A RANDOMIZED CONTROLLED TRIAL OF JIGSAW VERSUS E-LEARNING APPROACHES: PRACTICAL PARASITOLOGY TRAINING TO IMPROVE PARASITE IDENTIFICATION TECHNIQUES IN CLINICAL LABORATORY SCIENCE EDUCATION

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ABSTRACT: Japan is witnessing an increase in parasitic diseases caused by contaminated food, international travel, and sexual activity, but much less time is spent on parasitology education. To avoid incorrect identifications, students were required to master the technique in a limited amount of time. This requirement necessitates new and more effective teaching methods that allow students to identify parasites. In this study, we conducted practical parasitology training using two teaching methods. We assigned 33 students to the jigsaw method (class A) and another 33 to the e-learning method (class B). This study aimed to determine the effectiveness and limitations of these teaching methods. Therefore, we conducted an RCT to reduce confounding bias and increase the validity of our results. The primary outcome was the participants' scores in the microscopic test to identify helminth eggs and protozoa in faecal and blood specimens, while the secondary outcome was the participant' scores in the photo test. The results showed that the median scores for the microscopic test were 83.3 for class A and 91.6 for class B ($p = 0.085$), and the mean scores for the photo test were 79.4 for class A and 87.3 for class B ($p = 0.033$). Therefore, the e-learning method was more effective than the

jigsaw method.

***KEYWORDS**: Parasitology; Clinical Laboratory Science Education; Jigsaw Method; E-learning*

1.0 INTRODUCTION

In Japan, although public health advancements have lowered the number of soil-transmitted helminth infections, parasitic diseases due to contaminated food, international travel, and sexual activity are increasing [1]. Palmieri et al. highlighted the importance of conducting practical training for accurate diagnoses to address the demand for parasite testing caused by increased globalization [2]. However, Japan has seen a decline in the amount of time spent on parasitology education [3]. Therefore, educational institutions for clinical laboratory technologists require practical training with more effective teaching methods. In parasitology lectures, studies have reported the effectiveness of teaching methods that use flipped learning and problem-based learning [4]. However, no randomized controlled trials have evaluated the effectiveness of teaching methods in practical parasitology training. Therefore, we conducted an RCT to reduce confounding bias and increase the validity of our results. We adopted two teaching methods to conduct the training: the jigsaw method and the e-learning method with a learning management system (Moodle). This study aimed to describe the effectiveness and challenges of these educational methods. The research proposition was that the jigsaw method is better than the e-learning method at improving students' ability to identify parasites. We also predicted that the jigsaw class would attain higher scores than the e-learning class on the microscopic and photo tests. In the jigsaw method, students must assume the role of experts and explain the parasite to others. Therefore, we formulated this hypothesis because we believe students would responsibly participate in the practical training after sufficient preparation.

2.0 METHODOLOGY

2.1 Research Design

2.1.1 Study Design

We conducted a randomized controlled trial to examine how the two teaching methods affect practical parasitology training.

i. Practical training period: January 2017 (follow-up surveys conducted between May 2017 and April 2018)
ii. Practical training hours: 15 (10 sessions of 90 minutes each)
iii. Practical training contents: Observation of helminth egg, larvae, and protozoa (a total of 26 parasite species)

2.1.2 Participants

We recruited 66 students in the first grade of the Department of Clinical Examination at Kitasato Junior College of Health and Hygienic Sciences.

2.1.3 Intervention

i. Jigsaw Method (Class A)

The jigsaw method is a cooperative learning technique in which students interact with and teach one another [5]. According to Colosi et al., the jigsaw method positively affects the teaching of biology experiments with practical training [6]. Therefore, we chose this method because students would responsibly participate in the practical training.

ii. E-learning Method (Class B)

We uploaded videos, photos, and quizzes to Moodle, an open-source learning platform. Abdul suggested that traditional parasitology education would benefit from a Web-based teaching system as a support tool [7]. With e-learning, students can undergo virtual practical training as often as they wish, with no time or location constraints. Therefore, we selected this method because conducting practical training virtually in advance will facilitate real-world practical training.

2.1.4 Outcome Measures

The primary outcome was students' scores on the microscopic test. The microscopic test contained three questions per category (i.e., nematodes, trematodes, cestodes, and protozoa) for 12 questions. Meanwhile, the secondary endpoint was students' scores on the photo test. The photo test involved photographic identification, with five questions per category (i.e., nematodes, trematodes, cestodes, and protozoa) for 20 questions. Percentages of correct answers were calculated. Exploratory outcomes were the longitudinal changes in students' photo test scores and questionnaire results.

2.1.5 Sample Size

Before this study, parasitology lectures were conducted using two teaching methods: active learning and e-learning [8]. Based on these results, the class scores were 15 points higher for the jigsaw method than for the e-learning method. The sample size was estimated with a standard deviation of 22 points for each class score, a significance level (alpha) of 0.05, and a power of 0.8. This resulted in 35 participants per class when following a 1:1 assignment. Since the study involved 33 participants per group, its power was 0.78.

2.1.6 Randomization

Random assignment was conducted using minimization, using three factors to adjust for allocation: gender, age (<20 years or ≥20 years; the age of majority or not the age of majority), and parasite photograph pretest results (scored or not scored). We used the minimization method to produce the random assignment for two reasons: the small sample size of the classes and the need to reduce differences among prognostic factors.

2.1.7 Blinding

This manuscript was based on an open-label study.

2.1.8 Ethical Considerations

All participants attended a briefing session and provided consent forms. Approval was obtained from the Ethics Committee of Niigata University and Kitasato Junior College of Health and Hygienic Sciences.

2.2 Teaching Methods

2.2.1 Jigsaw Method (Class A)

The teacher assigned one species of parasite eggs to each of the six teams (groups A–F), which were designated as expert groups for that species (Figure 1). Each team consisted of five to six students. The participants shared information with their expert team members for 20 minutes while examining their assigned eggs under a microscope (expert activity).

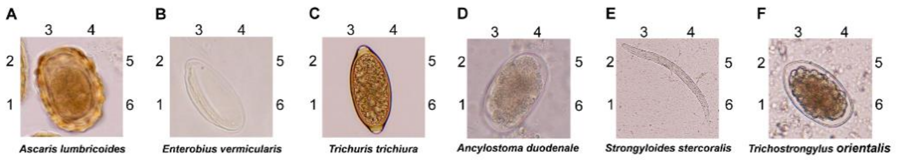

Figure 1: Expert teams: letters indicate groups; numbers indicate members

New round groups comprised one member selected from each expert team (Figure 2). The expert had five minutes to describe the eggs to the other students. Afterwards, the students observed and recorded the results on their worksheets for 20 minutes. The round groups then moved to the next table by turns. The teacher facilitated the activity to ensure that the practical training was conducted smoothly.

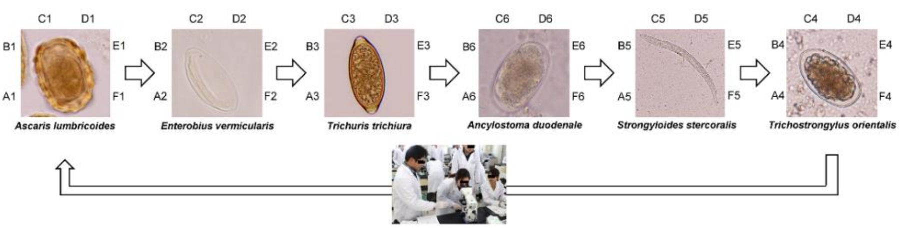

Figure 2: New round groups: alphanumeric codes represent team members from the expert team

2.2.2 E-learning Method (Class B)

The participants viewed an egg detection video and identification slide using Moodle and then answered egg photo quizzes before undergoing practical training. The students spent 25 minutes observing and recording each specimen during the training. The teacher provided direct instructions to participants who had difficulty detecting the eggs.

i. Egg detection video (Figure 3)

Videos of the egg detection process were recorded under a microscope at 4×, 10×, and 40× magnification. A video was 1.5 minutes on average, and 29 movies were recorded.

Figure 3: Egg detection video (example: unfertilized egg of *Ascaris lumbricoides*)

ii. Egg identification slide (Figure 4)

This educational material allows the user to reproduce changes similar to when a microscope's focus is fine-tuned using a fine-adjustment screw by clicking on the slide. A total of 23 specimens were used.

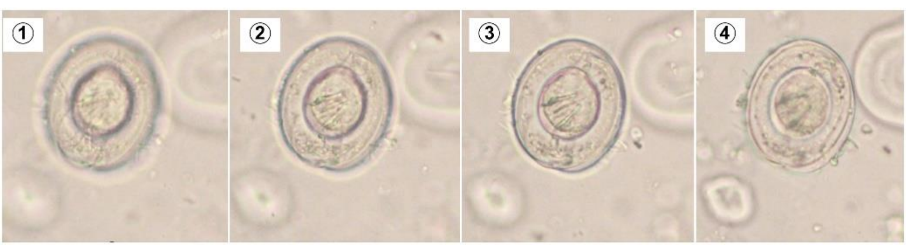

Figure 4: Egg identification slide (example: egg of *Hymenolepis nana*); clicking the image changes the view from ① to ② to ③ to ④

iii. Egg photo quiz (Figure 5)

After viewing the egg detection videos and identification slides, the participants answered several egg picture quizzes containing 30 questions.

Figure 5: Egg photo quiz (example: egg of *Schistosoma mansoni*)

2.3 Statistical Analysis

We used a box-and-whisker plot to represent the score distribution for the microscopic test. We performed the Wilcoxon rank-sum test to compare the scores of the two groups and expressed the difference as a Hodges–Lehmann estimator (HLE) and 95% confidence intervals. We estimated the sample size using a t-test but adopted a nonparametric method because the actual score distribution was skewed. We also used Fisher's exact test to compare the baseline characteristics and compare the percentages of correct responses for each microscopic test. We performed Welch's t-test to compare the photo test scores. We assessed longitudinal changes in photo test scores using a linear mixed-effects model for repeated measures (MMRM) in which the objective variable was the photo test score, and the explanatory variables were time, class, and their interactions. This model assumed an unstructured covariance error structure, and degrees of freedom were adjusted using Satterthwaite's method. We performed the Wilcoxon rank-sum test for interclass comparisons of questionnaire response rates and the Bowker test for intraclass comparisons. Test results were considered statistically significant at $p < 0.05$. For statistical analyses, we used SAS 9.4 and JMP PRO 16.2 (SAS Institute Inc., Cary, NC, USA).

3.0 Results

3.1 Overview of the Randomized Controlled Trial (Figure 6)

We observed no significant differences in the allocation factors at baseline (Table 1). All students completed the practical training with perfect attendance.

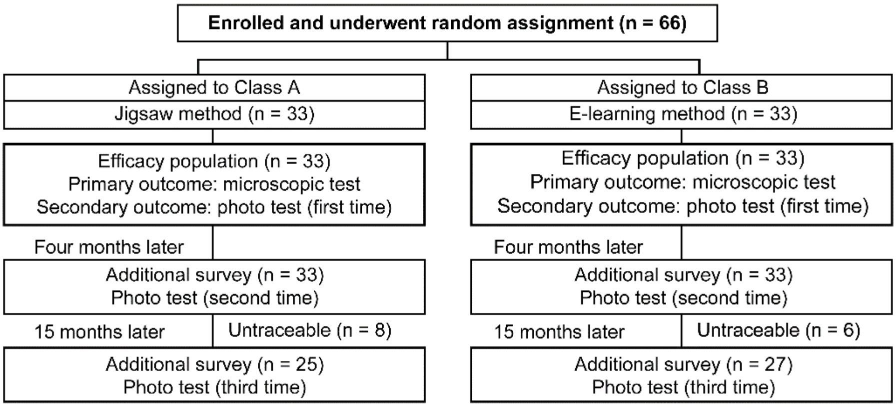

Figure 6: Trial profile

Table 1: Baseline demographics and characteristics of the intention to treat population

Characteristics	Class A (n = 33)	Class B (n = 33)	Total (n = 66)	p-value
Gender				
Male	12 (36.4%)	13 (39.4%)	25 (37.9%)	0.99
Female	21 (63.6%)	20 (60.6%)	41 (62.1%)	
Age				
20 years old and over	6 (18.2%)	5 (15.2%)	11 (16.7%)	0.99
Under 20 years old	27 (81.8%)	28 (84.8%)	55 (83.3%)	
Pretest score				
Scored	16 (48.5%)	14 (42.4%)	30 (45.5%)	0.81
Not scored	17 (51.5%)	19 (57.6%)	36 (54.4%)	

3.2 Primary Outcome (Microscopic Test)

Figure 7 shows the score distribution for the microscopic test. While the HLE was 8.3 points higher for class B than for class A, this difference was not statistically significant (Figure 7). Four parasites differed in the percentage of correct responses by more than 10 points, which were all higher in class B than in class A (Table 2).

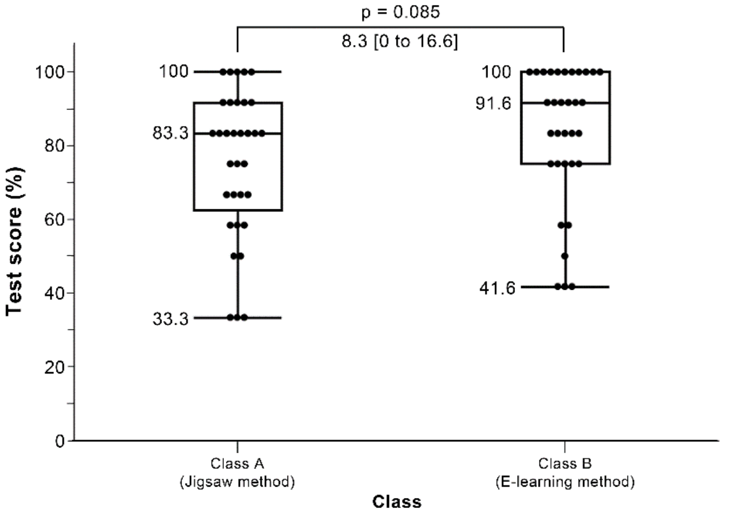

Figure 7: Microscopic test scores per class

Table 2: Percentage of correct responses by question and differences between class A and class B

Genus	No.	Species	Class A	Class B	Difference [95%CI]	p-value
Nematoda	1	*Ascaris lumbricoides*	93.9	100	6.1 [−5.1 to 17.2]	0.49
	2	*Ancylostoma duodenale*	75.8	69.7	−6.1 [−30.4 to 18.4]	0.78
	3	*Trichuris trichiura*	97.0	93.9	−3.1 [−16.1 to 10.0]	1
Trematoda	4	*Clonorchis sinensis*	51.5	69.7	18.2 [−8.0 to 44.4]	0.21
	5	*Metagonimus yokogawai*	57.6	72.7	15.1 [−10.6 to 40.9]	0.30
	6	*Schistosoma mansoni*	81.8	84.8	3.0 [−18.0 to 24.0]	1
Cestoda	7	*Diphyllobothrium nihonkaiense*	54.5	81.8	27.3 [2.8 to 51.8]	0.032
	8	*Hymenolepis diminuta*	66.7	78.8	12.1 [−12.2 to 36.4]	0.41
	9	*Taenia saginata*	87.9	90.9	3.0 [−14.8 to 20.9]	1
Protozoa	10	*Balantidium coli*	84.8	90.9	6.1 [−12.7 to 24.8]	0.71
	11	*Plasmodium vivax*	54.5	63.6	9.1 [−17.6 to 35.7]	0.62
	12	*Trichomonas vaginalis*	100	97.0	−3.0 [−11.9 to 5.9]	1

3.3 Secondary Outcome (Photo Test)

The mean score was 7.9 points higher for class B than for class A—a significant difference. The variance of scores for class B was significantly smaller than that for class A (F-statistics = 0.41, p = 0.015), with 60 being the lowest score (Table 3).

Table 3: Comparison of photo test scores between classes A and B

Class	n	Mean	Median	Max	Min	SD	Mean difference between Class B and Class A [95%CI]	p-value
A	33	79.4	80	100	35	17.4	7.9 [0.7 to 15.1]	0.033
B	33	87.3	90	100	60	11.2		

3.4 Exploratory Outcomes

3.4.1 Longitudinal Changes in Photo Test Scores

Figure 8 presents changes in scores up to 15 months. The results of the MMRM analysis showed that the time–class interaction was not statistically significant (p = 0.764). Thus, the mean scores for both teaching methods varied similarly over time, but those for class B were always higher than those of class A.

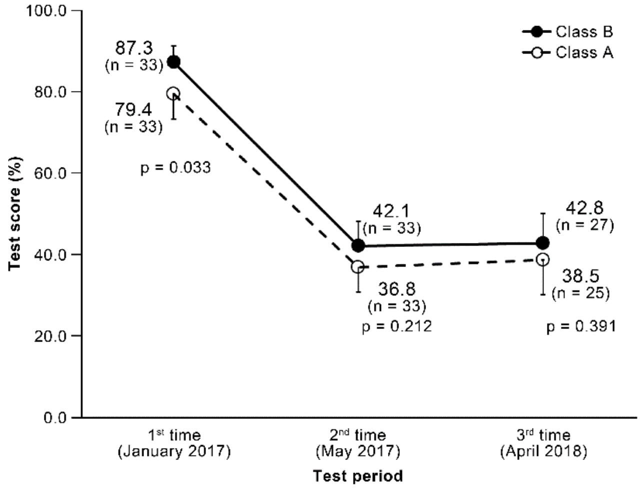

Figure 8: Mean scores up to 15 months later; error bars indicate a 95% confidence interval for the mean

3.4.2 Questionnaire Results

Table 4 shows the questionnaire table. The response rate was 100%. No items indicated significant differences between classes; however, class B tended to show higher self-efficacy in identifying parasites than class A (no. 3). In the jigsaw activity, students in class A were able to share information but were unable to explain it to others. Students in class B had a slight tendency not to use Moodle for review.

Table 4: Results of the questionnaire on practical training; data are represented as the number of students (proportion)

Item	No.	Question	Class	Response[i]					p-value[ii]
				①	②	③	④	⑤	
Self-assessment	1	Did you actively conduct your preparatory studies?	A	22 (66.7)	7 (21.2)	3 (9.1)	1 (3.0)	0 (0)	0.915
			B	21 (63.6)	9 (27.3)	3 (9.1)	0 (0)	0 (0)	
	2	Were you willing to do the practical training?	A	27 (81.8)	6 (18.2)	0 (0)	0 (0)	0 (0)	0.556
			B	25 (75.8)	8 (24.2)	0 (0)	0 (0)	0 (0)	
	3	Do you think you have mastered the ability to identify parasite using a microscope?	A	19 (57.6)	12 (36.4)	2 (6.0)	0 (0)	0 (0)	0.098
			B	25 (75.8)	8 (24.2)	0 (0)	0 (0)	0 (0)	
Satisfaction	4	Was the training satisfactory overall?	A	25 (75.8)	8 (24.2)	0 (0)	0 (0)	0 (0)	0.239
			B	29 (87.9)	3 (9.1)	1 (3.0)	0 (0)	0 (0)	
Jigsaw activities	5	Did you share information in advance within your team of experts?	A	23 (69.7)	7 (21.2)	2 (6.1)	1 (3.0)	0 (0)	0.018
	6	Were you able to explain yourself well to others as an expert?		9 (27.3)	16 (48.5)	7 (21.2)	1 (3.0)	0 (0)	
Using Moodle[iii]	7	Did you use Moodle to do your preparatory studies before each practical training?	B	25 (75.8)	5 (15.2)	2 (6.0)	1 (3.0)	0 (0)	0.416
	8	Did you use Moodle for your review?		17 (51.5)	8 (24.2)	4 (12.1)	1 (3.0)	3 (9.1)	

i) Responses: ① agree, ② slightly agree, ③ neither, ④ slightly disagree, and ⑤ disagree. ii) Nos. 1–4: Wilcoxon rank-sum test; a combination of nos. 5 and 6 and nos. 7 and 8: Bowker test. iii) All students in class B entered Moodle based on its access logs. Among the students, 19 (57.6%) used all the materials, and 26 (79%) used more than 80%.

4.0 DISCUSSION

We conducted this study to verify the effectiveness of teaching methods in practical parasitology training. Although not significantly different, class B had a higher median score than class A. Specifically, class B also tended to attain higher scores in the parasites Trematoda and Cestoda, which are essential to be distinguished from other similarly shaped eggs (e.g., *Clonorchis sinensis* and *Metagonimus yokogawai*). We considered the eggs to be well-identified by class B. Class B scored significantly higher on the photo test than class A, scoring 60 or higher. For both classes, we halved the scores on the second photo test. These results were consistent with those of Shomaker et al., who reported that scores on a photo test after a lecture were reduced by half after four months [9]. Both teaching methods showed similar longitudinal changes, but class B tended to attain consistently higher mean scores than class A. This observation shows that the e-learning method may be more effective for knowledge retention. Contrary to our hypothesis, the scores for the e-learning method were higher than those for the jigsaw method. The reasons are as follows.

The jigsaw method promotes student-centred and motivated practical training [6], but its effectiveness depends on the appropriate teaching materials, students' willingness to participate, and information accuracy [6,10,11]. In this study, students did not present incorrect information because the teacher had checked the prepared content in advance. Based on the questionnaire results, 81.8% of class A reported being actively engaged in practical training. Although 69.7% of the students shared information with a professional team, only 27.3% could explain the content to others. The open-ended comments in the questionnaire highlighted that some students needed detailed explanations from the teacher. Mori reported that, in active learning, a certain number of students felt anxious about not understanding the content because of the low quality of internalization [12]. Therefore, we presume that teachers must assist with internalization. As a countermeasure, conducting a preassessment test, such as the iRAT and tRAT in team-based learning, was necessary [13].

The e-learning method is characterized by flipped learning [14], in which students use the knowledge they acquired from virtual practical training in real practical training. Studies have verified the effectiveness of flipped learning in Asian universities [15].

The Moodle access logs showed that about 80% of the students used more than 80% of the course materials. Therefore, we considered that the e-learning program was successful. The questionnaire results indicated that students in class B who acquired identification skills scored 18.2 points higher than those in class A; hence, class B had more students who felt a sense of self-efficacy. Satisfaction with practical training was also increased. We hypothesized that virtual practical training would lead to real practical training, which would not only improve test scores but would also produce psychological advantages. Besides the benefits of the virtual practical training provided by

Moodle materials, another beneficial aspect was involved: the teacher's individual instructions' effect on students who could not identify parasites. Students who already had a sufficient understanding of the content from the virtual practical training could conduct practical training without direct instructions from the teacher. Therefore, the teacher could take their time in providing individual instructions to students with identification challenges.

Based on these results, we conclude that the e-learning method is more effective in improving performance than the jigsaw method. This study was an RCT adjusted for three possible confounding factors. Although the sample size was insignificant, the confounding bias for the results obtained was suppressed as far as possible. Therefore, we expected that the validity of the results would be ensured.

In medical education, e-learning is a valuable method that complements traditional lectures [16]. Digital images, videos, and virtual microscopes are necessary Web-based educational materials for parasitology education [4,7,17–19]. Educational materials that incorporate gamification elements are also helpful [20]. In the future, we aim to improve the e-learning materials created in this study and use them to deliver not only education at the technical college but also practical education.

This study has several limitations. We did not assess attitudes toward the jigsaw method. If each student had been regularly provided feedback on the evaluation results, their scores could have improved. However, it took much work for one teacher to evaluate all 33 students. In the e-learning method, we did not enforce the use of Moodle materials because of the upper limit of the communication volume of personal devices. Therefore, not all students used all the materials, but we infer that their scores would have been even higher had they all done so. Donkin et al. showed that not only did students engage with the e-learning materials before participating in the training, but teachers also provided feedback after the training was complete, significantly improving student performance [21]. In the future, we must improve our teaching methods to allow space for feedback to be given to the students.

5.0 CONCLUSIONS

This study sought to verify the effectiveness of jigsaw and e-learning methods in practical parasitology training. Based on the student's performance in the microscopic and photo tests, we found that the e-learning method was more effective than the jigsaw method. Enhancing e-learning materials and improving the utilization rate of LMS is essential for students to learn techniques within a limited period.

6.0 ACKNOWLEDGMENTS

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