
Original Article

Longitudinal Comparison between Flipped Classroom and Team-based Learning in a Prosthodontic Class

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Abstract : Active learning is a concept that allows students to study and learn actively by themselves to get knowledge. There are several methods of active learning, including flipped classroom (FC) and team-based learning (TBL). In FC, students are required to study before classes. In TBL, students also study before class, take individual readiness assurance test (iRAT) and team readiness assurance test (tRAT), then discuss group assignment projects (GAPs) during class. The purpose of this study was to compare the effectiveness between FC and TBL.

The effectiveness of FC and TBL was assessed from the results of the term-end examinations, questionnaires and practice examinations. To check the difficulty of the term-end examinations, control dentists took the same examinations and we calculated the equating score with item response theory.

Statistical analysis showed that the correct answer rate in term-end examinations was significantly different in comparison with the time of the trial, and for the participants (students and dentists). The term-end examination score of FC and TBL did not show a statistical difference. The student questionnaire showed that TBL had higher scores than FC on various factors such as student positive attitude, preparation, ingenuity of teacher and achieving the class goals. The crown & bridge score from the practice examination of 6th-year students who had FC + TBL were constantly higher than the Japanese national average score. The identification index of FC and TBL did not show the statistical difference and there was no statistical difference on item response theory between FC and TBL.

Introduction

Active learning is a concept that allows students to study and learn actively by themselves to get knowledge. There are several active learning methods¹⁻¹⁶⁾ including flipped classroom (FC) and team-based learning (TBL). FC gives educators a shift in paradigm, and students are required to study before their classes. In some FC, students take their examinations after the pre-class study and before the class,

then the students attend the class^{3,17-20)}. The teachers give some task to the students in the FC (feedback lecture, question and answer time or examinations again, etc.). Recently, personal computers or electric devices have become popular, and the study materials used before classes are mostly electronic slides or videos^{1,4-6,12)}. A systematic review on flipped learning model in dental education reported that it was more effective to increase student knowledge than conventional lecture and

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Table 1 Class format in a semester

Class	1 ←→ 7	8	9 ←→ 15
Class format	FC	Special lecture	TBL

An academic year in Tokushima University comprises two semesters, 15 classes per semester and 60 minutes per class. Two types of active learning (FC and TBL) were introduced in fixed prosthodontic classes. FC: flipped classroom, TBL: teambased learning.

students can learn at their own spaces²¹). Moreover, a meta-analysis reported that FC improved theoretical performance and student practical skills more than conventional lectures in radiology education²²).

TBL is a modified style of FC²³) and the class advances through small group discussion. Problem based learning (PBL) is another form of small group discussion wherein the students discuss clinical cases in a small group with a tutor^{9, 24-28}). However, in PBL class, each group needs to have a tutor and many tutors need to work at the same time. On the other hand, TBL small group discussion does not require a tutor in each group. In TBL, the students study before classes, and take the individual readiness assurance test (iRAT) and team readiness assurance test (tRAT), then discuss group assignment projects (GAPs) in class^{7, 8, 10, 11, 13-16}). It was reported that TBL improved study motivation⁸), National Board Dental Examination results¹⁰), course grade¹¹), students' performance²⁹) and students' attitude³⁰) more than conventional lectures.

We started TBL in prosthodontic classes in 2013 and reported that TBL is an effective method for student learning¹³⁻¹⁶). We also reported that the term-end examination results of TBL classes were significantly higher than those of the traditional lecture classes¹³).

Although FC and TBL showed bigger effect than conventional lecture, there are not many studies that compared the effectiveness between FC and TBL. The purpose of this study was to compare the effectiveness between FC and TBL using longitudinal term-end examination data. Previously, we have reported one semester results on the effectiveness between FC and TBL¹⁶). However, the results from one semester were not enough to evaluate the comparison, because students and examinations differ every semester. In the current study, we gathered data for several years and analyzed them.

Materials and Methods

This study was approved by the Tokushima University Hospital Clinical Research Ethics Committee (No. 1893). An academic year in Tokushima University comprises two semesters, 15 classes per semester, and 60 minutes per class. From 2014 to 2017, two types of active learning (FC and

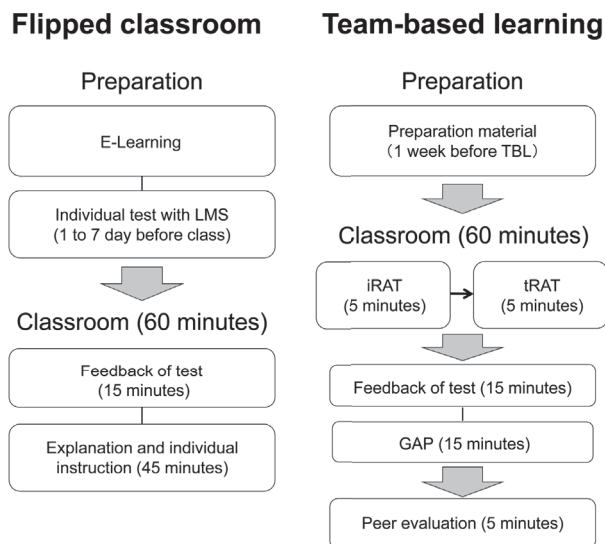


Fig. 1 Flipped classroom and team-based learning formats.

Both class formats have two-steps; preparations for the classes and classes. For the preparations, FC used the e-learning system, and TBL used printed handouts for the teaching materials. In the FC, the students received the feedback of the individual tests and the explanation of the teaching materials. In TBL, the students took iRAT and tRAT, then performed group works (GAP). LMS: Learning Management System, Tokushima University, iRAT: individual readiness assurance test, tRAT: team readiness assurance test, GAP: group assignment project.

TBL) were introduced in fixed prosthodontic classes (3rd and 4th-year dental school students). In the 15-class series, seven FC classes using e-learning (Tokushima Learning Management System (LMS); Moodle (<http://Moodle.org/>)) and one special lecture were done in the first half. The second half was composed of seven TBL classes (Table 1).

Fig. 1 shows the framework of FC and TBL. In FC, the students were required to study the topic with the study materials and to answer the pre-class examinations through e-learning. The students could access the system through their personal computers or smartphones. The students were required to answer five questions in each pre-class study,

tRAT answer sheet

Date: _____ Group number: _____

Answer	1	2	3	4	5	Score
Q1	●	●	Yeah! (^ ▽ ^)	●	●	10
Q2	●	●	Oops! (; _ ;)	●	Yeah! (^ ▽ ^)	5
Q3	Oops! (; _ ;)	●	Oops! (; _ ;)	Yeah! (^ ▽ ^)	●	0
Q4	●	●	●	●	●	
Q5	●	●	●	●	●	
Total						

Do not scratch marks except for the answer.

Fig. 2 tRAT answer sheet.

The students scratched the answer. If the students answered correctly, they received 10 points. If the students scratched one wrong answer, they received 5 points. If the students scratched two wrong answers, they did not receive any points.

where the correct answers were unknown to them until they attended the actual classes. The students took the pre-class examinations within seven days before the class. The teacher reviewed each student’s score before class, while the system calculated the percentage of correct answers for each question. The teachers were able to know who answered the questions correctly. In class, the teacher gave feedback lecture to the students and accepted questions.

The TBL format was described in our previous reports¹³⁻¹⁶. Briefly, the students were given a printed handout for their home study, one week before each TBL class. At the beginning of the TBL class, the students took an iRAT with multiple-choice questions to check their preparation level. The students were then divided into small groups with five to seven members, and each group took the tRAT after the group discussion, which had the same questions as the iRAT. tRAT questions were answered with a scratch-off sticker sheet (Fig. 2). Following teacher feedback on the iRAT and tRAT, the students worked for GAPs, which involved practical clinical questions. Each group showed the answers using number boards. Finally, the students were evaluated by the other students on their performance in peer evaluation (Fig. 1).

FC and TBL effectiveness were assessed from the results of the term-end examinations. Multiple-choice questions were answered by the students and the questions contained

FC and TBL study topics. A referential examination with the same questions was given to dentists who did not make the term-end examinations. To investigate the learning effects of the class format (FC and TBL), the results of the term-end examinations, which adopted multiple-choice questions from the Japanese National Board examination, were calculated (289 students). Also, to check the degree of difficulty of the term-end examinations, dentists (64 members) who were not involved in the preparation of the term-end examination questions took the same examinations. They were dental residents and PhD students (average age ± SD: 27.5 ± 6.3 years old). They did not have preparation study for the examination.

The dental students were asked to answer the questions (Table 2) which were the same as that of previous study which Tokushima University used. Moreover, we asked two more questions “Please answer the good points of this class” and “Please answer what you want to improve in this class” at the end of the FC and TBL classes.

Most of the 6th-year dental school students in Japan take practice examinations from private companies for the Japanese national dental board examination before their graduation. In Tokushima University, the students take the practice examinations 2 years after the prosthodontic class. We received the last examination score in each year from

Table 2 Student questionnaire items for flipped classroom and team-based learning

<p>What was the level of your understanding in this class? On a scale of 0 (poor) to 4 (excellent), score in this class for the following items:</p> <ol style="list-style-type: none"> 1. Was your attendance attitude positive? (Positive attitude) 2. Did you do enough preparation and review before and after class? (Preparation / review) 3. Did the teacher explain the goals and objectives of the class? (Class objective) 4. Were the important things emphasized in the class? (Important things) 5. Did you understand the study subjects easily? (Study subjects) 6. Did you feel the ingenuity of the teacher in managing the class? (Ingenuity of teacher) 7. Was the class managed as planned? (Class plan) 8. Did you achieve the class goals? (Class goals) 9. Do you think this class is useful for your future? (Class usefulness) 10. Did this class deepen your understanding of the subject? (Student understanding) 11. Did you feel the need or interest in studying the subject through this class? (Need / interest) 12. Did this class improve your ability to study the subject? (Improve ability) 13. Overall, were you satisfied with this class? (Overall satisfaction)
<p>Student's free comments Please answer the good points of this class. Please answer what you want to improve in this class.</p>

Questionnaire was administered at the end of each FC and TBL class.

Azabu Dental Academy, and extracted data on crown & bridge subjects and all study subjects. The scores of the Tokushima University students were divided by Japanese student data who took the practice examination in Japan. The data show long term effect of crown & bridge prosthodontic education. The students who took the practice examination before 2015 had conventional lectures in their prosthodontic classes. The students who took the practice examination in 2015 and 2016 had conventional lectures + TBL. They took the conventional lecture at the first half and TBL at the second half of the semester. The students who took the practice examination from 2017 to 2019 had FC and TBL.

We analyzed the validity of the student examination questions by calculating identification index. We also analyzed the question difficulty by calculating the equating score with item response theory³¹⁻³³.

Kruskal-Wallis test with Bonferroni post hoc correction was performed to check the effectiveness of FC and TBL and participant type (students and dentists). We compared the validity and difficulty of the examination questions between FC and TBL with Mann-Whitney U test. EZR was used for all statistical analysis. EZR is a statistical software that extends the functions of R and R Commander, and is distributed free of charge on the homepage of Saitama Medical Center or Jichi Medical University. Statistical significance was accepted at $p < 0.05$.

Results

FC and TBL effectiveness on term-end examination in each year

Fig. 3 shows the correct answer rate of each term-end

examination. Each examination showed a different score. As a result of Kruskal-Wallis test, the correct answer rate was significantly different in comparison with the time of the trial ($p < 0.01$) and for the participants (students and dentists) ($p < 0.01$). The reference examination scores by the dentists were significantly higher than the students ($p < 0.01$). However, the term-end examination score of FC and TBL did not show a statistical difference ($P = 0.77$). We added the data of the comparison between TBL and conventional lecture in 2013 and 2014. The term-end examination score of TBL was higher than conventional lecture in 2013, although there was no statistical difference.

Total comparison between FC and TBL effectiveness

There was no statistical difference between FC and TBL effectiveness in the total sample ($p = 0.73$) (Fig. 4). There was no interaction between the test period and the participants (students or dentists), as well as the test period and class format. There were statistical differences between student score and dentist reference examination score ($p < 0.01$).

Student perspective between FC and TBL

The questionnaire to the students showed that TBL had higher scores in most of items. Especially regarding the following questions, the scores of TBL were statistically higher than FC (Fig. 5), "Was your attendance attitude positive?", "Did you do enough preparation and review before and after class?", "Did the teachers explain the goals and objectives of the class?", "Did you feel the ingenuity of the teacher in managing the class?" and "Did you achieve the class goals?".

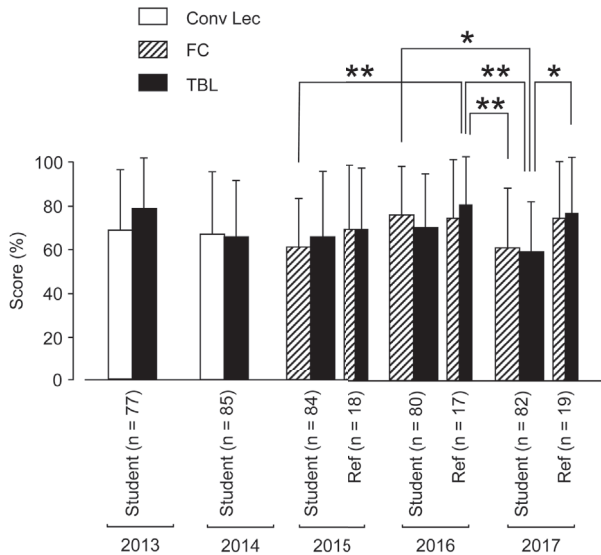


Fig. 3 Correction rate in each term-end examination. Data are presented as mean \pm SD. Reference examination was taken by dentists who did not make term-end examinations. Kruskal-Wallis test showed that there was a statistical difference on participants (students and dentists) and no difference between FC and TBL. Cov Lec: conventional lecture, FC: flipped classroom, TBL: team-based learning, Ref: reference examination. *: $p < 0.05$, **: $p < 0.01$ with Bonferroni post hoc correction.

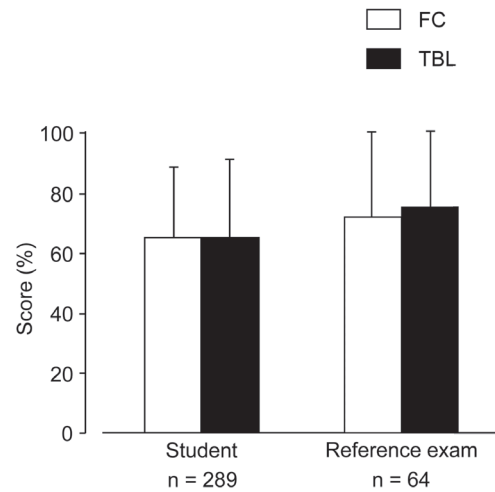


Fig. 4 Total correction rate of the examination. Data are presented as mean \pm SD. Reference examination was taken by dentists who did not make term-end examinations. Kruskal-Wallis test showed that there was a statistical difference on participants (students and dentists) and no difference between FC and TBL. FC: flipped classroom, TBL: team-based learning.

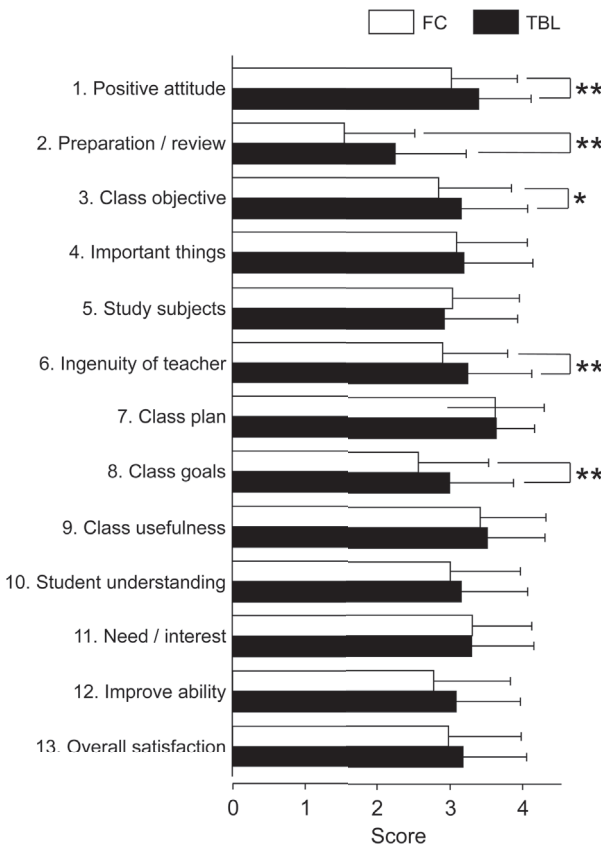


Fig. 5 Student perspective with the questionnaire. Data are presented as mean \pm SD. The questions are listed in Table 2. Mann-Whitney U test showed that there were statistical difference on “Was your attendance attitude positive?”, “Did you do enough preparation and review before and after class?”, “Did the teachers explain the goals and objectives of the class?”, “Did you feel the ingenuity of the teacher in managing the class?” and “Did you achieve the class goals?”. FC: flipped classroom, TBL: team-based learning. *: $p < 0.05$, **: $p < 0.01$.

Table 3 Favorable and unfavorable responses on flipped classroom

Favorable responses on flipped classroom
I did preparation to the class because of examination. The study materials were easily to understood and good for the study. The real lectures were easily to understood with the preparation. The study subject was interesting.
Unfavorable responses on flipped classroom
I wanted to have paper study material at least one week before the class. Study material should cover the examination contents. The deadline of the pre-examination should be just before the class. I wanted that the class progress was slow. I did not understand the important points. I do not like active learning.

Similar answers were summarized to one answer.

Table 4 Favorable and unfavorable responses on team-based learning

Favorable responses on team-based learning
Students can study actively and understand deeply. I have habit of preparation study because we have examination at first in the class. Students can learn more through the group discussion. Students could ask questions easily in the class. I could think about my future through this class.
Unfavorable responses on team-based learning
Study materials should have more detail information. It is difficult to evaluate each other in peer evaluation. I wanted to have detail explanation for the examinations and we did not have enough time. The examinations were very difficult.

Similar answers were summarized to one answer.

The students gave free comments on good points and points that they wanted to improve. Regarding the student's free comments on FC and TBL, favorable responses of FC were "I did preparation to the class because of examination.", "The study materials were easily understood and good for the study." and "The real lectures were easily understood with the preparation.". On the other hand, favorable responses of TBL were "Students can study actively and understand deeply.", "I have habit of preparation study because we have examination at first in the class.", "Students can learn more through the group discussion." and "Students could ask questions easily in the class." (Table 3, 4). There were several unfavorable responses in FC "I wanted to have paper study material at least one week before the class.", "Study material should cover the examination contents.", "The deadline of the pre-examination should be just before the class.", "I wanted that

the class progress was slow." and "I did not understand the important points.". The unfavorable responses of TBL were "Study materials should have more detail information.", "It is difficult to evaluate each other in peer evaluation.", "I wanted to have detail explanation for the examinations and we did not have enough time." and "The examinations were very difficult." (Table 3, 4).

Long term effect of prosthodontic education

Fig. 6 shows the practice examination score of 6th-year students in Tokushima University which is divided by dental school student score in Japan while Table 5 shows the number of students who took the examination. The score of the crown & bridge subject at Tokushima University was always higher than the Japanese national average score. Also, the score of crown & bridge subject at Tokushima University

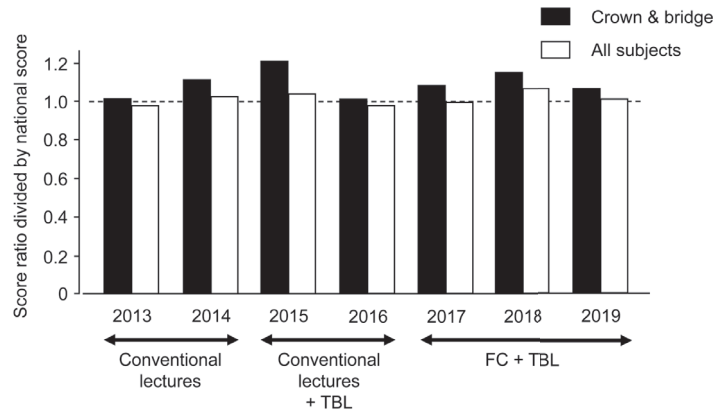


Fig. 6 Score ratio divided by national score in practice examination for Japanese dental national board. The subject numbers were shown in Table 5. The students who took the practice examination before 2015 had conventional lectures in 4th-year students, the students in 2015 and 2016 had conventional lectures + TBL, and the students from 2017 to 2019 had FC and TBL.

Table 5 Numbers of examinees who took the practice examinations for Japanese dental national board

	2013	2014	2015	2016	2017	2018	2019
Tokushima University	28	43	31	44	47	37	34
Japan	2919	2904	3073	2940	2792	2862	2918

was always higher than the scores of all subjects combined. The crown & bridge subject score was close to the Japanese national average with the conventional lecture (2013) and the conventional lecture + TBL (2016), but the scores of the students who had FC + TBL were constantly higher than the Japanese national average score.

Validity and difficulty of the questions

The identification index of FC and TBL did not show the statistical difference (Fig. 7A). There were some questions in which the identification index had a negative value. The question number that showed the negative value of identification index was six and eight in FC and TBL, respectively. The questions which had the negative value identification index do not have good validity and the questions should be checked carefully. We checked these questions and found that the questions were not bad questions. The reason of the negative value was that most of the students had correct answers. So, we included these questions.

There was no statistical difference on item response theory between FC and TBL (Fig. 7B). The result showed that there is no difference on question difficulty between FC and TBL.

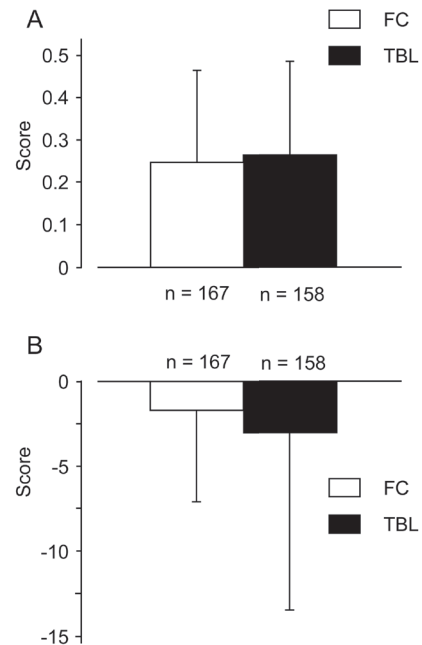


Fig. 7 Examination question validity and difficulty.

Data are presented as mean ± SD. A: Mann-Whitney U test showed no difference on the identification index between FC and TBL. B: Mann-Whitney U test showed no difference on item response theory between FC and TBL. FC: flipped classroom, TBL: team-based learning.

Discussion

Previous studies reported that TBL classes improved student's diagnostic skills and student's critical analytic ability⁸⁾, National Board Examination results¹⁰⁾ and course grades on removable denture prosthesis¹¹⁾. According to our previous report¹³⁾, the average correct answer rate of TBL class showed higher term-end examination scores than the regular class that teachers give as ordinary lectures. The current study and previous studies showed that active learning class (FC and TBL) is effective for student education^{13-16,20)}.

The term-end examination correct answer rate was significantly different in comparison with the time of the trial and for the participants. We consider that one of the reasons is that we made different questions every year, and the difficulty of the examinations changes. Also, the reference examination scores by the dentists were significantly higher than the students. The dentists had more experiences in clinical situations and might have been able to answer the examinations correctly.

There was no statistical difference between FC and TBL on term-end examination scores on each year (Fig. 3) or combined data (Fig. 4). There was no interaction between the test period and the participants; and the test period and class format. Both class types (FC and TBL) are more likely to be effective than regular classes. Since both FC and TBL are active learning activities and students can learn how to study by themselves^{3, 7, 8, 10, 11, 13-19)}, we consider that the difference between FC and TBL may not be big on the term-end examination score in this study. However, the details are unknown, and we need to conduct more research regarding the reason why FC and TBL are effective.

The questionnaire showed that TBL had higher scores than FC on student positive attitude, preparation, ingenuity of teacher and achieving the class goals. TBL requires preparation because the students should discuss in the class. Our students' answers to the questions regarding the favorable responses of FC and TBL showed that the students should study in the pre-class to understand the class easily. Also, the students wanted to have study materials which were printed out and did not like peer evaluation.

We examined the long-term effect with the practice examination score from a private company and found that the scores of crown & bridge subjects at Tokushima University were higher than the Japanese national average scores before starting the active learning activities. We consider that our basic training to make patient prosthesis and clinical training are good for the practice examination. We also found that scores of the students who had FC + TBL were constantly higher than Japanese national average score and consider that active learning induces acquiring knowledge constantly.

However, we need to have more studies in the future.

The identification index of FC and TBL did not show the difference, and the number of questions that had negative value were not much different. It shows that the validity of the examination questions was similar between FC and TBL. The item response theory result showed that there is no difference on examination question difficulty between FC and TBL.

There is no statistical difference between FC and TBL on term-end examination scores for each year and the combined data. There was no interaction between the test period and the participants (students or dentists), and the test period and class format. We can conclude that both FC and TBL are effective and that active learning is more effective than regular lectures.

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Conflict of interests: The authors declare no conflict of interest.

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