one of the topics covered in the Guilin Medical University laboratory manual of pathophysiology. In the sequence, students follow the step-by-step instructions in the manual to perform a pathophysiology exercise. For each experiment, students’ understanding of the concepts covered was assessed by laboratory reports. Laboratory reports consisted of a series of short questions found at the end of the laboratory exercise in the laboratory manual, and the quizzes were administered by the teacher. This report was designed to require students to write in groups of five to six students and was completed within 3 wk after the laboratory exercise. Given that our study was carried out with students in the class of 2013 majoring in clinical medicine, students in the class of 2012, who received the traditional pathophysiological laboratory exercises, served as the control group. Ethical review for normal educational research projects is not required in China.

Student-Centered Course Design

The present study was set within the framework of an 8-h laboratory exercise (~2–3 h/course) on hypoxia of pathophysiology. This project was done over a 3-wk period of the spring semester of 2013. Approximately 75 students of the 2013 class were grouped into 15
The student-centered course ensured greater student participation and was better at fulfilling the learning objectives in the study. Responses from medical students to the questionnaire regarding the student-centered course were administered to gather feedback from every student at the end of the course. The questionnaire consisted of two categories: the student-centered structure and an open-ended question about the course, which are shown in Table 1; answers to the open-ended question are also shown in Table 2.

### Table 1. Sequence of weekly activities offered to each group in the study

<table>
<thead>
<tr>
<th>Activity</th>
<th>Control group</th>
<th>Treatment group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Experimental design</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Oral research presentation</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Free question</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Small group discussion</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Laboratory exercise</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Laboratory report</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Research paper</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Quiz</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

team of 5 students each. Teams were formed based on students’ comfort/familiarity with the equipment and knowledge involved in the pathophysiology laboratory exercise. Each team appointed one member to serve as the team leader for the laboratory exercise. The traditional laboratory exercise included four sections: a lecture, a laboratory exercise, a report, and a quiz. In contrast, the student-centered exercise contained an experimental design, an oral research presentation, a free question session, a small-group discussion, and a research paper (Table 1). Students participating in student-centered courses need to work out how to establish mouse models of hypoxic and hemic hypoxia and to evaluate the influence of hypoxia on physiological activity.

**Laboratory experimental design.** The laboratory exercise began with a 30-min lecture given by teachers, providing a brief introduction to the purpose of this experiment. The next week, students were given time to design their experiment in teams. Students were required to have a rationale for their experiment. Students were asked to submit their assignment to their team leader at least 3 days before its due date. The leader then assembled the work of the entire team and e-mailed it to the instructor for the discussion in the next class. A successful design required the full participation of each team member. Therefore, each member was asked to evaluate the contributions of all his or her team members using a standardized evaluation rubric. Evaluations were e-mailed to the teacher as attachments.

**Oral presentation of the experimental design report.** At the beginning of the experiment, each team was required to present an oral presentation of their experimental design. In the presentation, a representative of each team gave an introduction of their collected information and the experimental design (10–15 min, using a PowerPoint template). The objective, materials, and methods of the experiment were required to be included in the presentation as well as the expected results and main problems that may be encountered. Each team member could make a supplementary presentation if needed.

**Free question session.** At the end of each experimental design presentation, students were invited to respond to free response questions related to the experiment. They could respond individually or as a team using any didactic materials available. The goal was to develop students’ ability to give an oral presentation. Moreover, this activity was a supplement to the active learning exercise, which created an opportunity for students to express themselves.

**Small-group discussion.** Immediately after each free question, the team leader initiated and guided the small-group discussions. These discussions were closely monitored by the teacher, who circulated in the classroom to encourage the students to participate and provide individual assistance as necessary. In this part, students compared their knowledge with their peers and got feedback from the teacher about misconceptions and correct answers.

**Laboratory exercise.** After the oral presentation and discussions, students improved their experimental design according to comments. In the next week, teams began the laboratory procedures following the revised instructions of their manual. The teacher’s duty was to help the students to control the procedure and offer help if needed. Unlike before, the role of the teacher transferred from a leader to a facilitator, offering students more chances to implement their experimental designs in practice.

**Research paper.** After the laboratory exercise, the team leader collected and posted all of the data on a web document that all students could access. In lieu of a traditional “laboratory report,” team members needed to interact outside of class with others to generate a laboratory report that summarized the previous week’s protocol, results, and conclusions and answered the research question. Moreover, students were asked to reflect on their laboratory results after the completion of a laboratory report, explaining how and why the result was reached.

**Survey**

A survey using a series of five-point Likert-scale questions was administered to gather feedback from every student at the end of the course. The questionnaire consisted of two categories: the student-centered structure and an open-ended question about the course, which are shown in Table 2; answers to the open-ended question are also shown in Table 2.

**Statistical Analysis**

Quiz scores were expressed as means ± SD. To compare each participant’s score in quizzes from the 2013 and 2012 classes, Statistical Package for Social Sciences (version 13.0) software (SPSS, Chicago, IL) was used for statistical analyses with an independent-sample t-test. For results of Likert scale-based questionnaires, significant deviations of student responses to questions from the neutral score of 3 were analyzed using a one-sample Wilcoxon sign-rank test. P values of <0.05 were considered to be of statistical significance.

### Table 2. Responses from medical students to the questionnaire regarding the student-centered course

<table>
<thead>
<tr>
<th>Questionnaire Item</th>
<th>Agree (Scores of 5 and 4)</th>
<th>Neutral (Score of 3)</th>
<th>Disagree (Scores of 2 and 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of students</td>
<td>%</td>
<td>Number of students</td>
</tr>
<tr>
<td>The student-centered course was better at fulfilling the learning objectives</td>
<td>56</td>
<td>75</td>
<td>12</td>
</tr>
<tr>
<td>The student-centered course enabled me to better understand concepts</td>
<td>48</td>
<td>64</td>
<td>16</td>
</tr>
<tr>
<td>The student-centered course was more interesting than traditional laboratory courses</td>
<td>52</td>
<td>69</td>
<td>14</td>
</tr>
<tr>
<td>The student-centered course ensured greater student participation</td>
<td>58</td>
<td>77</td>
<td>9</td>
</tr>
<tr>
<td>Students produced greater effort in the student-centered course</td>
<td>48</td>
<td>64</td>
<td>16</td>
</tr>
<tr>
<td>More student-centered courses should be organized in the future</td>
<td>49</td>
<td>65</td>
<td>15</td>
</tr>
</tbody>
</table>

n = 75 students. Responses were scored using a five-point Likert scale, where 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree.
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RESULTS

Student Responses

A total of 75 students were anonymously surveyed at the end of the course. Most students reported liking the structure of the active course based on student-centered learning. Responses to each statement were scored from 1 to 5 and are shown in Table 2. The Wilcoxon test showed that student-centered learning caused more positive scores on each of the six questions relative to the neutral response value ($P < 0.001$), indicating that this method will probably be welcomed by most students. The majority of students (75%) were of the opinion that the student-centered method was more effective in achieving the learning objectives in laboratory courses. Moreover, the modified method helped most of the students (64%) to gain a better understanding of the theory and was considered to be more interesting than traditional laboratory courses by 69% of the students. Compared with the traditional method, 77% and 64% of students, respectively, believed that the student-centered course would lead to a higher willingness to participate and make greater effort in laboratory courses. Therefore, most of the students (65%) responded that many more student-centered laboratory courses should be conducted in the future. However, they also commented that traditional lectures may be required for certain theories that were difficult to understand. In addition, 11% of the students reported that they could not fully participate in the laboratory courses due to the limited preparation time, but most of the students (77%) felt that they were given enough time to prepare for these sessions.

Student Performance on the Laboratory Quiz

Finally, a laboratory quiz was used to measure the effectiveness of the student-centered study in improving the retention and understanding of information. As shown in Fig. 1, mean scores of 2013 class ($77.52 \pm 14.11$) were significantly increased compared with the control 2012 class ($71.68 \pm 13.48$, $P < 0.05$), indicating an improvement in performance by the student-centered method. Meanwhile, an obvious change occurred in the grade distribution between groups with and without the team project. The percentage of students who met or surpassed a minimum passing score (set at 60) was higher in the 2013 class than in the 2012 class (85% vs. 71%). Furthermore, there were fewer individuals that scored below 70 (33% vs. 55%) and more individuals that scored between 80 and 99 in the 2013 class (37% vs. 19%), but the proportion of students between 70 and 79 was close to the 2012 class (29% vs. 27%).

DISCUSSION

Student-centered learning has been extensively used in lecture courses; however, its use in laboratory courses is seldom reported (6). In this report, student-centered learning will be described first followed by how it was implemented in an undergraduate pathophysiology laboratory course and then by a discussion of this implementation in China. The present study was done with the goals of 1) increasing student-centered learning practices; 2) linking theory with laboratory exercises; 3) increasing content learning, skill development, and information collection; 4) improving working with the equipment and analyzing results; and 5) enhancing students’ critical thinking and problem-solving abilities (4, 5, 7). Student-centered learning is completely different from traditional educational approaches. More and more reports have illustrated the need for fostering medical students’ skills and attitudes that would help them become lifelong learners (1). Actually, the importance of teaching methods that could promote active learning and critical thinking has been well highlighted.

In our study, the results showed that student-centered learning was an effective and efficient method to promote active learning in medical students attending a pathophysiology laboratory course. In fact, many of the students reported that the method was good and satisfying, helping them to monitor their own learning progress and evaluate their success in achieving the course objectives. Moreover, the responses of students in this study indicate that most of the students preferred the modified student-centered method to the traditional pathophysiology laboratory course. As an active learning method, student-centered instruction can be a highly effective tool for developing students’ mastery of important skills: self-study, investigation, and presentation. In addition, designing effective group assignments helps to maximize the extent to which the learning tasks promote the development of a cohesive learning team. Also, a few students (11%) complained that the amount of time available for their preparation was insufficient and they felt incompatible with their own learning style. The possible reason is that these students have less familiarity with active learning methods, so they may take time to get used to it.

Student performance on the quiz was used to measure the effectiveness of student-centered study in improving the retention of students and linking theory with laboratory exercises. There was a significant difference in student performance, with students in the student-centered course earning higher quiz scores than students in traditional pathophysiology laboratory. We relate this difference to the specific features of course design. The essential principles of student-centered learning include students’ accountability for individual and team work and immediate feedback to correct learning errors or validate the rationale that formed the basis for the exercise. The change observed in the grade distribution further confirmed the effects
of teaching method on student performance. It was found that student-centered learning contributed to increased student learning, that is, fewer individuals scored below 70 and more scored between 80 and 99 in the 2013 group with the project compared with the 2012 group without the project.

Conclusions

Using student-centered learning in an undergraduate laboratory course was successful and well received by both students and teachers. Students took on the responsibility for learning and were more accountable. Rather than being dictated to, students controlled the process and took responsibility for their own education, and teachers focused on how to facilitate their development. On the one hand, students reported enhanced content learning, skill development, information collection, and retention. Therefore, students undertaking the student-centered course earned higher quiz scores than those in the traditional pathophysiology laboratory. On the other hand, teachers found that the student-centered course developed students to think critically and solve problem by themselves.

GRANTS

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: J.C. prepared figures; J.C. and J.Z. drafted manuscript; J.Z., L.S., and J.T. edited and revised manuscript; L.S. and J.T. conception and design of research; Q.W., H.L., and J.T. performed experiments; Q.W. and H.L. interpreted results of experiments.

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