Role of face-to-face lecturing in large enrollment physics classes

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The introduction of active learning into physics education at the university level may be crucial for improved learning outcomes. In UNIST (Ulsan National Institute of Science and Technology), introductory physics has been redesigned to reduce the time spent on unidirectional lectures, while increasing the time devoted to classroom activities which facilitate the interaction between students and the instructors, as well as increasing the interaction between student peers. We measured student achievement and the degree of student satisfaction in order to evaluate the impact of the new learning methods on student learning outcomes. In the first semester, we redesigned a class of N1 = 176 students with a reduction in lecture hours and replaced them with pre-class self studies and in-class problem solving, and compared it with the traditional lecture based class of N1 = 161 students. We found that even though the midterm results of two classes were similar, the final average score of the redesigned class was 10 points higher than the traditional class. In the second semester, we applied our strategy to three classes but controlled the proportion of face-to-face lectures to the entire class meeting hours systematically to be 1/3 in 'Class 1' of N2 = 160 students, 1/2 in 'Class 2' of N2 = 176 students and 2/3 in 'Class 3' of N3 = 177 students. The students’ achievements in those three classes were indistinguishable in both the midterm and the final exams. It is a common feature of the three classes that mastering pre-class assignments based on online self-study before each class is correlated with the students’ achievements. There are a few remarkable features of ‘Class 1’ compared with ‘Class 2’ or ‘Class 3’. The students of ‘Class 1’ who generally showed good achievements in the midterm and final exam tended to be more satisfied with the redesigned class. However, the students whose midterm score was less than the average but final score improved substantially tended to think that the face-to-face lecture was definitely effective in their learning.

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I. INTRODUCTION

Recently a popular trend of course redesign is to arrange educational tools optimally for active learning, which increases the interactions between instructors and students in class, rather than unilaterally imparting instructors’ knowledge in the form of traditional lectures. The course elements which make students engage with their peers in in-class activities are fruitful for physics education: cooperative problem solving and peer instruction/discussion are being implemented. Even in physics classes with a high enrollment, a relevant strategy for course redesign may overcome the challenges from the massive audiences and resolve problems due to the lack of experience that a young lecturer may have.

Additionally, the substantial progress of IT based education provides unprecedented chances to reform and redesign courses at universities. The advent of educational resources like MOOCs(Massive Open Online Courses), edX, Coursera, etc. not only gives chances for the general public to participate in the higher education but also provides educational materials for university leaders to develop creative learning models.

The 2014 Horizon report specifies that Flipped Classroom and Learning Analytics are two important developments in educational technology for higher education to be implemented in one year or less. According to a recent survey by the Center for Digital Education, 50% of American faculty members are already using the flipped learning method or plan to do by winter 2014. It is said that improved mastery of information is the top student benefit.

From its inception in 2009, UNIST(Ulsan National Institute of Science and Technology) has experimented the flipped learning model as a possible solution (1) to offer all courses in English, (2) to provide two-way interactive learning for critical thinking and problem solving, and (3) to reduce or at least contain educational costs without sacrificing quality. In line with the University’s policy, an introductory physics has been redesigned for Flipped Learning. We are trying to minimize the lecturing part, which is repeated without much change every semester, by replacing it with online self-study before the class and in-class problem solving/discussion. It may be possible to entirely replace the face-to-face lectures in classroom with the movie clips of famous lecturers, and to complement the class with other effective elements, which have been proven to be successful as in class activities, e.g. group problem solving/discussion.
However, the face-to-face lecture and the art of storytelling in class have their own virtues in physics education, especially for the comprehension of physics concepts. First, the instructor can control the pace and amount of the explanations or demonstrations according to students’ responses in the classroom. Second, the instructor can choose the methods and control the time necessary to explain physical phenomena, instantly according to students’ responses. In this regard, it is necessary to investigate carefully what will happen to our students when we reduce the proportion of the face-to-face lecture time and replace it with other course elements. A lot of research tends to focus on the direct comparison between traditional course formats heavily based on lecture and redesigned formats implemented with new techniques for students’ active learning. Hence, it is necessary to study the impact of the face-to-face lecture on students’ learning by systematically adjusting the lecture hours, and this is the main motivation of this work.

In this paper, we report achievements and reflections of our students who have taken the first part of introductory university physics - calculus based classical mechanics and thermal physics - at UNIST, for two semesters. We systematically controlled the proportion of the face-to-face lectures by spending different amounts of lecturing time in different classes, compensating it with other online materials or activities. In the first semester, two instructors joined to teach two different types (traditional and redesigned) of classes separately and concluded that the redesigned class was more effective than the traditional class by comparing students’ performances in the midterm and final exams. After gaining confidence in our strategy, during the second semester, two instructors ran three redesigned classes by assigning the proportion of face-to-face lectures differently in each class. The result of measuring students’ exam scores is that the reduction of lecture hours did not significantly affect our students’ achievements. However, our survey questionnaire shows divergent student opinions about lecture hours, with a significant proportion of the sample responding that a face-to-face lecture was a necessary part of the learning experience.

II. COMPARISON BETWEEN REDESIGNED CLASS AND TRADITIONAL CLASS IN THE FIRST SEMESTER

In Semester 1, two classes of the first part of the physics course for freshmen were opened. One instructor decided to apply the redesign method to his class, ‘Class I’ of $N_I = 176$ students, and the other instructor took traditional method heavily based on lecture in his class, ‘Class II’ of $N_{II} = 161$ students. Students were assigned to one of the two classes randomly by the university, so we could safely assume that initial knowledge of the students about physics was equivalent over those two classes.

A. Course redesign for Semester 1

Since we wanted to spend as much time as possible in doing various interactive activities among students in class, we reduced the lecturing time and required students to do self-studies and assignments before class. The core materials for the class, including lecture notes and movie clips, were opened to students on LMS (Learning Management System) before the class.

However, since it was the first attempt at changing our format and seemed drastic for both instructors and students, we decided to take a hybrid model approach, spending half the class time doing face-to-face lectures for summarizing the chapters, and the other half on interactive activities. Not all of the contents could be covered by the face-to-face lecture within the limited time, and much of the material in the chapters was assigned to students for self-study.

In class, the instructor gave summary lectures reviewing the main contents of the chapters and emphasizing essential parts. Often clicker questions are prepared to help the students catch the important concepts, and then group activities are followed. Students make groups of 2 - 4 and discuss the lecture within their group. The instructor showed problems one by one on a big screen and then gave some time, normally 10 - 15 minutes per problem, for each group to make their own solution. While students discussed a possible solution to the problem, the instructor and 2 - 3 TA’s walked around the discussion groups, answered students’ questions, and explained some crucial concepts that students might misunderstand. Then the instructor showed standard solutions to all students while emphasizing important points.

After class, the activities were generically typical. Homework problems were assigned to students weekly, and the students were required to submit their solution to TA’s. We arranged recitation classes for students to get help directly from the TA’s. In summary, the class format applied to Class I consists of mainly three parts as follows:

- Pre-class: lecture notes, movie clips and reading materials.
- In-class: summary lectures, clicker questions and group problem solving.
- Post-class: homework assignments and recitation classes.

In Class II, the instructor delivered a traditional type of lecture for the whole class time. After class, the same homework problems were assigned to students as in Class I. The same format of recitation classes for Class I were open to students of Class II.
TABLE I. Number of students and average exam score in classes for Semester 1: Even though the average scores of both classes in the midterm exam were similar, the average score of Class I in the final exam is 10 points higher than that of Class II.

|                | Class I (redesigned) | Class II (traditional) |
|----------------|----------------------|------------------------|
| number of students | $N_1 = 176$         | $N_2 = 161$           |
| midterm exam     | $71.4 \pm 19.6$      | $68.2 \pm 19.2$       |
| final exam       | $34.4 \pm 20.4$      | $23.9 \pm 16.0$       |

FIG. 1. Students’ population according to the scores of Class I and Class II in the midterm and final exam. The distributions of both classes in the midterm exam are not meaningfully distinguishable. However, for the final exam, there are more students whose score is greater than 50 points in Class I than in Class II, and less students whose score is less than 50 points in Class I than in Class II. The distributions in the final exam are clearly different.

B. Results from Semester 1.

Even though the course formats of Class I and Class II were different from each other, we gave exactly the same problems in the midterm and final exams, to compare the effectiveness of students’ learning in both classes.

For the midterm exam, the average scores for both classes in Table I and students’ distributions in Figure I were not meaningfully distinguishable, which means that there was no essential difference in students’ learning in both of Class I and Class II up until that point. Usually the freshmen are familiar with the first part before the midterm exam because they have already covered most of the topics in their high schools. We think that the effectiveness of our strategy could not be seen due to the students’ familiarity with the topics.

For the final exam, the average scores of both classes seemed to decrease substantially in comparison with the midterm scores, because the topics covered after the midterm exam were new and are challenging to the students. However, the average score of Class I was 10 points higher than that of Class II in Table I and the population of Class I students whose score was more than 50 points was remarkably bigger than that of Class II students in the right panel of Figure I. Hence, we could see that students’ achievement of Class I was better than that of Class II. We can conclude our class redesign would be effective in increasing students’ learning, especially when students started dealing with relatively new topics.

III. EFFECTS OF VARYING THE PROPORTION OF FACE-TO-FACE LECTURE IN THE SECOND SEMESTER

In Semester 2, we intended to explore the effect of the proportion of the face-to-face lecture on students’ learning. It was crucial to check whether students’ self-study enhanced by IT technology could actually replace the face-to-face lecture as a preferable future model for UNIST. Based on the positive results in Semester 1, two instructors joined and decided to adopt the same format of course design to all three classes, while assigning different proportion of the face-to-face lecture to them. Again, students were distributed randomly over the three classes by the university.

A. Course redesign for Semester 2

The course format was similar to ‘Semester 1’, except for two things. To emphasize students’ self-study, we added pre-class quiz assignments based on the contents that students had to prepare before coming to class. The pre-class quizzes were multiple-choice problems assigned on LMS to be evaluated automatically. Students had an
### Table II. Number of students and average exam score in classes for Semester 2

|                         | Class 1 | Class 2 | Class 3 |
|-------------------------|---------|---------|---------|
| number of students      | $N_1 = 160$ | $N_2 = 176$ | $N_3 = 177$ |
| time for face-to-face lecture per week | 1.3 hours | 2.00 hours | 2.7 hours |
| time for group problem solving per week | 2.7 hours | 2.00 hours | 1.3 hours |
| portion of face-to-face lecturing | 1/3 | 1/2 | 2/3 |
| midterm exam            | $55.9 \pm 18.7$ | $56.7 \pm 17.7$ | $54.8 \pm 19.2$ |
| final exam              | $43.6 \pm 21.1$ | $47.4 \pm 21.4$ | $42.4 \pm 21.5$ |

Instructors assigned the face-to-face lecturing time differently for the three classes in the following way. One instructor taught two classes: in ‘Class 1’, he met $N_1 = 160$ students and per week spent 1.3 hours for face-to-face lecturing and 2.7 hours for group discussion and problem solving (the portion of face-to-face lecture is 1/3). In ‘Class 2’, he met $N_2 = 176$ students, and per week spent 2 hours for face-to-face lecturing and 2 hours for group discussion and problem solving (the proportion of face-to-face lecture is 1/2). The other instructor met $N_3 = 177$ students in ‘Class 3’. He per week spent 2.7 hours for face-to-face lecturing and 1.3 hours for group discussion and problem solving (the portion of face-to-face lecture is 2/3).

#### B. Results from Semester 2

1. **Exam results**

   The exam results of the three classes are not as clearly distinguishable as shown in Table II. The average scores of the midterm exam for Class 1, Class 2 and Class 3 are 55.9, 56.7 and 54.8 respectively. The average scores of the final exam for Class 1, Class 2 and Class 3 are 43.6, 47.4 and 42.4 respectively. From the results of the final exam, Class 2 seems to be the highest achieving group, but actually they are indistinguishable in 1-σ level by $t$-test. Even though it is not certain which type of approach adopted in Class 1, Class 2 or Class 3 was more effective, we demonstrate some important features and differences in the following discussion.

2. **Two parameters: $M+F$ and $FR-M$**

   Now we introduce two parameters: $M+F$ and $FR-M$. First, $M+F$ is the algebraic sum of the scores of the midterm and final exams.

   $M + F \equiv \text{midterm exam score} + \text{final exam score}$ \hspace{1cm} (1)

   $M+F$ shows the total scores that each student gained from the midterm and final exams, no matter how much each one’s final score improved compared to the midterm result. Second, we define $FR-M$ to represent the students’ improvements by the comparison between the score of midterm exam and that of final exam. Since the distribution with the large number of samples like the student numbers of our classes would follow Gaussian distribution, the score of the final exam for each student can be renormalized so that the average and standard deviation of the final exam would be the same as those of the midterm exam in Class $i$ where the student belongs. For the score of each student, $FR-M$ is defined by

   \[
   FR-M \equiv \left[ \left( \frac{F - FA}{\sigma_F} \right) + MA \right] - M \tag{2}
   \]

   where $M$ and $F$ are the scores of the midterm and final exams of the student, respectively, and $MA$, $FA$, $\sigma_M$ and $\sigma_F$ are the average scores and standard deviations of the midterm and final exams for all three classes.

3. **Prequiz assignments (PQ) versus $M+F$ or $FR-M$**

   We thought that a crucial part of our model is to provide pre-class activities, so as to have enough time in class to maximize the interactions among students. It is our primary concern whether pre-class activities can really contribute to the improvements of students’ understanding of the subject matter. The scores of pre-class quiz assignments are an indicator of how well the students mastered the pre-class material in preparation for their classes.

   First, we classified all the students of Class 1, Class 2 and Class 3 together according to their $M+F$ scores into ‘below 50’, ‘50 to 75’, ‘75 to 100’, ‘100 to 125’, ‘125 to 150’ and ‘higher than 150’, and then took the average pre-class quiz score (PQ) of the students for each $M+F$ range. The correlation is shown as in Figure 2. We see
FIG. 2. PQ vs. M+F: correlation between the average prequiz score (PQ) assigned before every class and the sum of midterm and final exam score (M+F) among all the students of Class 1, Class 2 and Class 3.

FIG. 3. PQ vs FR-M: correlation between total pre-class quiz score (PQ) assigned before every class and the relative gain of final exam score to midterm (FR-M). The left panel shows the PQ vs FR-M of each of Class 1, Class 2 and Class 3. The right panel shows the PQ vs FR-M of all the students in those three classes.

that the students who did well in the midterm or final exam were well prepared for class.

Second, we classified the students of Class 1, Class 2 and Class 3 according to their FR-M scores into ‘below -20’, ‘-20 to -10’, ‘-10 to 0’, ‘0 to 10’, ‘10 to 20’ and ‘higher than 20’, and then took the average pre-quiz score (PQ) of the students for each FR-M range. In the left panel of Figure 3, the relation between PQ and FR-M of each class is shown. The finding shows that the average PQ score of Class 3, where the instructor met the students most frequently, was substantially lower than that of Class 1 or Class 2. We could see that the frequent face-to-face lectures did not seem to motivate the students to do self-study. Rather, it made the students dependent on the instructor’s lecture and therefore passive in their learning. In the right panel of Figure 3, the total average of PQ for three classes is shown. The overall tendency continues to support the importance of students’ self-study. We see that as a student prepares for class and masters the pre-class quiz problems, he or she would then achieve a higher score in the final exam relative to the midterm, which means student understanding of physics has been significantly improved during the semester.

4. Students’ satisfaction on face-to-face lecture vs group problem solving

Right before the final exam, we had a chance to get students’ feedback on the educational strategies adopted in our classes, through a questionnaire. We now discuss the students’ reflections on the face-to-face lecture and group problem solving, since they are most relevant in the line of thought of this paper. The face-to-face lecture and group problem solving are competitive with each other in the sense that if the proportion of face-to-face lecture is increased, then the proportion of group activities is decreased, and vice versa.

We asked student opinions about the satisfaction with the face-to-face lecture and group problem solving/dis- cuffusion by asking these questions, “Did the face-to-face lecture contribute much to your learning of physics?” and “Did group problem solving contribute much to your learning of physics?” The students could choose one
We classified the students of each class according to their M+F scores into ‘below than 50’, ‘50 to 75’, ‘75 to 100’, ‘100 to 125’, ‘125 to 150’ and ‘higher than 150’, and then took the average score of satisfaction of the face-to-face review lecture (L), and group discussion and problem solving (GPS) for each M+F range. The results are shown in Figure 4. They indicate that the students’ evaluation of the review lecture or group activities was mostly positive. However, there is a clear contrast: More than any other group of students in Class 2 or Class 3, the students of Class 1 who had M+F scores higher than 125, tended to think that group problem solving contributed to their learning of physics. Group problem solving was useful in students’ learning but especially helpful for the students who did well generally in their midterm and final exam in Class 1, whose proportion of the face-to-face lecture was lowest.

We classified the students of Class 1, Class 2 and Class 3 according to their FR-M scores into ‘below than -20’, ‘-20 to -10’, ‘-10 to 0’, ‘0 to 10’, ‘10 to 20’ and ‘higher than 20’, and then took the average score of usefulness of the face-to-face review lecture (L) and group discussion and problem solving (GPS) for each FR-M range. We were interested in the students who did not do well on their midterm exam but clearly improved for the final.
TABLE IV. Satisfaction level on the face-to-face lecture and group problem solving for the students whose final scores were improved compared to the midterm score in Semester 2. Specifically, for those whose FR – M > 10 but the midterm score is less than the average of the midterm exam;

| Class | Students | L average | GPS average |
|-------|----------|-----------|-------------|
| Class 1 | 18 students | 1.14 | 0.86 |
| Class 2 | 25 students | 0.83 | 0.96 |
| Class 3 | 27 students | 1.00 | 1.16 |

In TABLE IV we explicitly compared the average score of L and GPS in each class with the average score of L and GPS for a special group of students whose midterm score was lower than the midterm average, but FR-M > 10. A remarkable contrast of Class 1 to Class 2 and Class 3 is that the group of Class 1 students tended to consider the face-to-face lecture a more useful tool for their learning than the group problem solving. We think that those students in Class 1 might have problems adopting to our substantial reduction in the lecture hours of the redesigned class.

IV. CONCLUSION

In this paper, we have presented achievements and reflections of the students who have taken General Physics I, the first part of the calculus-based introductory physics course at UNIST for two semesters. In Semester 1, our primary concern was whether a combination of pre-class self-study based on IT technology, and in-class group problem solving, could be a reasonable substitute for a face-to-face lecture. We have found that our redesigned course offered students a more effective way of learning physics than the traditional type of classes based only on lectures. In Semester 2, we controlled the proportion of the face-to-face lecture systematically over three classes, while the remaining class hours were devoted to group problem solving. In addition, students in all three classes were required to do pre-class self-study. The students’ achievements were not distinguishable in the sense that their statistical distributions of scores in the midterm and final exams were not different.

The fact that students’ achievements in the three classes in Semester 2 were not distinguishable suggests that the face-to-face lecture does not figure predominantly in students’ learning of physics. On the other hand, the fact that students in our redesigned course performed better than those in the traditional type of class in Semester 1 suggests that the pre-class self-study and in-class group problem solving play an important role in students’ learning. Our main conclusion therefore is that students learn more from pre-class self-study and peer instruction through group problem solving than from traditional face-to-face lecture by an instructor.

In our analysis, we have not taken into account effects of the different teaching abilities and skills of the two instructors, both in Semester 1 and Semester 2. This neglect, however, is consistent with our conclusion that the instructor’s lecture does not play a major role in students’s learning of physics.

We need to mention the contrasts of the class, where the proportion of the face-to-face lecture was smaller than the other two classes in the students’ reflection: while the students who generally scored higher in the midterm and final exams tended to be satisfied with our new method of reducing the proportion of the lecture and having enough time for group problem solving/discussion, the students whose midterm scores were less than the average, but whose final score was improved substantially think that the storytelling lecture was useful for their learning.

The ‘affirmation’ of our model could be a challenge. Even though our strategy of increasing the interactions among students and instructors by reducing lecture hours was proved to be fruitful for the learning of the majority of students, still there were students who could find benefits from the face-to-face lecture. Whether our model is effective generically for all physics courses is still questionable. Our experiment was done only on the first part of an introductory university physics, and most UNIST freshmen have already been exposed to the topics in their high schools. We are going to build up a similar model for the second part and study it using the same method.

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