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Blended Learning Effectiveness: Improving Japanese Medical Laboratory Science Students' Identification of Parasite Eggs

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Abstract

Parasitic infections are declining in Japan, resulting in fewer hours of parasitology instruction in medical laboratory science and medical schools. However, there are growing concerns that the parasite identification skills of medical laboratory technologists and the diagnostic skills of physicians may be compromised as a result. Effective teaching methods are required to improve the identification of parasites in pre-graduate education. We therefore adopted a new teaching method: the blended learning method, in 2018. This method combined the e-learning and jigsaw methods, which had already been implemented separately in 2017. This study aimed to evaluate the pedagogical effectiveness of this blended learning approach compared to that of 2017 in teaching parasitology practice to students enrolled in the Department of Medical Laboratory Science. The results show that the median score for the practical test was 83.3 points for the blended learning lessons, which was not significantly different from the scores for jigsaw or e-learning lessons. However, blended learning had the lowest percentage of failures on the practical test, at 10.7%. Additionally, the microscopic image test results indicate a significant memory retention effect. From the questionnaire results, 94.7% of the students were satisfied with their practice. In conclusion, the blended learning did not significantly improve parasite identification skills, but it may reduce the number of failures, suggesting a knowledge retention effect and a high level of satisfaction with this practice.

Keywords: blended learning, parasitology practice, medical laboratory science, identification skills

1. Introduction

1.1 Background

In Japan, education on clinically meaningful parasites is provided mainly to students of medicine, pharmacy, and medical laboratory science (Kobayashi & Ikeda, 2015; Sekine, 2022). Although parasites (such as the Japanese indigenous lymphatic filaria, *Schistosoma japonicum*, and malaria parasites) have been eradicated, parasitic diseases have not disappeared (Tada, 2008; Kasai, Nakatani, Takeuchi, & Crump, 2007). The number of hours spent on parasitology education has been reduced in medical school recently, and there are concerns that physicians' diagnostic skills may be deteriorating (The Japanese Society of Parasitology Board of Education, 2015). Similarly, parasitology education in universities is undervalued in Western countries (Acholonu, 2003; Bruschi, 2009). On the contrary, parasitic diseases are expected to increase in the future (Palmieri, Elswaifi, & Fried, 2011). China has been working on parasitology education using various teaching methods (Peng, Zhang, Wang, & Chen, 2012); therefore, parasitic disease education in Japan needs to be improved owing to its subtropical climate and international status (Kobayashi & Ikeda, 2015).

1.2 Aim and Research Hypothesis

Against the abovementioned background, we considered that new teaching methods are required to improve the identification skills of parasites in pre-graduate education. The use of digital technologies (David, 2017; Jabbar, Gasser, & Lodge, 2016) and the usefulness of the jigsaw method (Colosi & Zales, 1998) have already been shown. Hence, we conducted a parasitology practice using e-learning and jigsaw methods for medical laboratory science students to evaluate their performance in 2017 (Kobayashi, Kosuge, & Akazawa, 2023). Based on the results, we designed a blended learning approach. Blended learning is a method that combines e-learning and face-to-face classes (Caner, 2012). It is more effective than non-blended learning (Liu et al., 2016). However, the pedagogical effects of blended learning incorporating cooperative learning in parasitology practice have yet to be clarified. Therefore, this study aimed to evaluate the pedagogical effects of blended learning and identify its improvements. In this study, blended learning consisted of preparatory learning through e-learning (internalization), and collaborative learning through the jigsaw method (externalization). We hypothesized that blended learning would improve the identification skills of parasite eggs (including larvae and protozoa), compared to either the e-learning or jigsaw method alone.

2. Method

This was a non-randomized, comparative study that compared the performance of the blended learning lessons (from 2018) with the e-learning and jigsaw lessons (from 2017) in parasitology classes. In this blended learning study, students prepared with e-learning materials in addition to the textbook, and they then practiced using the jigsaw method.

2.1 Implementation Summary

The participants were first-year students in the Department of Medical Technology at Kitasato Junior College of Health and Hygienic Sciences (Niigata Prefecture, Japan). The students in the blended learning (2018), e-learning (2017), and jigsaw (2017) classes were all different individuals; no participant attended more than one of the aforementioned classes. Students are required to take this practice to graduate and thus all new students complied in their first year.

2.1.1 Blended Learning Class

Eighty-four students participated in the practice, of which 75 were analyzed. The practice period was January 2018 (additional surveys were conducted in May 2018 and April 2019), and the practice time was 15 hours (10 sessions of 90 minutes each). The practice was the observation of parasite eggs (26 species in total, including larvae and protozoa), and two teachers were in charge during the sessions. The primary outcome was the percentage of correct answers on a practical test (12 specimens in total), in which students made their own specimens and identified parasites using a microscope. The secondary outcome was the percentage of correct answers on the microscopic image test (20 questions in total). The exploratory outcome was longitudinal changes in microscopic image test scores (conducted three times) and questionnaire responses.

2.1.2 E-Learning and Jigsaw Classes

All 66 students who participated in the practice were included in the analysis (Kobayashi et al., 2023). The practice was divided into e-learning (n = 33) and jigsaw (n = 33) classes. Each class had one teacher in charge. The practice period was January 2017 (additional surveys were conducted in May 2017 and April 2018). The practice's location, time, content, and assessment items were identical to those of the blended learning class.

2.2 Ethical Considerations

We informed the 84 students taking the parasitology course in 2018 about the practice’s procedure, their grades, and the use of the questionnaire results in our study; 75 participants submitted completed informed consent forms. This study was approved by the Kitasato Junior College of Health and Hygienic Sciences Ethics Review Committee. Additionally, all 66 participants in 2017 consented to participating in the study (Kobayashi et al., 2023).

2.3 Sample Size and Power

The sample size in this study had limitations. The blended learning class comprised 75 students. For the practical test score, we assumed that students in the blended learning class would answer one question more correctly than the jigsaw or e-learning class. However, the statistical power of the Wilcoxon rank sum test at a significance level (α) of 0.05 was 0.51 and 0.45 for comparisons with the jigsaw and e-learning classrooms, respectively.

2.4 Teaching Materials and Methodology

2.4.1 Practical Worksheet

Before the day of the practice, students recorded their preparation on a worksheet. The preparation included questions on how the infection was transmitted, how to test, the morphological characteristics of eggs, and answers to a quiz on egg photo. The teachers reviewed the results of everyone’s preparation before the practice commenced. Students recorded all of their observations during the practice on a worksheet.

Note: The same worksheets were used in the blended learning (2018), e-learning (2017), and jigsaw (2017) classes.

2.4.2 E-Learning Method

The teacher uploaded the following preparatory materials to Moodle (a learning management system), which the students were encouraged to use actively:

A. Video of the egg detection process (Figure 1)

This part included a video (MP4 format) about detecting eggs, while increasing the magnification of the microscope step by step. A total of 29 kinds of videos were uploaded, with audio commentaries that took an average of 90 seconds to complete.

Figure 1. Video (Example: *Trichuris trichiura*)

B. The egg identification slide (Figure 2)

This section included images of a slide reproducing the changes that occur when the microscope's fine adjustment knob is moved. In the actual examination, the focus is varied to check the structure of the egg; therefore, the educational material conformed to realistic microscope operation. A total of 23 types were uploaded.

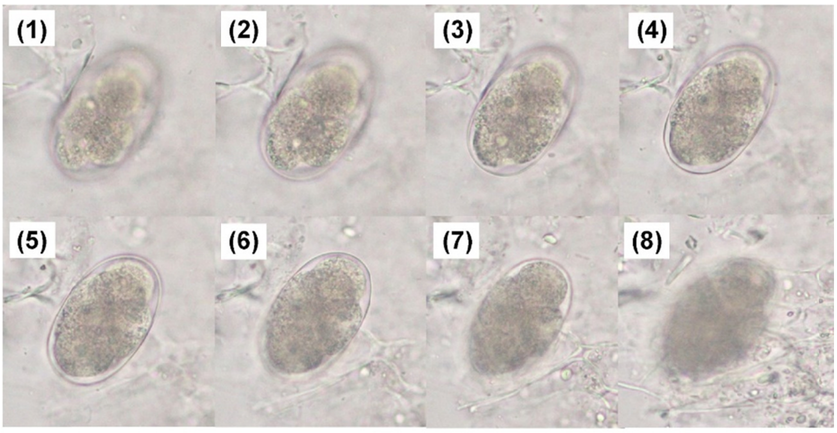

Figure 2. Slides (Example: *Ancylostoma duodenale*)

Note. This slide changed from (1) to (8) when clicked, in that order. It was created by pasting photos taken while shifting the focus into a PowerPoint file in sequence, and saving the file in PowerPoint format.

C. Image quiz

This section included image quizzes on eggs, larvae, and protozoa. A total of 30 questions were uploaded.

Note: Students from the e-learning class (2017) used this method to prepare for the course. In the practice session, students observed specimens assigned by the teacher (Kobayashi et al., 2023).

2.4.3 Jigsaw Method

In this method, a teacher assigned students to a team of parasite experts at the beginning of the practice (Figure 3).

1) First, students shared information about their assigned parasite within the same expert team for 20 minutes (expert activity).
2) Next, the teams were divided into groups with an equal number of members (Figure 4). At each table with a parasite specimen, an expert on that parasite explained that egg's characteristics. Following this, each student was responsible for detecting, observing, and recording the eggs, while the expert answered questions from other students. The time limit was 25 minutes per table (jigsaw activity).
3) During the practice, the teachers worked as facilitators to keep the practice running smoothly, and supported groups that experienced difficulties in detecting an egg.
4) After the practice, reflection was conducted among the students.
5) Finally, the teacher explained the observed eggs to all students.

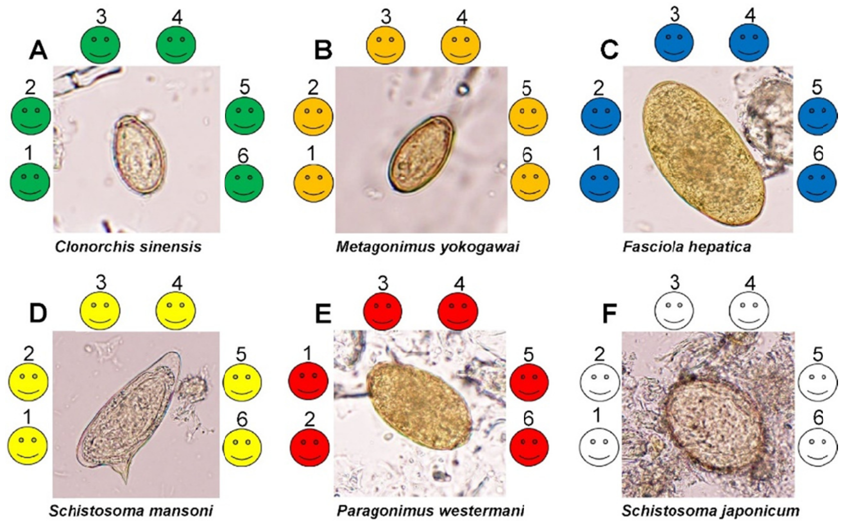

Figure 3. Expert team (Example: *Trematoda*)

Note. Teams A to F, six to seven students per team.

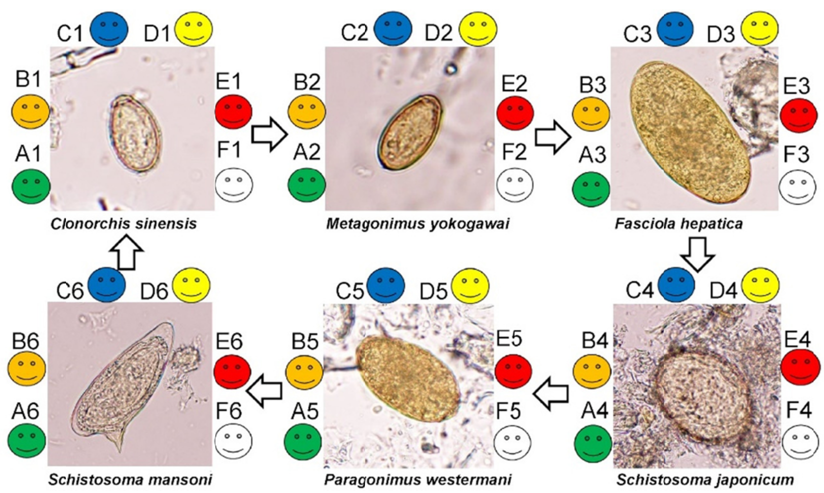

Figure 4. Jigsaw group (Example: *Trematoda*)

Note. Students in the jigsaw class (2017) used the textbook and color atlas to prepare for the course. In the practice, students performed a similar jigsaw activity (Kobayashi et al., 2023).

2.5 Statistical Analysis

Box-and-whisker plots represented the distribution of practical test scores and the differences in scores between classes; the 95% confidence intervals were shown by the Hodges-Lehmann estimator. The Wilcoxon rank sum test was used to compare scores, and p values were adjusted using Bonferroni's method. The χ^2 test was used to compare the percentage of those who scored below 60 (failing). Welch's t test was used to compare the microscopic image test scores. Longitudinal changes in mean scores were evaluated with a repeated measures linear mixed model (error structure unstructured and degrees of freedom adjusted using Satterthwaite's method), with the microscopic image test scores as the dependent variable and class, time, and class × time interactions as the independent variables. The mean scores of classes at each time point were compared. The questionnaire results (on a 5-point Likert scale), were presented in terms of the number of respondents and their percentages. The Bowker test was used to test the symmetry of responses for each question in the jigsaw method and the Moodle system. Open-ended opinions about the good and bad aspects of the practice were visualized using a Word cloud display. A structural equation model was used to analyze the relationship between microscopic test scores and teaching methods. At the time of analysis, responses to the questionnaire were replaced by a score of "1" for 5 points, "2" for 4 points, "3" for 3 points, "2" for 2 points, and "1" for 1 point. Test results were considered statistically significant when $p < 0.05$. SAS 9.4 and JMP PRO16.2 (SAS Institute Inc, Cary, NC, USA) were used for the analyses, and Amos version 24.0.0 (IBM®SPSS®) was used for the structural equation model analysis.

3. Results

3.1 Flowchart of the Blended Learning Method

Figure 5 presents a flowchart of the blended learning method. All 75 participants included in the analysis, completed the practice without missing a class.

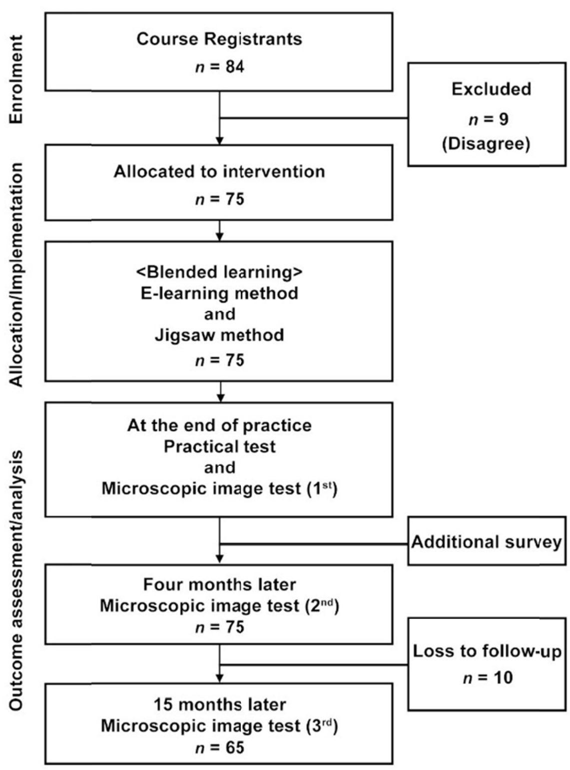

Figure 5. Flow chart of the blended learning method

Note. The same schedule was used for the 2017 e-learning and jigsaw classes to obtain test scores (Kobayashi et al., 2023).

3.2 Characteristics of the Participants

The 2018 blended learning, the 2017 jigsaw, and the 2017 e-learning classes were represented as 2018BL, 2017JG, and 2017EL, respectively. There were no significant differences in background characteristics (percentage of age, percentage of sex, and parasitology pretest scores) among the three classes (Table 1).

Table 1. Characteristics of the participants

Characteristics		2017JG (n = 33)	2017EL (n = 33)	2018BL (n = 75)	p value
Sex	Male	12 [36.4]	13 [39.4]	34 [45.3]	0.65[i)]
	Female	21 [63.6]	20 [60.6]	41 [54.7]	
Age	Age of majority	6 [18.2]	5 [15.2]	6 [8.0]	0.27[ii)]
	Age of minority	27 [81.8]	28 [84.8]	69 [92.0]	
Parasitology pretest score	Mean	72.2	71.5	75.2	0.25[iii)]
	Standard deviation	11.4	11.0	12.5	

Note. Sex and age are expressed as a number [percentage]. The parasitology pretest as a multiple-choice question on parasites. i), ii); χ^2 test, iii); one-way analysis of variance

3.3 Practical Test Scores

Figure 6 shows the distribution of scores. Median scores were the same for 2018BL and 2017JG at 83.3 points, and 91.6 points for 2017EL. No significant differences were observed, but the 2018BL median score was 8.3 points (one question) lower than the 2017EL's. 2018BL had the lowest percentage of failures (less than 60 points) at 10.7%, 13.5 points lower than 2017JG, and 7.5 points lower than 2017EL (Figure 7).

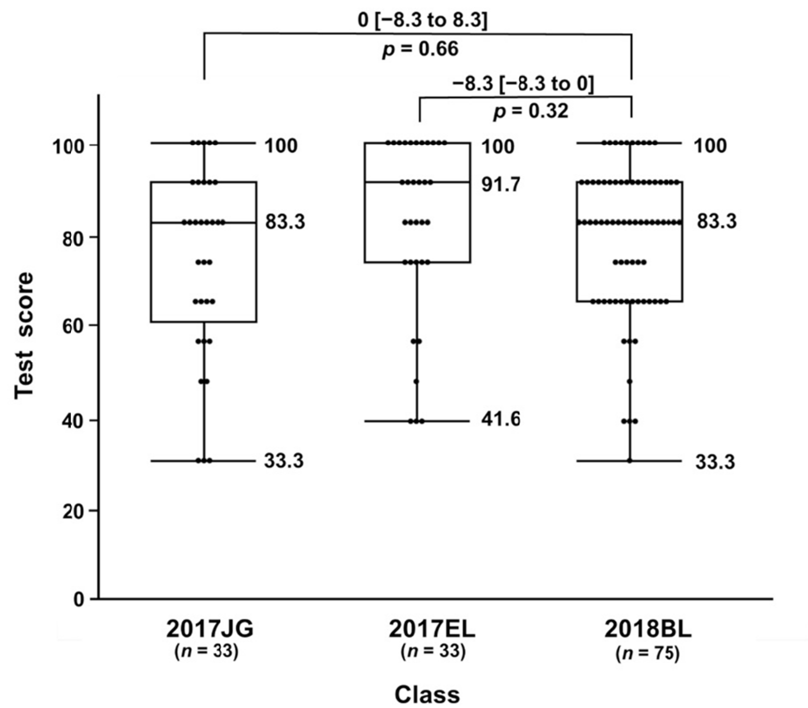

Figure 6. Distribution of the practical test scores

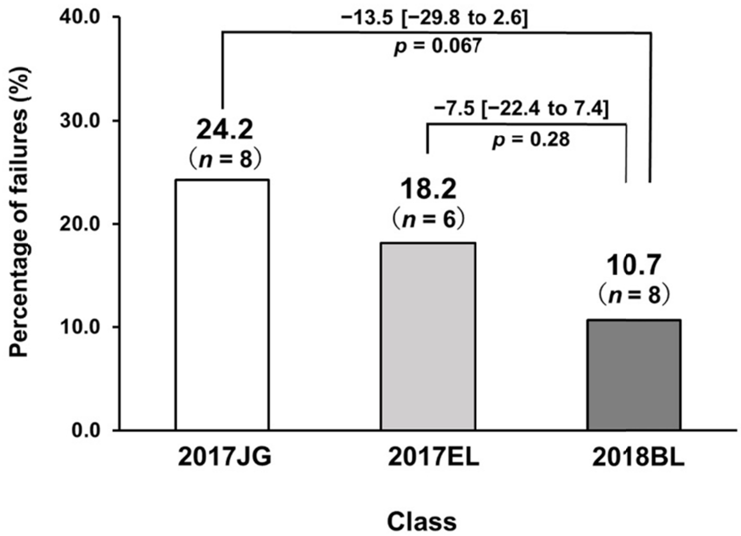

Figure 7. Percentage of failures (less than 60 points)

3.4 Microscopic Image Test Scores

Table 2 shows the egg image test scores conducted at the end of the practice. The mean scores for 2018BL were 4.5 points higher and 3.4 points lower than the 2017JG and 2017EL classes, respectively, but the difference was not significant.

Table 2. Comparison of microscopic image test scores (1st time)

Class	2017JG (n = 33)	2017EL (n = 33)	2018BL (n = 75)
Mean	79.4	87.3	83.9
Median	80	90	85
Max	100	100	100
Min	35	60	55
Standard Deviation	17.4	11.2	11.7
Mean Difference	4.5	−3.4	
[95%CI]	[−2.2 to 11.2]	[−8.1 to 1.3]	
p value	0.18	0.16	

Note. 2018BL vs. 2017JG (t statistics = 1.35, df = 45.3). 2018BL vs. 2017EL (t statistics = −1.44, df = 64.0).df: degree of freedom.

3.5 Longitudinal Changes in Microscopic Image Test Scores

Figure 8 shows the mean scores for each class over time. There was a significant interaction between class and time (Table 3). After four months, the mean scores for 2018BL were significantly higher than those of 2017JG and 2017EL classes by 14.9 and 9.6 points, respectively. However, there was no significant difference in scores 15 months later.

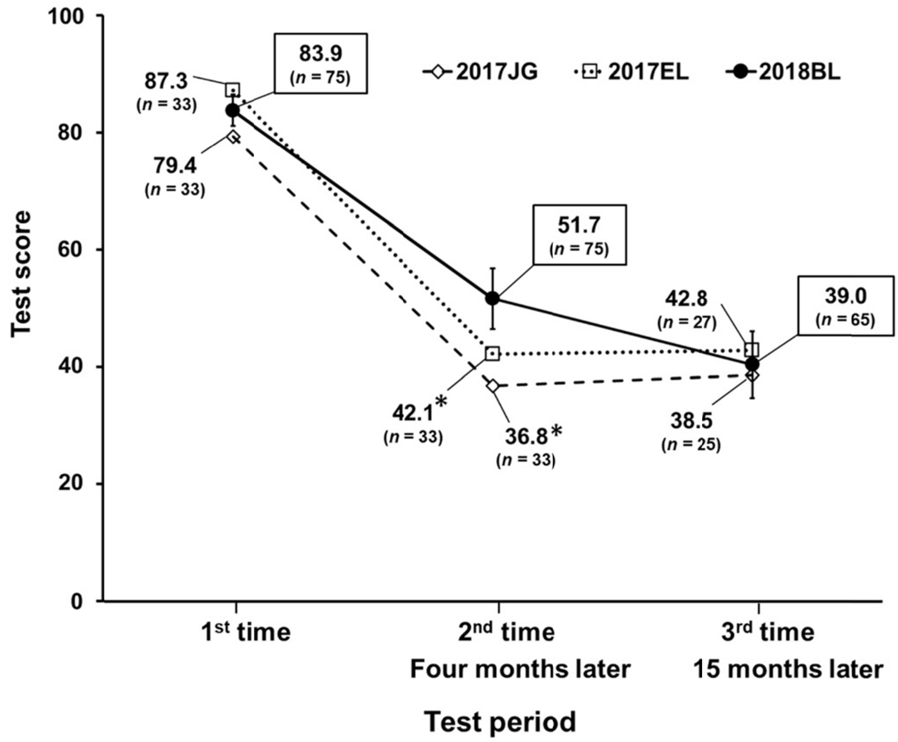

Figure 8. Longitudinal changes in microscopic image test scores

Note. Values were means for each class at each point in the period. Error bars indicate 95% confidence intervals for the mean of 2018BL.* indicates $p < 0.05$ (The results compare 2018BL with other classes).

Table 3. Fixed effects of repeated measures linear mixed model

Fixed effect		*df* (numerator)	*df* (denominator)	*F* value	*p* value
Main effect	Class	2	87	2.17	0.121
	Time	2	83.3	336.41	< 0.0001
Interaction effect	Class × Time	4	78.2	8.38	< 0.0001

Note. Null Model Likelihood Ratio Test: $p < 0.0001$ ($\chi^2 = 177.1$, $df = 17$).

3.6 Questionnaire

Table 4 shows the results of the 2018BL questionnaire. From questions 1–10, the mode of response was "1 = agree," and the total percentage of responses (agree + slightly agree) for "1" and "2" was approximately 90% or even more (except for question 2). Regarding the jigsaw activity (questions 6 and 7), 75% of the students reported that they could share information in advance within the expert team, and explain it to others in the jigsaw group. Regarding Moodle (questions 8 and 9), 82.7% of the students used the course materials for preparation. In contrast, the number of students who used the course materials for review decreased significantly.

Table 4. Results of the questionnaire survey

Item	No.	Contents of Questionnaire	Response				
			1	2	3	4	5
Purpose and progress	1	The purpose of the practice was clear.	72 (96.0)	3 (4.0)	0 (0)	0 (0)	0 (0)
	2	Progress in practice was good.	31 (41.3)	31 (41.3)	11 (14.7)	2 (2.7)	0 (0)
Worksheet materials	3	It was designed to help students understand the practice.	60 (80.0)	12 (16.0)	3 (4.0)	0 (0)	0 (0)
	4	The format made it easy to describe preparations and observations.	55 (73.3)	16 (21.3)	3 (4.0)	1 (1.3)	0 (0)
Teachers	5	Teachers had adequately prepared practice equipment and specimens.	66 (88.0)	9 (12.0)	0 (0)	0 (0)	0 (0)
	6	Teachers made an effort to increase students' understanding.	67 (89.3)	7 (9.3)	1 (1.3)	0 (0)	0 (0)
About yourself (self-assessment)	7	I prepared well.	49 (65.3)	18 (24.0)	5 (6.7)	3 (4.0)	0 (0)
	8	I actively practiced.	60 (80.0)	13 (17.3)	2 (2.7)	0 (0)	0 (0)
	9	I acquired the ability to identify parasite eggs (including protozoa and larvae).	46 (61.3)	26 (34.7)	2 (2.7)	1 (1.3)	0 (0)
Overall satisfaction	10	Overall, the practice was satisfactory.	52 (69.3)	19 (25.3)	4 (5.3)	0 (0)	0 (0)
Jigsaw activities	11	I could share pre-information on identifying parasite eggs within the team of experts.	31 (41.3)	26 (34.7)	14 (18.7)	4 (5.3)	0 (0)
	12	I could explain the identification of parasite eggs to others in the jigsaw group.	31 (41.3)	26 (34.7)	16 (21.3)	2 (2.7)	0 (0)
Using Moodle	13	Before the practice, we used Moodle to prepare.	42 (56.0)	20 (26.7)	5 (6.7)	5 (6.7)	3 (4.0)
	14	I used Moodle for review.	24 (32.0)	17 (22.7)	13 (17.3)	11 (14.7)	10 (13.3)

Note. Data were represented by the number of students (proportion). Response: 1 = agree, 2 = slightly agree, 3 = neither, 4 = slightly disagree, 5 = disagree. Bowker test: Jigsaw activities (combination of questions 6 and 7); $p = 0.94$, using Moodle (combination of questions 8 and 9); $p = 0.0028$.

Figure 9 shows a word cloud based on the open-ended responses to the questionnaire. “Microscopic identification” was the most frequently mentioned positive opinion by 26 (34.7%) students. For negative opinions, “time” was the most common, with 18 (24%) students reporting insufficient time.

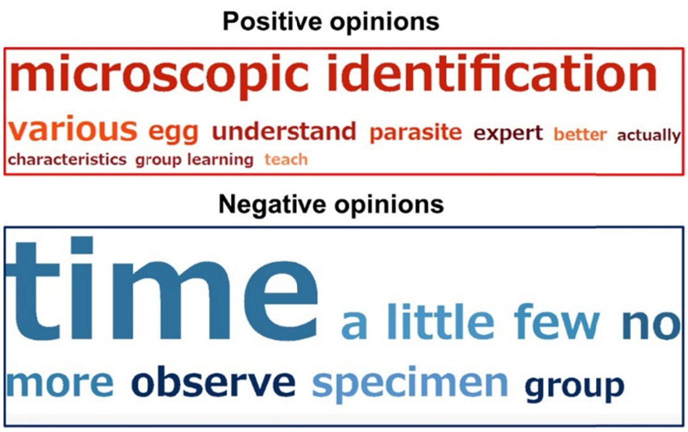

Figure 9. Word cloud of the positive and negative opinions

3.7 Relationship Between Practical Test Score and Questionnaire Results

Figure 10 shows the results of the analysis of the questionnaire data and the effect of each teaching method on the scores of the 2018BL practical test using the structural equation model. The jigsaw was assumed to be a latent variable constituted by "pre-information sharing" (No. 11) and "explanation to others" (No. 12), and Moodle by "preparation" (No. 13) and "review" (No. 14). Standardized path coefficients and correlation coefficients are shown in the Figure 10. Moodle was significantly indexed by "preparation" (No. 13), and jigsaw by "explaining to others" (No. 12). There was a significant direct effect from Moodle to practical test scores.

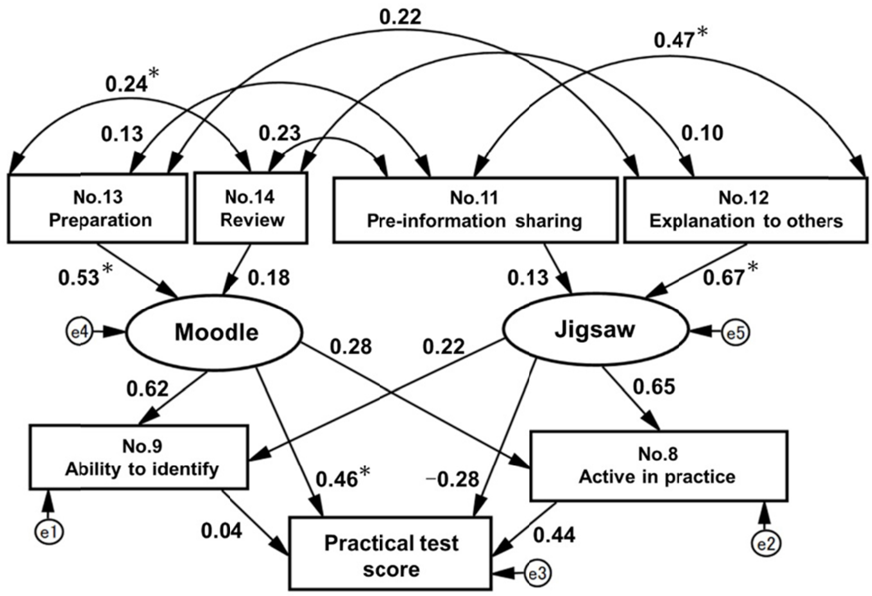

Figure 10. Multiple indicators multiple cause model for the practical test scores

Note. * indicates $p < 0.05$; e1 through e5 are error variables. The total effect on practical test scores was 0.608 (= 0.62 × 0.04 + 0.46 + 0.28 × 0.44) from Moodle and 0.015 (= 0.22 × 0.04 + (−0.28) + 0.65 × 0.44) from the jigsaw. Model fit indices: CMIN (chi-square minimum)/df = 0.329 (p = 0.859), GFI (goodness of fit index) = 0.995, AGFI (adjusted GFI) = 0.965, NFI (normed fit index) = 0.988, CFI (comparative fit index) = 1.000, RMSEA (root mean square error of approximation) = 0.000

4. Discussion

This is the first report on blended e-learning and jigsaw methods to teach parasitology practice to students in the Department of Medical Laboratory Science. We hypothesized that 2018BL would improve parasite identification skills more than 2017EL or 2017JG. The findings reveal that the practical and imaging test scores for 2018BL were not significantly higher than those for the other classes. Thus, although the hypothesis was not supported, the blended learning method may have other pedagogical effects.

4.1 Pedagogical Effects

One of the pedagogical effects of the blended learning method was the reduction in the percentage of students who failed the test. The percentage of students with practical test scores less than 60 was approximately 10% in 2018BL, which was the lowest compared to the other teaching methods.

Although not statistically significant, the results suggest that jigsaw activities may improve scores through active practice from the structural equation modeling analysis results. From this, we infer that students with poorer performance benefited from the support of others through cooperative learning, and that being taught helped them improve their performance. Chen et al. (2020) reported that, in a basic medical experiment, the percentage of failures decreased in the experimental group that practiced blended learning (Chen et al., 2020). Our study supports this finding.

The other effect pertained to short-term memory retention. 2018BL scored significantly higher on the second image test than the other teaching methods. This could be because of the synergistic effect of Moodle use and jigsaw activities. The results of the structural equation modeling analysis indicate that the use of Moodle had a significant direct effect on improving scores. The repeated use of microlearning has a memory retention effect, according to Shail (2019). In addition, we deduce that the students retained more memory than other parasites with respect to the parasites on which the students were experts in the jigsaw activity.

Blended learning increases learner satisfaction even when scores do not improve significantly (Sadeghi, Sedaghat, & Shaahmadi, 2014). Our questionnaire results indicated that the total number of positive responses was high (approximately ≥ 90%) in each category related to satisfaction, worksheet materials, teachers, and self-assessment. Therefore, we considered the practice itself a success.

Alternatively, the reasons why the results contradicted the hypothesis and improvements in teaching methods in blended learning were considered as follows: regarding e-learning, the questionnaire results showed that approximately 83% of the students engaged in preparation for each practice. Preparation is a useful tool to reduce the cognitive load in practice, and to improve learning effectiveness (O'Brien & Cameron, 2008). Especially in practices where observation is the focus, preparation of what one should look for before the actual practice helps eliminate any anxiety during the practice itself (Jones & Edwards, 2010). Additionally, the repetition and feedback of gamification materials have a memory retention effect (Krishnamurthy et al., 2022). For this reason, preparation through e-learning materials is essential. We therefore hold the considered view that the jigsaw method should be improved for blended learning.

4.2 Improvement of Jigsaw Method for Blended Learning

The jigsaw teaching method is effective in transforming students from passive to active learners (Bhandari, Mehta, Mavai, Singh, & Singhal, 2017). This method performs better than traditional teaching methods that do not motivate students in biology practices where specimens are observed (Baken, Adams, & Rentz, 2020).

However, in this study, all negative opinions were about the jigsaw method. The number of students who could share information within the expert team and explain it to others in the jigsaw group, was 57 (76%). For approximately one in four students, the jigsaw activity was not always a good fit. In particular, 18 students (24%) commented that they did not have enough practice time. These results agree with those reported by Soundariya, Senthilvelou, Teli and Deepika (2021) that the jigsaw method lacks time owing to the complexity of the learning method. Also, similar to the results of our study, approximately 75% of the students had positive opinions about the jigsaw activity (Soundariya et al., 2021).

Additionally, the team acknowledged negative comments for the jigsaw activity, such as "information could not be shared within the team," and "it is easy to make mistakes when students make decisions on their own." Mori (2018) reported that in learning through student interaction, some students could not gain proper understanding through peer interaction alone. In this study, two teachers served as facilitators during the practice, supporting groups that had difficulty detecting eggs. Furthermore, after the jigsaw activity, students were encouraged to reflect within their expert teams, followed by a commentary by the faculty. Of the students, 98.7% acknowledged this support from their teachers, but not all accepted the jigsaw activity. Jigsaw activities in experiments rely strongly on teamwork as well as individual contributions (Williams, Perlis, Gaughan, & Phadtare, 2018). Thus, the effectiveness may vary depending on the expert team members or jigsaw group. Based on the above, further benefits can be expected if three aspects are improved: time allocation, standardization of experts' knowledge level, and fostering teamwork when using the jigsaw method.

4.3 Limitations

This study had several limitations. The target students were not randomized, as this comparison of teaching methods was conducted across different years. Therefore, confounding factors may have influenced the results. However, because there were no significant between-class differences in background factors that might affect the results of this study, we did not consider them a heterogeneous group. Adjustment by propensity score using background factors and evaluation by analysis of covariance, were also considered analytical methods. However, it was not used because of the reduced sample size and low model fit. Additionally, we could not obtain accurate access logs because some students were engaged in learning with other students who shared the same device (smartphone, personal computer, or tablet), although they were all registered in the Moodle system. Despite these limitations, this study demonstrated the effectiveness of the blended learning method in parasitology practice, focusing on the identification of microscopic specimens.

4.4 Further Research and Prospect

Blended learning can give students confidence in experimental manipulation (Chen et al., 2020). Additionally, students' self-efficacy (I acquired the ability to identify parasite eggs) was ranked highly in this study. To improve instructional design, the ten tips presented by Hege, Tolks, Adler and Härtl (2020) for incorporating blended learning into medical education curricula, are helpful (Hege et al., 2020). Further research is required to determine the best way to combine e-learning with teaching methods (Vallée, Blacher, Cariou, & Sorbets, 2020).

From another perspective; the blended learning can also be used in practices, such as microscopic examination of urine sediment and blood specimens, with the same effect as in the present study.

Currently, there are 100 million patients in each of the three major intestinal helminth infections, which are part of the neglected tropical diseases, in Association of Southeast Asian Nations (ASEAN) countries (Sripa, Leonardo, Hong, Ito, & Brattig, 2022). In addition, there is also concern about the increase in helminth and protozoan infections in urban areas owing to global climate change (Hotez, 2018). We must improve students' parasite identification skills during pre-graduate education so that clinical laboratory technologists' test results do not lead to misdiagnoses.

5. Conclusions

This study demonstrated the pedagogical effectiveness of blended learning, which combined e-learning and jigsaw methods, in parasitology practice for medical laboratory science students. Test scores for the blended learning class were not significantly different from those for the e-learning or jigsaw classes. However, the practical test results showed a reduction in the percentage of failures, and the microscopic image test results indicated a short-term memory retention effect. The preparation through e-learning should be actively used to enhance blended learning. Additionally, cooperative learning, such as the jigsaw method, can help encourage active participation in practice. Further benefits can be expected if three aspects are improved: time allocation, standardization of experts' knowledge level, and fostering teamwork when using the jigsaw method. To verify the effectiveness of these improvements, further validation is required.

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