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Application and Evaluation of a Grouped Flipped Classroom Method

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Abstract—We proposed a new flipped classroom method in which students are divided into three groups before each class on the basis of their e-learning self-study logs and level of understanding. The three groups are students who studied the lesson and fully understand the contents, students who studied the lesson but do not fully understand the contents, and students who did not study the lesson and so do not understand the contents. The face-to-face learning in class is done separately for each group. We called this a "grouped flipped classroom." We applied the above grouped flipped classroom method to 16 weeks of actual lessons in the autumn semester of 2017 at our university. The results revealed that the grouped flipped classroom improved students' performance. In particular, for the group of students who had low understanding during self-study, there was a statistically significant difference between their average scores in the tests after the self-study and after the face-to-face lesson. In addition, the average score in the test after the face-to-face lesson was higher for students in the grouped flipped classroom than for students in conventional style classes (lecture style class and mixed ability class).

Keywords—Flipped-Classroom, e-Learning, Blended-Learning, Effective Classroom

I. INTRODUCTION

Classroom flipping, i.e., the reversal of the roles of the classroom and home study, has been attracting increased attention due to the expected improvement in learning. In a flipped classroom, as shown in Fig. 1, students study the lesson before coming to class and then obtain more advanced face-to-face learning in class. Flipped classroom method was proposed by Jonathan Bergmann and Aaron Sams [1][2]. They reported that using a flipped classroom increased the attendance rate and decreased the failure rate.We have developed and evaluated a method to make classroom flipping more effective [3].

In our proposed flipped classroom method, students are divided into three groups before each class on the basis of their e-learning self-study logs and level of understanding. The three groups are students who studied the lesson and fully understand the contents, students who studied the lesson but do not fully

understand the contents, and students who did not study the lesson and so do not understand the contents. The face-to-face learning in class is done separately for each group. We called this the "grouped flipped classroom."

We compared a grouped flipped classroom with a conventional flipped classroom without grouping [3], and the effectiveness of the grouped flipped classroom was shown by final test results [4] and a questionnaire [5]. We showed bottoming up to be effective for students with low understanding and showed that not only bottoming up but also advanced classes could be effective for students with high understanding. However, references [3]‑[5] were reports that applied to one experimental lesson.

We applied the above grouped flipped classroom method to actual lessons in the autumn semester of 2017. The results revealed that the proposed grouped flipped classroom method improves students' performance. The groups of students who had low understanding during self-study (Groups B and C) had higher test scores after the face-to-face classes. In addition, there was a statistically significant difference between the average scores in the tests after the self-study and after the face-to-face lesson for students in the grouped flipped classroom but not for those in lecture style class and mixed ability class.

In Section II, we describe the objectives and effects of the flipped classroom and our previous studies concerning electronic teaching materials and e-learning as related work. We describe a technical method collecting the logs of self-study using e-learning at home and explain the details of the proposed flipped classroom method. In Section III, we describe how to apply the grouped flipped classroom method to actual classes. Specifically, we describe a learning method using Moodle (a learning management system) during self-study, contents of the self-study, and the method of the self-study achievement test. We evaluate the results for different groups and the effect of grouping in face-to-face classes in Section IV. Section V concludes this paper by summarizing the key points and mentioning future works.

Fig. 1.   Illustration of Flipped Classroom

II.   RELATED WORK

A.   Flipped Classroom

The flipped classroom method was first proposed by Jonathan Bergmann and Aaron Sams [1][2]. They reversed traditional lecture style teaching methods and conducted a reversal lesson using recorded lecture videos. They reported that using a flipped classroom increased the attendance rate and decreased the failure rate. Many studies (e.g., [6][7]) agree that information and communications technology (ICT) can be effectively utilized in the flipped classroom, the order of classwork and homework can be changed flexibly, and the flipped classroom promotes advanced and deep learning. Flipped classrooms are widely adopted in many countries and have been proved to improve learning effects.

In a typical flipped classroom, students do self-study using lecture videos that lecturers themselves have made, but flipped classrooms not using the lecturer's own videos have also been reported. Westermann utilized a social networking site [8]. In addition, Sataline utilized Massachusetts Institute of Technology's (MIT) online course material for a flipped classroom [9]. The method we conducted in this study is a flipped classroom that does not use video.

Many studies dealing with flipped classroom have been reported, and many survey papers have classified and compared these studies. For example, Giannakos et al. classified 32 existing studies as flipped classroom practice in computer science education from the viewpoints of educational level, methodology type, target for measurment, measurement method, experiment design, collaboration among students, etc. [10]. In addition, Bishop and Verleger classified 26 existing studies from the viewpoints of grade level, in-class activities, out-of-class activities, measurement method test structure, etc. [11]. However, there are no studies that change the way face-to-face lessons are conducted depending on the students' degree of understanding at the time of self-study.

Many of the previous studies are based on the assumption that all students are seriously preparing for lessons by self-studying. Furthermore, these studies assume that all the students' prior knowledge is increased by self-study. However, not all intermediate- or low-level students at university do self-

study. Also, there are students who cannot understand the contents by themselves or enhance their knowledge in self-study. There is also a question as to whether students can be handled as one group in a lesson where the degree of understanding differs greatly. Many previous studies have not distinguished students with different levels of understanding as described above.

B.   Browsing History Visualization System

When browsing teaching materials on the Web, the log of the Web server shows that someone has downloaded the teaching material (PDF). However, we cannot grasp the information on how many minutes the material was viewed. To solve this problem, we developed a web-based learning support system called the browsing history visualization system [12]. In this system, information such as the number of seconds each page of teaching material is opened can be recorded. Furthermore, this system can authenticate users in cooperation with Moodle. In other words, we can use this system to figure out who is viewing which page for how many seconds.

C.   Edit History Visualization System

We developed a learning environment of a programming language specialized for beginners [13]. This system has features such as easy preparation of the learning environment and grasp of the learning situation of the learner. For "ease of preparing the learning environment," we created an environment that can be used only by the browser. Therefore, learners can learn on not only a PC but also a smartphone and tablet. As for "grasping the learning situation of the learner," the difference from the previous state of the source code and execution result is displayed on the teacher screen. If the teacher sees this difference, he or she can check where and what the learner modified.

D.   Grouped Flipped Classroom

In this section, we will describe the grouped flipped classroom method that we proposed. In our proposed grouped flipped classroom, students are divided into three groups on the basis of their learning time and understanding level during self-study, and face-to-face classes are conducted in a way appropriate for each group. The learning time can be aggregated by the browsing history visualization system mentioned above. Also, the understanding level in self-study is measured by a short test. Using self-study time and understanding level, we divide face-to-face classes into three groups: (A) students who can understand the contents regardless of self-study time, (B) students who cannot understand because they did not self-study, and (C) students who spent a lot of time self-studying but cannot understand. By using the proposed grouped flipped classroom, optimal face-to-face lessons can be provided depending on students' level of understanding.

III.   APPLICATION TO ACTUAL CLASS

A.   Overall Explanation of Class

We applied the grouped flipped classroom method to actual lessons in "Practical Training for Basic Programming" in the

autumn semester of 2017 at Shonan Institute of Technology. Most of the students were freshman at college (18 years old), and the ratio between men and women was about 20: 1. This class was conducted by two faculty members. We divided 16 weeks into 2 sets of 8 weeks. One faculty member conducted grouped flipped classroom classes, and the other conducted regular classes. There were two 90-minute classes (180 minutes in total) per day. The content of the lesson is the basic content of the Java programming language. In consideration of the effectiveness of iterative learning, the overlapping of class contents was allowed between two faculty members.

In this paper, one of the two faculty members mentioned above (Faculty A) uses a grouped flipped classroom. Faculty A conducted 8 lessons for 98 students (Dimidiate 1) and then 8 for 85 students (Dimidiate 2) and used the proposed grouped flipped classroom method for six lessons. As for the other lessons, one was conducted in a lecture style as usual (lecture style), and the other was conducted by mixing students who did well on the self-study achievement test and students who did not (mixed group).

As shown in Table I, students in Dimidiate 2 had already received regular classes for the first 8 weeks in Java programming language by Faculty B before changing to the flipped classroom conducted by Faculty A. Note that the basic understanding of the students in Dimidiate 2 was possibly higher than that of the students in Dimidiate 1.

TABLE I.   DESCRIPTION OF CLASS

First 8 weeks	
Faculty A	carries out flipped classroom for Dimidiate 1
Faculty B	carries out regular classes for Dimidiate 2
Second 8 weeks	
Faculty A	carries out flipped classroom for Dimidiate 2
Faculty B	carries out regular classes for Dimidiate 1

B.   Overall Explanation of Flipped Classroom

First, Faculty A conducted eight weeks of flipped classroom lessons for Dimidiate 1 and then another eight weeks of flipped classroom lessons for Dimidiate 2[1]. The lessons for all 8 weeks are shown in Table II. Also, as shown in Fig. 2, all lessons in Table II were implemented as an eight-week flipped classroom.

TABLE II.   CONTENTS OF CLASS OF FACULTY A

	Contents
1st (9th) week	Java language (Input/Output)
2nd (10th) week	Java language (Variable/Arithmetic)
3rd (11th) week	Java language (Branch)
4th (12th) week	Java language (Repetition)
5th (13th) week	Java language (Array)
6th (14th) week	Java language (Method)
7th (15th) week	Java language (Class I)
8th (16th) week	Java language (Class II)

C.   Explanation of Flipped Classroom for One Week

The procedure for each week is as follows. We prepared the materials and tests for 8 weeks and gathered results in Moodle.

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[1] Faculty B's regular classes are outside the scope of this paper.

- [at home] Self-study material
- [at home] Self-study achievement test
- [at school] Self-study achievement test (again)
- [at school] Lecture materials
- [at school] Final achievement test
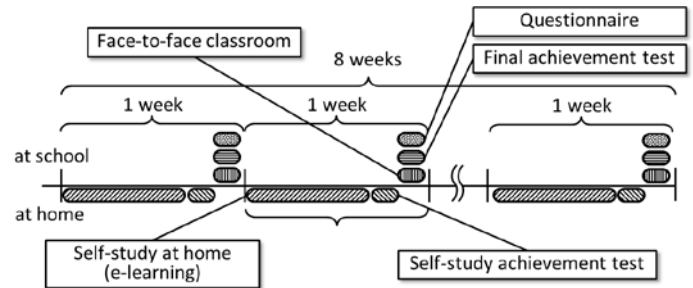- [at school] Questionnaire after class

Fig. 2.   Overall Composition of Flipped Classroom Approach

1) Self-study material: We used the browsing history visualization system [14] described in Section II-C to acquire the learning log of how much time the learner took for self-study. User authentication was realized by linking the browsing history visualization system with Moodle. Fig. 3. shows an example of the log. In Fig. 3., a user called "17axxxx" read the fourth page for 27.1 seconds, the fifth page for 57.7 seconds, and the sixth page for 3.4 seconds.

```
userId=17Axxxx page=4 start=2017-09-28T10:08:26
end=2017-09-28T10:08:54 time=27.1
userId=17Axxxx page=5 start=2017-09-28T10:08:54
end=2017-09-28T10:09:52 time=57.7
userId=17Axxxx page=6 start=2017-09-28T10:09:52
end=2017-09-28T10:09:56 time=3.4
```

Fig. 3.   Example of Self-Study Log Information

2) Self-study achievement test: At the end of the self-study period, a self-study achievement test was carried out by using the quiz function on the same Moodle system. The test was as a hole filling problem of the Java program. The maximum score was 10 full points.

3) Grouping of learners: The self-study achievement test was closed at 23:55 the day before classes were held. From this deadline to the beginning of classes the next day, the students needed to be divided into three groups on the basis of the relationship between self-study time and self-study achievement test score. We developed a grouping tool to make this work more efficient. The appearance of the grouping tool is shown in Fig. 4. Here, vertical axis is self-study time, and horizontal axis is achievement test score. This tool is designed to automatically divide the students into three groups and graphically display them on the screen by giving the logs of the learning time of self-study and the achievement test score after self-study. This tool enables students to be regrouped with a mouse.
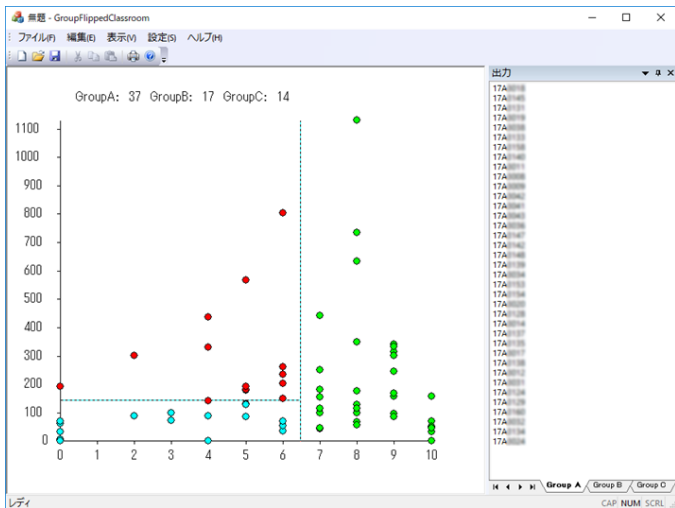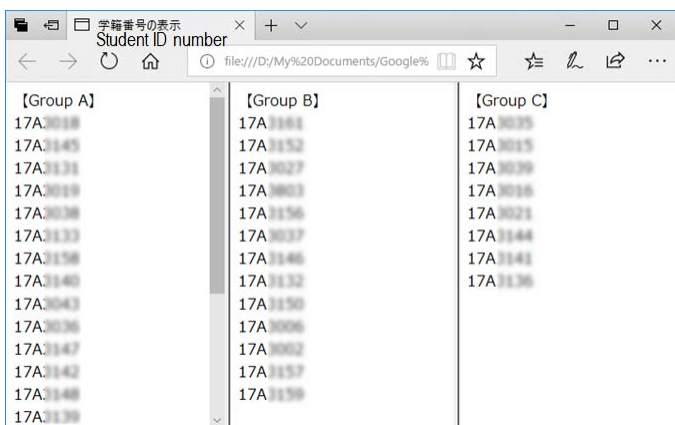
Fig. 4.   Appearance of Grouping Tool

Fig. 5.   Student Number Display of Grouping Tool

We can also display the student ID number for each group as shown in Fig. 5 by selecting [Display Student ID Number] from the [View] menu. By showing this screen to the students in the classroom, it is possible to indicate the seating position of each group.

4) Face-to-face class: In face-to-face classes in the university's classroom after one-week self-study, students were grouped using the student number display function of the grouping tool in Fig. 4. Specifically, we conducted classes in different face-to-face lessons for each group as described below[2].

Group A: As a result of self-study, learners understood the contents of the week's lesson, so they solved the exercises on Moodle at their own pace. Some learners finished the prepared exercises beforehand, so we prepared more additional problems for them to work on.

Group B: These are students who were unable to understand the content because they did little or no self-study. They moved to a different room and studied the self-study content. After that, a second self-study achievement test (Again) was carried out to measure comprehension degree. They were reorganized into Group A or C in accordance with the test results.

Group C: Students who did not understand the contents even though they spent a lot of time doing self-study were seated near Faculty A, who explained the lesson content in an easy to understand way. After encouraging feedback, the learner solved the exercise problems prepared on Moodle like Group A.
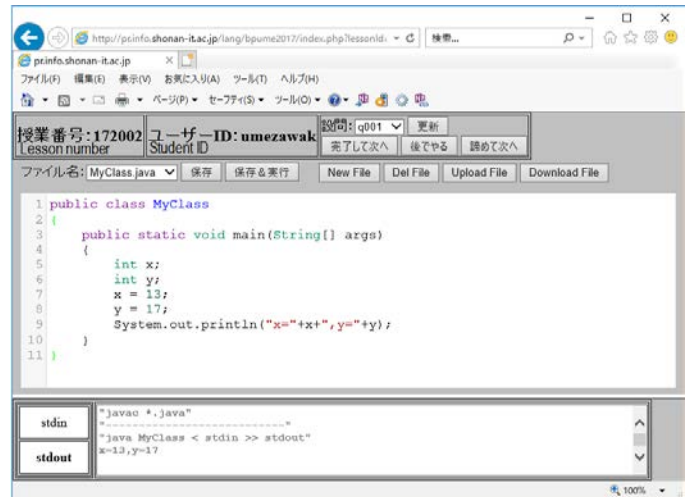

Fig. 6.   Editing History Visualization System

When solving problems prepared on Moodle, students used the editing history visualization system shown in Fig. 6. It can implement and execute Java programming on the Web, does not require development software to be installed, and can be used to develop programs. Faculty members can check the progress of each student and the modification history of the program. Since progress details are displayed, it is possible to respond individually to students who are progressing slowly. Also, as shown in Fig. 7, since we can understand the editing process of the program, it is possible to extract what kind of mistakes are likely to occur[3].

5)   Final achievement test: At the end of each lesson, a final achievement test was conducted to measure the final understanding level. The final test was also carried out as a self-study achievement test as described in Section III-C2 by using the quiz function on Moodle. The problem was to complete a full-scale Java program different from that in the self-study achievement test.

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[2] As described in Section III-D, there was a week in which face-to-face classes were conducted without grouping as a control experiment.

[3] By using this information, we think that debug exercises to fix mistakes can be generated by giving the wrong source code.
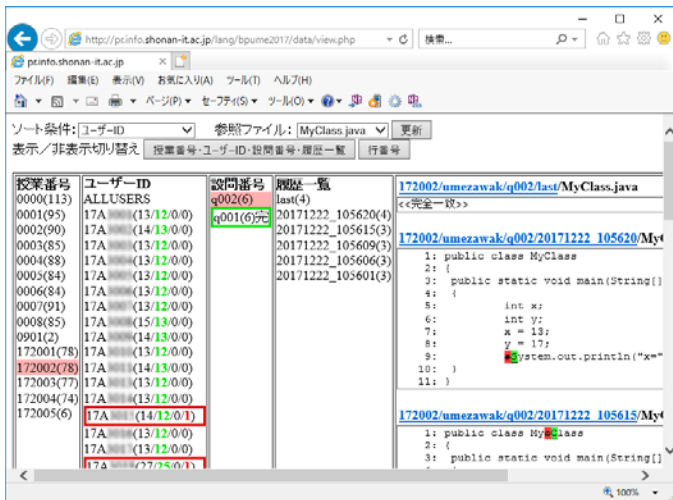
Fig. 7. Screen for Teacher on Editing History Visualization System

D. Explanation of Lessons for 16 Weeks

Basically, the flipped classroom described in Section III-C was conducted for students of Dimidiates 1 and 2 for eight weeks. To analyze the control experiments, lecture-style lessons were also conducted in the 4th and 13th weeks as shown in Table III.

TABLE III.   DESCRIPTION OF CLASS

Dimidiate 1		Dimidiate 2	
1st week	Grouped	9th week	Grouped
2nd week	Grouped	10th week	Grouped
3rd week	Grouped	11th week	Grouped
4th week	Lecture-style	12th week	Grouped
5th week	Grouped	13th week	Lecture-style
6th week	Mixed-group	14th week	Grouped
7th week	Grouped	15th week	Mixed-group
8th week	Grouped	16th week	Grouped

As a result, it is possible to compare test results for the 4th and 12th weeks and test results for the 5th and 13th weeks. The mixed groups in the 6th and 15th weeks contained one Group A student (leader) and one or two Group B and C students (total of 2 to 3 people). As a result, it is possible to compare test results for the 6th and 14th weeks and test results for the 7th and 15th weeks.

IV.   EVALUATION

In this chapter, we will evaluate the results of applying the grouped flipped classroom method to actual classes. The legend of the graphs in Figs. 8 to 12 follows the following regular expression.

$$(1|2)(Total|A|B|C)(Self|Last)$$

Here, 1 and 2 represent students in Dimidiates 1 and 2. Total represents the entire group of students. A, B, and C represent groups A, B, and C. In addition, "Self" denotes a self-study achievement test, and "Last" denotes a final achievement test[4].

A. Total Evaluation

The overall average scores per week for the self-study achievement test and final achievement are shown in Figs. 8 and 9[5]. As described in Section III-A, we divided students into Dimidiates 1 and 2. Students in dimidiate 2 were expected to have had a lot of prior knowledge about the Java language as they had taken regular lessons in the first eight weeks given by Faculty B. This is considered to be the reason that students in Dimidiate 2 scored higher overall. The arrows in Figs. 8 and 9 mean that there is a difference in the average value at or above the 5% significance level in a t-test. We show the p-values in t-tests in Tables IV and V.
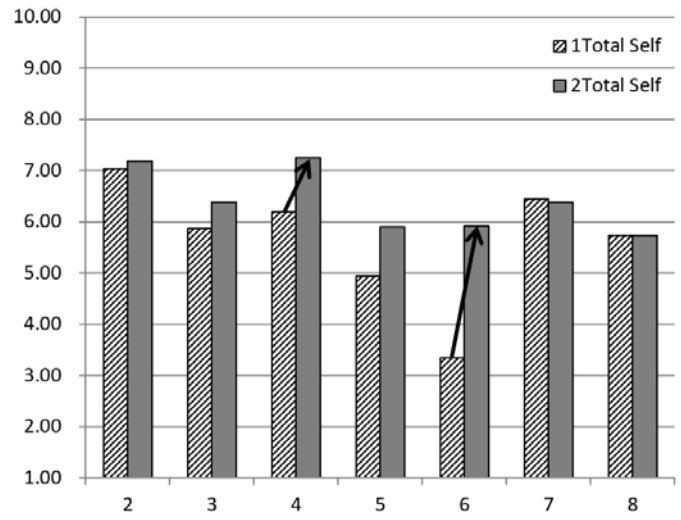

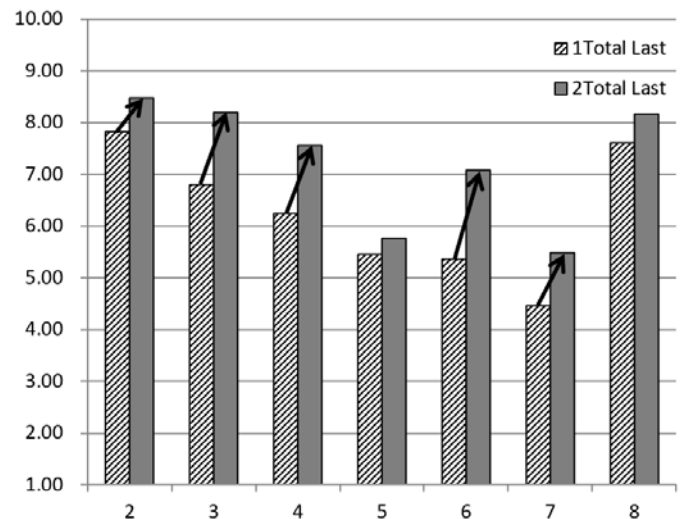Fig. 8.   Weekly Overall Average Scores in Self-Study Achievement Test

Fig. 9.   Weekly Overall Average Scores in Final Achievement Test

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[4] For example, "1Total Self" represents the average self-study achievement test result for all students in Dimidiate 1, and "2A Last" represents the average final achievement test result for Group A students in Dimidiate 2.

[5] For the first week, students were told to avoid self-study in advance and were not subject to evaluation. The same applies to the subsequent graphs.
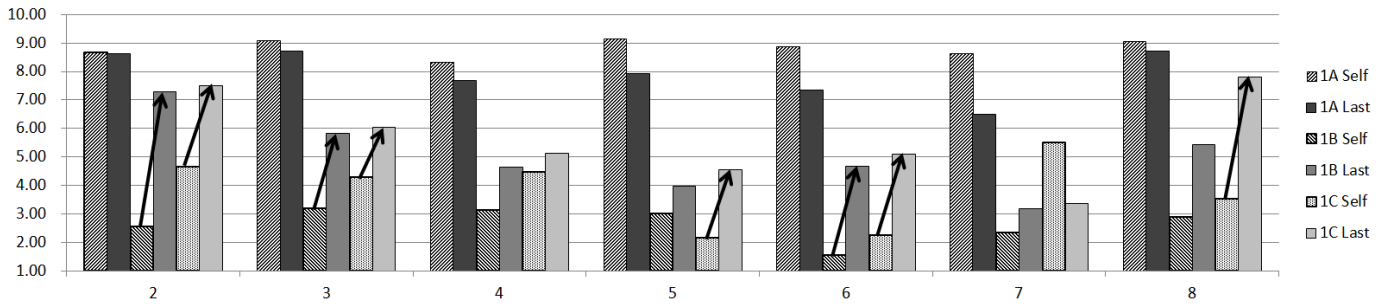
Fig. 10. Changes in the Score in Self-Study Achievement Test and Final Achievement Test for Group A, B, and C Students in Dimidiate 1
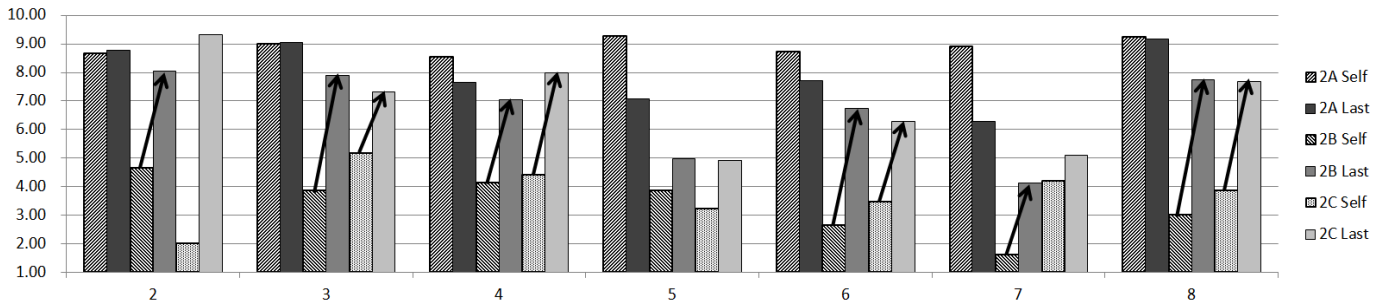

Fig. 11. Changes in the Score in Self-Study Achievement Test and Final Achievement Test for Group A, B, and C Students in Dimidiate 2

TABLE IV. THE P-VALUE BY T-TEST OF THE DATA IN FIG. 8

Week	2	3	4	5	6	7	8
p-value	0.793	0.320	**0.015***	0.121	**0.000***	0.901	0.998

$*: P < 0.05$

TABLE V. THE P-VALUE BY T-TEST OF THE DATA IN FIG. 9

Week	2	3	4	5	6	7	8
p-value	**0.035***	**0.000***	**0.001***	0.535	**0.000***	**0.048***	0.180

$*: P < 0.05$

B. Comparison by Group

Figs. 10 and 11 show the changes in the scores for the self-study achievement test and the final achievement test of the students in Dimidiates 1 and 2. Both sets of Group A students attained high marks in the self-study achievement test, and their scores did not rise further in the final achievement test. However, Group B and C students clearly scored higher in the final achievement test than in the self-study achievement test. The arrows in Figs. 10 and 11 mean that there is a difference in the average value at or above the 5% significance level in a t-test. We show the p-values in t-tests in Tables VI and VII.

TABLE VI. THE P-VALUE BY T-TEST OF THE DATA IN FIG. 10

Week	2	3	4	5	6	7	8
1A	0.976	0.257	0.083	**0.004***	**0.007***	**0.001***	0.373
1B	**0.000***	**0.002***	0.117	0.270	**0.000***	0.422	0.067
1C	**0.016***	**0.008***	0.248	**0.002***	**0.000***	**0.000***	**0.000***

$*: P < 0.05$

TABLE VII. THE P-VALUE BY T-TEST OF THE DATA IN FIG. 11

Week	2	3	4	5	6	7	8
2A	0.686	0.892	**0.008***	**0.000***	**0.033***	**0.000***	0.757
2B	**0.000***	**0.000***	**0.001***	0.136	**0.000***	**0.047***	**0.003***
2C	0.074	**0.013***	0.000*	0.166	**0.016***	0.271	**0.000***

$*: P < 0.05$

C. Effect of Grouping Face-to-Face Class

Fig. 12 shows the final achievement test scores for Group A students in Dimidiates 1 and 2. As mentioned in Section IV-A, students in Dimidiate 2 tended to have a high score overall. However, when we look at the weeks 5 and 7 (which were weeks 13 and 15 for students in Dimidiate 2) in Fig. 12, students in Dimidiate 2 have lower scores[6]. Week 5 and 7 are weeks in which lecture-style classes (week 5) and mixed ability grouping (week 7) were conducted for students in Dimidiate 2, without offering face-to-face lessons using the proposed method. This showed the effectiveness of the proposed grouped flipped classroom method.
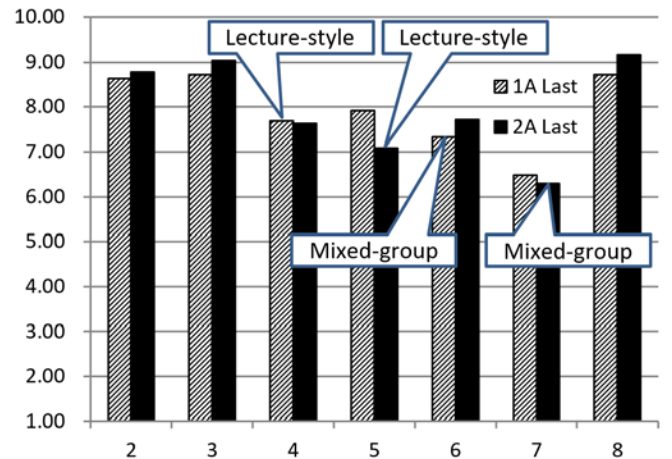

Fig.12. Scores of Final Achievement Tests for Group A Students in Dimidiates 1 and 2

[6] Unfortunately, there is no difference in the average value of the data in Fig. 12 at or above the 5% significance level in a t-test.

V. CONCLUSION

In this paper, we applied our proposed grouped flipped classroom to actual classes for 16 weeks and evaluated the results and its effectiveness. Specifically, (1) the degree of comprehension of students with low understanding level was significantly higher after the classes than before them. In addition, (2) we showed that grouped face-to-face lessons are more effective than conventional face-to-face lessons.

Some problems were highlighted such as cheating on self-study achievement test (e.g., by obtaining answers from other students) and difficulties in counting self-study time. We plan to apply our proposed flipped classroom method to classes in the next fiscal year while solving these problems.

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