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ORIGINAL RESEARCH

Online Physiology Practice with Team-Based Learning During the COVID-19 Pandemic

Yuki Fujiwara[1], Izuki Amano[1], Sumiyasu Ishii[1,2], Mikiko Kishi[3], Noriyuki Koibuchi[1]

[1]Department of Integrative Physiology, Gunma University Graduate School of Medicine, Maebashi, Gunma, Japan; [2]Niigata College of Nursing, Joetsu, Niigata, Japan; [3]Department of Medical Education and Development, Gunma University Graduate School of Medicine, Maebashi, Gunma, Japan

Correspondence: Noriyuki Koibuchi, Department of Integrative Physiology, Gunma University Graduate School of Medicine, 3-39-22 Showa-machi, Maebashi, Gunma, 371-8511, Japan, Tel +81-27-220-7923, Fax +81-27-220-7926, Email nkoibuch@gunma-u.ac.jp

Background: The spread of the coronavirus disease (COVID-19) has significantly affected medical education. In particular, conducting practical training in a face-to-face format has become difficult.

Purpose: To address this problem, online physiology practice combined with team-based learning (TBL) for deep learning of renal physiology was conducted among second-year medical students.

Participants and Methods: The experiment was performed by a group of students, while other students watched online. After the experiment, all students were grouped using breakout rooms. Following a discussion of the data, a clinical case study related to the experiment was conducted using TBL. To examine the effect of online practice in a case study under TBL, the participants completed an anonymous, open-ended, web-based questionnaire after the program, enabling us to compare their expectations and satisfaction. The questionnaire consisted of questions examining students' opinions on the appropriateness of online practice, degree of understanding, ease of asking questions, time efficiency, and the usefulness of case studies using TBL.

Results: There was no change in the number of students who participated in the online practice before and after class. After class, more students considered the level of understanding easier and displayed better on-time efficiency than with regular face-to-face training. However, these questions are difficult to answer.

Conclusion: Online-based physiology practice combined with clinical case studies under TBL helped maintain students' expectations and satisfaction with the training.

Keywords: online education, physiology practice, team-based learning, COVID-19, practical training

Introduction

The worldwide spread of coronavirus (COVID-19) led the Japanese government to declare a state of emergency on April 7, 2020, followed by a nationwide declaration on April 16, 2020. Consequently, access to the university campus was restricted and faculty and staff were strongly encouraged to work from home, thereby restricting research activities. Students were also required to stay at home, and the classes were conducted online.

Physiology is one of the most challenging disciplines in basic medicine.[1,2] Learning renal physiology requires systematic integration of various steps; thus, it is important to combine text- and lecture-based studies with practicals for effective learning.[3,4] Through laboratory practice, learners can create a concrete understanding of what needs to be learnt.[5,6] However, the COVID-19 pandemic has made it difficult to conduct practical, face-to-face training. Thus, we sought to address this new challenge in our physiology course by combining online physiology practice with team-based learning (TBL) using clinical case scenarios related to practice. In addition to simply transferring the content of the physiology practice from offline to online, we attempted to "review and consolidate the knowledge learned in the classroom", "efficiently understand and discuss the content of the practice", and "take action and confirm understanding through case problems", using TBL.

First introduced in medical education in 2001, TBL has gained popularity as a resource-efficient and student-centered pedagogy. Although TBL remains student-centered, it is highly structured, with core design elements and specific steps.[7] In a recent systematic review of the use of TBL in health professions, Reimschiesele et al reported that although learners' reactions

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to TBL have been mixed, students generally favor the active learning style of TBL, with multiple opportunities for peer learning, problem-solving, and feedback. This study also describes the results of a survey[8] that evaluated new challenges and clarified them by summarizing students' reactions.

Case studies have a long history of being traditionally used as educational tools, not only for medical students but also for healthcare professionals. Case studies present realistic clinical scenarios that can help students understand the practical applications of what they are previously learned. Additionally, this learning method stimulates learning by increasing student enjoyment, and students are actively engaged in the learning process.[9] Furthermore, students perceived significant learning gains from case-based learning and reported increased average exam scores in the anatomy and physiology courses.[10]

This study aimed to implement an online physiology training program for second-year medical students and to conduct a questionnaire survey to compare students' expectations and satisfaction before and after practice.

Materials and Methods

Participants

In the 2020 academic year, second-year medical students (n = 120) from the Gunma University School of Medicine who took a renal physiology course were selected as subjects. They were divided into two groups: students who volunteered to participate in the on-site experiment (six male students) and those who watched the experiment online (114 students). After completing the experiment, students were given a TBL-style online case study related to the experiment. Participants were recruited after their last lecture on renal physiology. Students were asked to confirm their health status (eg, no renal, cardiac, or hepatic dysfunction). Two teachers participated in this practice; one was responsible for the explanation and commentary on the practice, and the other provided support as an online operator.

Design of the Class

The flow of the "renal function test" in 2020 is illustrated in Figure 1. Renal function tests were performed according to the Guidebook for Student Practicals in Physiology,[11] published by the Physiological Society of Japan. The objectives of the class, practice schedule, and instructions for the experiment were provided before the class through Moodle, a learning management system (LMS) that enables students to prepare for class. The class schedule was as follows:

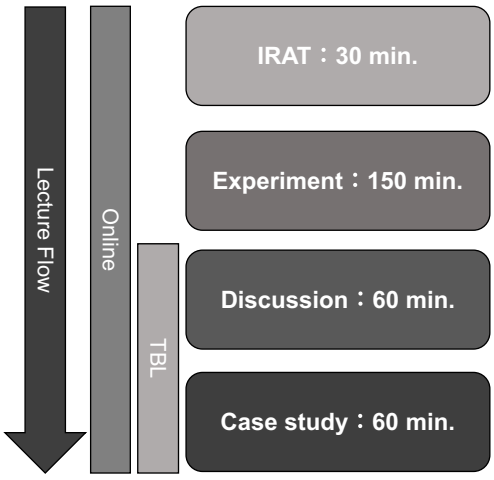

Figure 1 The flow of lectures used in this study. IRAT. Practice, Discussion, and Case study.

(1) Explanation of the objectives of the class
This study aimed to understand the function of posterior pituitary antidiuretic hormone (ADH) in water metabolism within the renal system. First, the teacher responsible for the class explained the study objectives. Except for the students who participated in the experiment, the objectives were explained using Zoom. The objectives were explained face-to-face to students who participated in the experiment.

(2) Individual Readiness Assurance Test
To check the level of understanding of renal physiology concepts and experimental procedures, a multiple-choice question-style Individual Readiness Assurance Test (IRAT) was performed. A paper-based test was conducted for students who attended offline, whereas Google Forms were used for those who attended online. After completion of the test, answers and explanations were provided to all students online.

(3) Water load: Onsite students were asked to urinate before drinking water. They were then divided into three groups and asked to drink 20 mL/kg of bottled water (n = 2), 5% glucose solution (n = 2), or 0.9% saline solution (n = 2). After the water load, the participants were instructed to rest until the first urine sample. The students were asked to calculate the osmolality of 5% glucose and 0.9% saline solutions, followed by an online explanation.

(4) First urine sampling (30 min after drinking): Participants were asked to urinate. The teacher performed the urine osmolality measurements. Osmolality was measured using the freezing-point depression method (OM-6060; ARKRAY Co., Ltd.). During the intermission until the next sampling, a video showing the urine osmolality measurement procedure was provided online to all students.

(5) Second urine sampling (60 min after drinking): Urine samples were collected from the same participants as in the previous case. During the subsequent intermission, the principle of measuring urine osmolality using the freezing point depression method was explained.

(6) Third urine sampling (90 min after drinking): Urine samples were collected from the same participants. During the subsequent intermission, the statistical methods used for data analysis were explained online.

(7) Fourth urine sampling (120 min after drinking): Urine samples were collected from the same participants. Following the measurements, students were given tasks (drawing graphs, calculating free water, osmotic clearance, etc.) before the afternoon lecture.

(8) The discussion of the results of the experiment was followed by a related case study in TBL format, and all discussions related to the experiment were conducted online. On the central Zoom dashboard, the teacher briefly summarized the experiment, asked the students questions, and assigned them several tasks to discuss. The teacher assigned the students to break out rooms (to 4–5 students/group, a total of 26 groups), where they discussed the results based on their calculations and the mechanisms causing urine volume and osmolality alteration. Subsequently, they returned to the central dashboard to summarize the experimental results. Following the teacher's summary and comments on the experiment, a case (polyuria caused by pituitary diabetes insipidus) with laboratory test results, including a hypertonic saline stress test, was presented. The students then regrouped and discussed their case-related assignments. After the discussion, the students returned to the main Zoom dashboard and exchanged their interpretations and opinions, followed by additional comments and summaries from the teachers. After the discussion, the students were given additional homework to submit.

Evaluation and Analysis of the Effect of Online Practical Training

To examine the effect of online-based practice with a case study in TBL format, participants were provided with an anonymous, open-ended, web-based questionnaire using Google Forms before and after the class, which enabled us to compare their expectations and satisfaction. The questionnaire was written in Japanese, and interpretations of the questions are presented below. Each question consisted of the following five evaluation levels:

(1) Appropriateness of continuing online practice after the COVID-19 pandemic: this question was answered before and after the training.

(2) Ease of understanding the experimental procedure, asking questions during the experiment, and time efficiency (compared with an on-site practical course).

(3) Preference for online discussion and self-study to analyze the results of the experiment.
(4) Usefulness of online discussion to understand the content of the training.
(5) Preference for the case study after the training.
(6) Usefulness of the case study to understand the content of the practice.

In addition to multiple-choice questions, we provided a free-description column in which students could freely describe their opinions. Students who participated in the onsite experiment did not answer questions related to the online experiment, whereas all other questions (online discussions and case studies) were evaluated. Before and after training, the responses were scored for each item and used as quantitative survey data (strongly agree = 5; agree = 4; not sure = 3; disagree = 2; strongly disagree = 1). For the quantitative survey data, the Shapiro–Wilk test was used to assess the normality of the students' ratings of the survey items. The results showed that student ratings were not normally distributed. A non-parametric Wilcoxon matched-pair signed-rank exact test was used to compare the median student ratings before and after practice for each survey item. Statistical analyses were performed using SPSS software (version 27, SPSS Inc., Chicago, IL, USA). For all analyses, a two-sided $p<0.05$ was considered statistically significant.

Ethical Considerations

This study was approved by the Ethical Review Committee for Medical Research Involving Human Subjects at Gunma University (approval number: HS2020-230). We collected participant responses anonymously and explained (online) the students that completion of the online survey indicated their consent to participate in this research study and to disclose all anonymized data. We explained that there would be no disadvantage even if the survey subjects refused to participate in the survey and that even if they consented, the disclosed data would not contain any personally identifiable information. Additionally, we confirmed that no personally identifiable information was included in the free text section of the questionnaire.

Results

The response rate was 95% (105/110). The questionnaire on "Appropriateness of continuing online practice after the COVID-19 pandemic" and "Ease of understanding of the experimental procedure, asking questions during the experiment, and time efficiency" were collected from 100 students, excluding those who attended onsite practical training. The remaining questionnaires were administered to the remaining 105 students.

Appropriateness of Continuing Online Training After the COVID-19 Pandemic

There was no significant change in the percentage of students who were for or against continuing online practice after the class (Figure 2). In terms of individual changes in replies, the responses of 13 students changed from negative to positive after training, whereas those of nine students changed from positive to negative. Statistical analysis before and after the

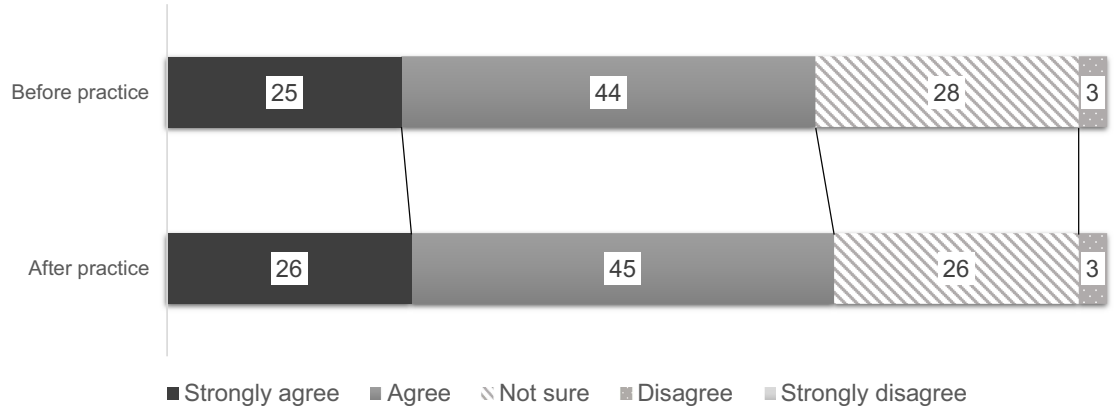

Figure 2 Students' responses before and after the class on appropriateness of continuing online practice after the COVID-19 pandemic.

online practice revealed non-significant correlations (p=0.891). In the free description column, representative replies for the continuation of online training included the following:

> Compared with other classes, we had to wait longer without using our hands until we obtain the result. However, I was able to work efficiently on assignments by using such period I felt that the online training was sufficient because we can concentrate on calculation and interpretation", "Regardless of face-to-face or online, I could understand the content of the experiment", and "It would have been nice to have the experiment online rather than cancelling it." Conversely, several representative replies of students who were against the online practice included the following: "It is difficult to understand the operation of the machines to measure osmolality when it was demonstrated online", "I cannot efficiently spend waiting periods to make tables and graphs", "Not being able to feel the emotional response of the subjects during experiments was not favorable.

Ease of Understanding the Experimental Procedure, Asking Questions During the Experiment, and Time Efficiency

Regarding the level of understanding compared with onsite practice, 70% of the students answered, "much easier to understand" or "easier to understand", whereas 6% answered, "difficult to understand", and 0% answered "very difficult to understand" (Figure 3a). Regarding the ease of asking questions, 52% responded: "much easier to ask questions" or "easier to ask questions", whereas 20% answered "difficult to ask questions" or "very difficult to ask questions" (Figure 3b). Regarding time efficiency, 70% answered "efficient" or "slightly efficient", whereas 19% answered "inefficient" or "slightly inefficient" (Figure 3c). These results demonstrate that the level of understanding and time efficiency were relatively good. However, the ease of asking questions may be an issue that needs to be addressed.

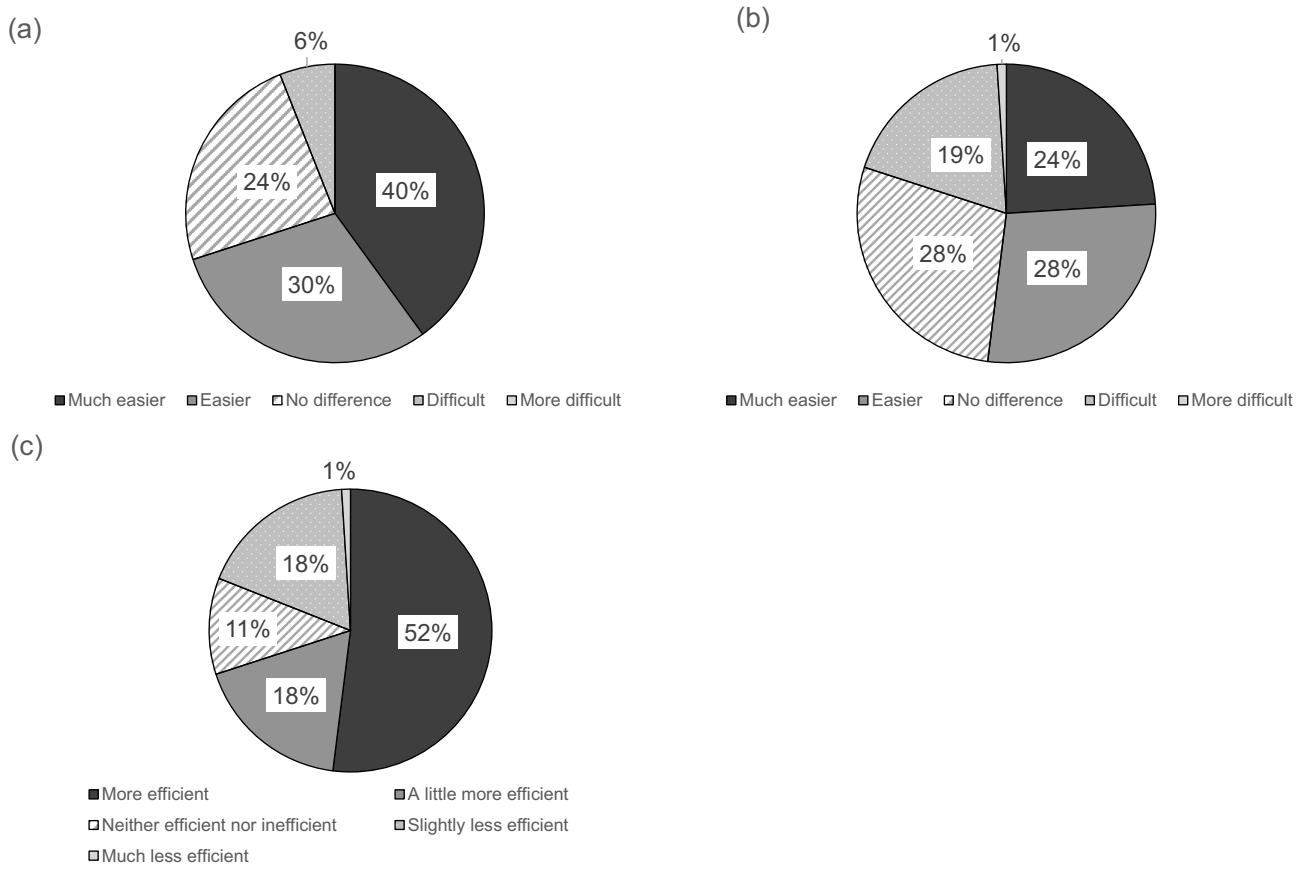

Figure 3 Survey questionnaire on ease of understanding of the experimental procedure, asking questions during the experiment, and time efficiency compared to the previous face-to-face practices: (**a**) ease of understanding the content, (**b**) ease of asking questions, and (**c**) time efficiency.

Preference for the Format (TBL or Self-Report) to Solve the Assignment Related to the Experiment

Regarding the preference for online TBL or the self-report format for solving assignments given after the experiment, 75% preferred online TBL, and 11% preferred self-reporting (Figure 4a). Regarding the usefulness of the TBL to understand the practice contents, 95% responded "Very useful" or "a little", whereas 1% indicated "not very useful" (Figure 4b). Regarding the question, "What aspect of using online TBL do you think helps to understand the content in more depth?" in the group with TBL preference, 26 students responded "awareness of new insights through group discussion", and nine indicated "quicker understanding of the concepts." In the group with a preference for the self-report format, two students responded "TBL did not allow us to discuss in more depth."

Favor and Usefulness of Case Studies

Regarding whether they were in favor of the case study after training, 86% were in favor, whereas 2% were not (Figure 5a). Regarding the usefulness of the case study to understand the practice contents, 94% responded "Very useful" or "a little useful", whereas 1% indicated "not very useful" (Figure 5b). In the group that favored the case study, 28 answered that it was

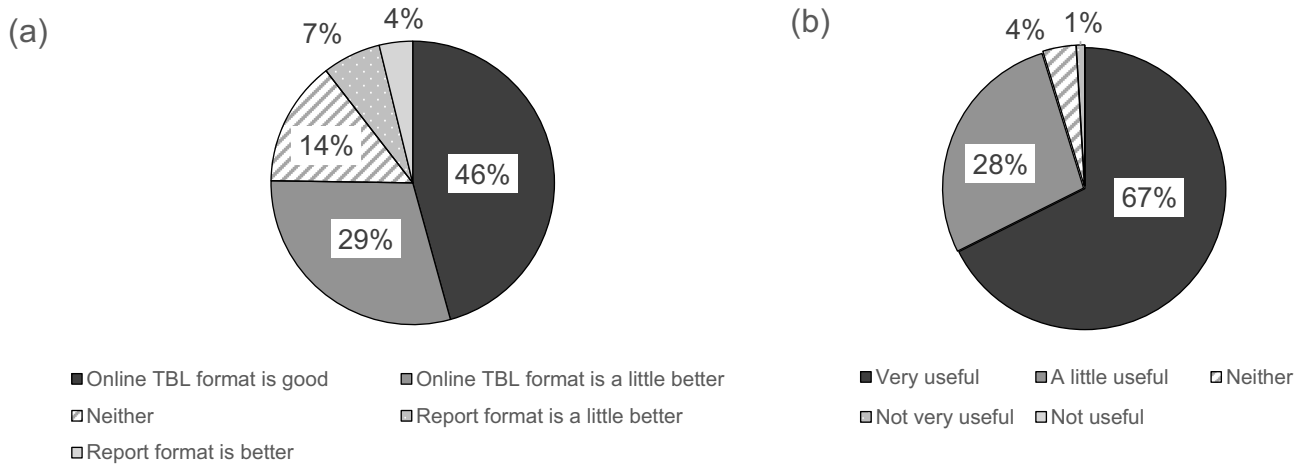

Figure 4 Survey questionnaire preference for the format (TBL or self-report) to solve the assignment related to the experiment. (**a**) The results of a survey on whether self-report or TBL format is preferable for solving post-practicum assignments. (**b**) Usefulness of online TBL to understand the contents of the practice in more depth.

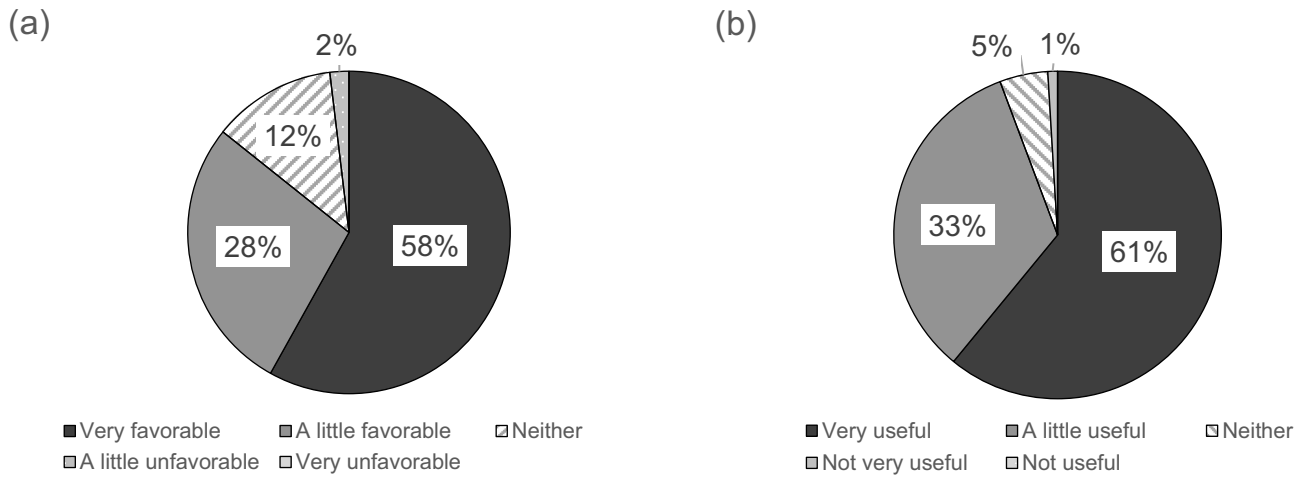

Figure 5 Results of a survey on preference and usefulness of post-practice case studies (**a**) In favor of case studies after the practice. (**b**) Usefulness of case study to understand the content of the practice.

useful for knowledge retention and five answered that it was useful for understanding the relationship between the experiment and clinical practice. In the group that did not prefer case studies, one participant responded that the TBL format did not allow for more in-depth discussion. However, in the other group, two students answered that the duration of practice was too long to concentrate throughout the class.

Discussion

This study evaluated the expectations and satisfaction with online practicum classes by collecting data on student reflections. As the COVID-19 pandemic has prevented us from conducting physical practice in a face-to-face format, we conducted an online practice class as a new attempt to provide practical experience and the opportunity to analyze data through discussion, followed by problem-solving trials similar to regular practice-based classes. Furthermore, we included a TBL-based discussion, including a case study rather than paper-based assignments, for submission in a self-report format. Because most regular classes were conducted online during the study period, we considered it important to provide students with more opportunities to interact online. Overall, the results of the questionnaire revealed that almost 70% of students were satisfied with their online physiology practice. They also preferred online discussions for self-study to solve tasks. Furthermore, they liked case studies related to the practice of understanding the content in greater depth. However, they found it difficult to ask the questions.

Regarding the appropriateness of continuing online training after the COVID-19 pandemic, there was no significant change in students' answers before and after the practice (Figure 1). In the present study, the students did not seem to experience stress in the online practice. In fact, 70% responded "good" regarding the level of understanding and time efficiency of the online-based practice, confirming their satisfaction with the class. Even before the COVID-19 pandemic, online practice involving real-time broadcasting of medical procedures was conducted, and students' responses were mostly positive.[12] Online classes have several advantages. First, students do not have to attend school for practice, which may be a positive aspect for students living far from school. Second, the development of information and communication technology (ICT) and real-time communication between students and between students and teachers can be performed relatively easily. These advantages make students feel comfortable with their online practices. In fact, in the free text, one student wrote, "I have done not only lectures but also TBL, etc. online, and all of them were quite comfortable, and thus I had almost no concern about online practice." However, it was difficult to ask questions during the practice classes. Although students and teachers can communicate through chat, they may be unable to obtain answers at an appropriate time.[13] Furthermore, such communication is not accompanied by "body language", making it difficult for the students to completely understand the teachers' answers.[14] It may be important for instructors to create an environment that allows and encourages students to ask questions freely and to continuously check their attitudes regarding whether they have any questions about the content.

As a method for solving assignments, many students preferred TBL to the self-report format, which was usually administered before the pandemic. Based on the results, students considered TBL more useful for knowledge retention because the discussion was conducted immediately after the practice, and they could expand their ideas through group discussions.[15] Our initial objective for online TBL was to provide students with an opportunity to exchange practical ideas. Without such opportunities, the students simply watched the experiment online and solved assignments without discussing them with their peers. Under such circumstances, the experiment may not be realistic, and students may misunderstand or misinterpret the procedures and results. Thus, we assumed that some students would not be able to consolidate the correct information to solve assignments. However, students not only evaluated online-based TBL as a tool to consolidate information through discussions but also favored it beyond our expectations. This could be because they strongly desired opportunities to connect with their peers, despite the restrictions imposed by the COVID-19 pandemic. Owing to the advantages outlined above, we may have to continue online TBL even after the pandemic.

However, some groups did not engage in active discussion. Although they were asked to switch on the camera during the discussion, some students did not and remained silent. This problem was also observed in other institutions.[16] Such students may not be interested in participating in discussions and may only attend classes to obtain credit. To encourage participation, the instructor visited each group during discussions more frequently than in face-to-face classes to check the activities of each student. Furthermore, we may have to establish an objective criterion to evaluate "unprofessional" behavior, and further research may be necessary regarding this aspect.

After practice, the case study revealed that the students favored this approach and considered it useful for knowledge retention. The main reason they favored clinical case studies could be that all students who took the course were medical students who liked practical training that was directly linked to their future careers.[17] The cases used in this study were strongly related to the content of the practice, thus facilitating an understanding of their significance. However, some students highlighted that they lost concentration because the class lasted longer than eight hours and the group discussion time was only 30 minutes; therefore, the schedule needed to be improved.

There are two major issues that teachers in charge of online practice must consider before training.

1) How to manage the online system efficiently and effectively.
2) How to facilitate the student's understanding of the practice.

For Issue 1, an instructor was assigned to supervise the online system. During class, although there were some delays due to sound issues, we minimized the delays caused by operational problems. Therefore, to provide more systematic practice, we decided to conduct a practice based on the well-established TBL flow:[7] IRAT → practice → discussion (TBL) → case study (TBL) → additional lecture. The IRAT was designed to make it easier for students to understand the content and significance of practice. Indeed, the students had to prepare for exams. As demonstrated by the questionnaire results, the students reacted positively to the class, probably because they were sufficiently prepared. However, because the questionnaire was voluntary and anonymous, it was not possible to link the IRAT scores and student activities in the TBL group to each answer. Thus, we could not evaluate student satisfaction and activities based on their fundamental knowledge and performed activities.

In the free comments, the online participants stated, "It was very interesting to feel the osmotic pressure change", whereas other students stated that they would have wanted to experience it. Even if we prepare carefully and precisely, online experiments may not fully compensate for in-person experiences.[13,18] While the effectiveness of online classes has already been demonstrated and thus may be conducted even after the pandemic era, we may have to combine online and face-to-face classes in an appropriate ratio. Further analyses and trials are required to improve the effectiveness of this method.

The results reported for the online TBL conducted in this study are similar to those of other studies that have addressed similar objectives. In the same basic science anatomy course, online grades and assessments were comparable to those of face-to-face lectures.[19] Furthermore, online learning is reportedly equal to or better than face-to-face classes.[20–22] Therefore, face-to-face and online teaching methods are expected to perform similarly.[23] Therefore, even if face-to-face lectures are no longer possible because of emerging infectious diseases or natural disasters that may occur in the future, online lectures should be an alternative.

Limitations

The questionnaire used in this study was not validated for validity and reliability, and its results may not have been properly assessed. Furthermore, the survey was not conducted in all online practices but was limited to physiological practices (renal physiology).

Conclusion

Online physiology practice combined with clinical case studies under TBL helped maintain student expectations and satisfaction with the training. Therefore, even if face-to-face lectures are no longer possible because of emerging infectious diseases or natural disasters that may occur in the future, online lectures should be an alternative.

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Disclosure

There are no companies, organizations, or groups with conflicts of interest that should be disclosed in this research. Conflicts of interest related to clinical research at Gunma University were discussed and subsequently approved by the relevant authorities.

The authors report no conflicts of interest in this work.

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